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ARCTIC RESEARCH

OF THE UNITED STATES

INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published semi-annually (spring and fall) by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee (IARPC) and the Arctic Research Commission (ARC). Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act (ARPA) of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

- Reports on current and planned U.S. Government-sponsored research in the Arctic;
- Reports of ARC and IARPC meetings; and
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector and other nations.

Arctic Research is aimed at national and international audiences of government officials, scientists, engineers, educators, private and public groups, and residents of the Arctic. The emphasis is on summary and survey articles covering U.S. Government-sponsored or -funded research rather than on technical reports, and the articles are intended to be comprehensible to a nontechnical audience. Although the articles go through the

normal editorial process, manuscripts are not refereed for scientific content or merit since the journal is not intended as a means of reporting scientific research. Articles are generally invited and are reviewed by agency staffs and others as appropriate.

As indicated in the U.S. Arctic Research Plan, research is defined differently by different agencies. It may include basic and applied research, monitoring efforts, and other information-gathering activities. The definition of Arctic according to the ARPA is "all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain." Areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

Issues of the journal will report on Arctic topics and activities. Included will be reports of conferences and workshops, university-based research and activities of state and local governments and public, private and resident organizations. Unsolicited nontechnical reports on research and related activities are welcome.

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Cover

Frostfire, an experimental prescribed fire of 900 acres, completed by USDA Forest Service Research in cooperation with the USDI Bureau of Land Management (Alaska Fire Service) and the Alaska Department of Natural Resources in July 1999 in the Caribou-Poker Creek Long-Term Ecological Research (LTER) site near Fairbanks, Alaska. The Frostfire experiment was planned so future research in the LTER can be better focused toward understanding the large-scale ecological consequences of fire in permafrost-dominated boreal forests. Future research in the burned site is expected to make significant contributions to improving our understanding of the importance of boreal forests to global change and to understanding the ecology of the boreal forests covering much of northern North America and northern Eurasia.

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This issue of *Arctic Research of the United States* presents highlights and results of major fiscal year 1998 and 1999 Arctic research programs and selected projects of the Federal agencies. For more information, you may contact the agency staff representatives listed on page 154.

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National Science Foundation

National Science Foundation research is concerned with the entire Arctic region, including Alaska, Canada, Greenland, Svalbard, the Arctic Ocean and adjacent seas, the upper atmosphere, and near space. Research falls principally within eight major scientific disciplines: atmosphere, ocean, biology, earth science, glaciology, social science, engineering, and science education.

The NSF supports a formal Arctic research program within the Office of Polar Programs (OPP). Other divisions and programs throughout NSF, primarily in the Directorate for Geosciences and the Division of Environmental Biology in the Directorate for Biological Sciences, support research in and on the Arctic as part of their overall funding. Most research grants are awarded on the basis of unsolicited proposals and are merit reviewed.

In FY 99, NSF awarded funds for 418 Arctic research projects at 147 institutions in 40 U.S. states and the District of Columbia. NSF's support of Arctic research, including facilities support and field operations, over the past several years is shown below (in thousands of dollars).

	Funding (thousands)	
	FY 98	FY 99
Arctic Natural Science	10,494	9,578
Arctic System Science Prog	12,827	14,558
Arctic Social Sciences Prog	1,317	1,385
Arctic Education research		242
Arctic Research Support	1,897	469
Arctic Data/Info/Coord	95	100
Arctic Research Commission	500	680
Arctic Logistics/Instrumentation	4,500	22,524
Other NSF Science Programs	17,383	17,386
Total	49,013	66,922

port from the OPP, the Divisions of the Geosciences Directorate, and other components of NSF as appropriate. ARCSS is coordinated and managed by the OPP. Through a series of workshops and interactions with a broad scientific community, ARCSS has developed goals and priorities aimed at understanding the role of the Arctic in global change and how the Arctic will respond to global change. ARCSS is an interdisciplinary program that examines the interactions within and between the climatic, geologic, biologic, and socioeconomic subsystems of the Arctic. ARCSS is predicated on the knowledge that the Arctic system is sensitive to and important in global change.

ARCSS has five linked components. The current ARCSS program includes Ocean/Atmosphere/Ice Interactions (OAI); Land/Atmosphere/Ice Interactions (LAI); Paleoenvironmental Arctic Sciences (PARCS); Russian-American Initiative on Shelf-Land Environments in the Arctic (RAISE); and Human Dimensions of the Arctic System (HARC).

Science steering committees (SSCs) for each component facilitate and enhance the ARCSS program and provide a focal point for communication with the scientific community. Recommendations

	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99
OPP	14,696	20,638	22,072	24,205	25,809	29,118	30,715	31,630	49,536
Other	12,445	14,308	13,779	16,279	19,386	16,959	18,674	17,383	17,386
Total	27,151	34,946	35,851	40,484	45,195	46,077	49,389	49,013	66,922

The following sections present highlights of several major programs and selected projects. A complete listing of NSF Arctic funded projects can be found in the publication *Arctic Science, Engineering, and Education Awards: FY 1999*, available from the Office of Polar Programs, National Science Foundation, Arlington, VA 22230.

Arctic System Science

The NSF established the Arctic System Science (ARCSS) program in 1989. ARCSS is structured to be a regional component within the U.S. Global Change Research Program. Administration of the program uses review expertise and financial sup-

for overall coordination and integration of the ARCSS components and individual projects are provided by the ARCSS committee. The committee includes representatives from each SSC, as well as an investigator not supported by ARCSS with a disciplinary interest in that component of ARCSS to enhance the scientific breadth and experience of the group.

NSF/ARCSS has been particularly successful at establishing partnerships with other Federal agencies. In 1998 and 1999 significant cost sharing on Arctic ocean science for ARCSS projects came from the Office of Naval Research (ONR). Considerable cost sharing with NASA, DOE, ONR, and NOAA on current projects has occurred for projects dealing with Arctic climate and ocean processes and modeling research.

Paleoenvironmental Studies

GISP2, PARCS, and its predecessor, PALE, contribute to understanding the past climate, atmosphere, and ecology of the Arctic. This historical information gives valuable insight into understanding system interactions. Starting in FY 98 the paleoenvironmental components of ARCSS were incorporated into the NSF program called Earth System History.

The overall goal of GISP2 was to obtain a history of global climate and atmospheric chemistry from the Greenland ice cap. This very successful program began in FY 86, completed its field phase in FY 93, completed most of the laboratory analyses of the ice core in FY 97, and now has finished its project goals. GISP2 results provided evidence of global changes in atmospheric circulation, chemistry, and temperature that have altered our perceptions of the intensity and rate of climate change during the most recent glacial-interglacial cycle.

The PARCS program developed out of the earlier Paleoclimates from Lakes and Estuaries (PALE) program, which had the goal of constructing paleoclimatic history from the sediments of Arctic and sub-Arctic bogs and lakes. PARCS incorporates the goals and focus of the PALE project but recognizes that important and untapped information about Arctic environmental history also resides as tree-ring records and in sediments from the marginal seas, continental shelves, slopes, and abyss of the Arctic Basin. A variety of proxy indicators (such as pollen, diatoms, sediment chemistry, and grain size) in the sediments yield vital information on the responses of terrestrial and marine ecosystems to climate, land use

change, and the physical conditions and productivity of the Arctic Ocean, but additional new proxies are sought. With the emphasis on variation of climate over the last 20,000 years, the PARCS program is a part of an international program, Circumpolar Arctic Paleoclimate Experiment (CAPE), to produce a reconstruction of the circumarctic environment.

Contemporary and Process Studies

OAI and LAII are process oriented and rely more on experiment and less on description than GISP2 and PARCS. An important goal of OAI is to investigate the effects of energy exchange on the structure of the Arctic Ocean and the interactions within the overlying atmosphere. Carbon sequestration, ecosystem dynamics, sedimentation, and carbon deposition in the Arctic Ocean and its interactions with the surrounding land and river systems are also important topics of investigation. OAI has conducted the Surface Heat Budget of the Arctic Ocean (SHEBA) project from a ship frozen into the drifting ice pack in the Beaufort Sea. SHEBA measured the impact of clouds and albedo on sea ice for a full annual cycle. Although the experimental phase of the project is now completed, analysis and modeling efforts to better understand the impacts of solar heating on the climatologically changing ice cap will soon begin. The Shelf-Basin Initiative (SBI) was begun to better understand the role of the large continental shelf seas in terms of marine biological productivity and the exchange of water, nutrients, heat, and energy with the permanently ice-covered central Arctic basins.

An objective of the LAII-Flux study was to investigate feedback processes within the Arctic terrestrial system that modify global climate change, climate variability, and fluxes of ice, fresh water, water-borne materials, and greenhouse gases. LAII also assessed the effect of changing temperature and snow regimes on critical terrestrial organisms and their communities. LAII-Flux discovered that the Alaskan tundra has shifted in the last 20 years from being a net sink of carbon dioxide to being a net source in winter. If this change is long term, it could lead to major positive reinforcing of global warming via the greenhouse effect.

These terrestrial studies were expanded under the new Arctic Transitions in the Land-Atmosphere System (ATLAS) project. ATLAS is examining a series of terrestrial sites across the gradient from boreal forest in central Alaska to the tundra in

northern Alaska. Detailed understanding of the plant–soil ecosystem in each site may allow predictions about the likely impact of global warming on the northward migration of terrestrial ecosystems. In close association with ATLAS, the United States Tundra Experiment project (USTEX), a part of the ITEX (International Tundra Experiment), is using the same sampling methodologies to evaluate tundra plant growth as used by all other participating countries. The use of these common methods will allow direct comparison of the regional tundra responses to climate change.

The Russian–American Initiative on Shelf-Land Environments in the Arctic (RAISE) is designed to foster closer collaboration between Russian and U.S. scientists. As most of the river flow into the Arctic Ocean is from the major Russian rivers, evaluating the impacts of climate change on the Arctic would be difficult without collaborative studies within Russia. Current projects include an investigation of the hydrologic cycle in tributaries of large Russian rivers, which would allow a better understanding and prediction of river flow, and an evaluation of sediment discharge from large eastern Russian rivers.

Human Dimensions of the Arctic System

Human Dimensions of the Arctic System (HARC), the ARCSS component of the NSF Human Dimensions of Global Change program, is a collaborative effort with the Arctic Social Sciences Program to integrate natural and social sciences research that will demonstrate the interactions of climate and human development with the use of natural resources. Arctic Native peoples have sustained themselves through hunting, fishing, whaling, and wage employment derived from petroleum revenues. The continued sustainability of that culture and regional development could be affected by global environmental changes that may affect vegetation and marine productivity, year-round sea ice maintenance, and construction and land use practices.

In the next five years, interdisciplinary groups will focus on developing models that predict natural responses to global changes. Research at the natural sciences–human dimension interface will increase policy makers' understanding of regional natural and social systems and build linkages between communities in the Arctic. Those linkages will enhance the knowledge base necessary for examining policy choices and risk assessments within the context of global and regional climate changes.

Arctic Natural Sciences

The National Science Foundation established the Arctic Natural Sciences (ANS) program in 1995. The program is unique in NSF in the variety of disciplines supported. ANS supports research in glaciology, atmospheric sciences, ocean sciences, earth sciences, contaminants, biological sciences, and environmental research.

Glaciology

Research in glaciology includes the study of all forms of naturally occurring ice and its history. Some examples are studies of past climates and atmospheric paleochemistry from ice cores, ice stream and valley glacier dynamics, glacial geology, glacial hydrology, and glacier mass balance. The research takes place in Alaska, Greenland, the High Canadian Arctic, Svalbard, Russia, Iceland, Norway, and Sweden. In addition, some limited funding goes to support research in high-altitude and midlatitude regions of the Northern Hemisphere.

The program also supports research on new methods of studying glaciers and ice sheets, including the development of improved remote sensing capabilities, such as synthetic aperture radar (SAR) interferometry. In addition, declassified intelligence satellite photos are providing information on decadal-scale changes.

The U.S. National Ice Core Laboratory (NICL), located at the Denver Federal Center, is operated through an interagency cooperative agreement with the U.S. Geological Survey. The NSF funding is from both the Arctic and Antarctic science programs and the Paleoclimate Program.

One of the important areas of research is to better understand the mechanisms responsible for the surge behavior of glaciers and the seasonal fluctuations of glacier flow. Work has focused on the role of subglacial water and basal water pressure, ice temperature, internal deformation, till rheology, electrical conductivity, and turbidity of glacial meltwater. These parameters are measured in boreholes in the ice at several locations on the glaciers. Recent studies of the Greenland ice sheet have shown that the ice-covered area around the southern Greenland periphery has receded over the past decade.

Among the largest uncertainties in ice volume changes during the late Quaternary is the extent of ice sheets over Franz Josef Land, Novaya Zemlya, and the adjacent seas. Deglaciation of the Barents/Kara Sea ice sheet may have been initiated by a

rapid global sea-level rise 13,000 years ago. This sea-level rise would have destabilized this marine-based ice sheet, particularly in the deep troughs bordering the Russian Arctic seas.

Studies on natural climate signals in ice cores have relied on the information preserved in the ice caps about past atmospheric conditions. Over 50 chemical species and physical properties have been measured in ice cores and are used to reveal past climatic conditions. Significant progress has also been made in characterizing the atmosphere-to-ice "transfer function." For example, it has been shown that the transfer function is nonlinear and depends on temperature, water accumulation, and the abundance of other species.

Atmospheric Sciences

Several investigators are studying climate change, how it is characterized, and its consequences for the Arctic. The program supports research aimed at the physical understanding of the processes responsible for climate change as well as the processes affected by climate change.

Conditions in the magnetosphere, ionosphere, and thermosphere can influence the performance and reliability of space-borne and ground-based systems. Arctic observations are essential to understanding the physical processes that govern space weather. NSF's program focuses on high-latitude observations aimed at understanding the coupling between the magnetosphere, ionosphere, and upper atmosphere and predicting the weather in space. A specific emphasis of NSF programs is to understand Arctic and Antarctic conjugate phenomena. Conjugate studies provide a unique tool for tracing time-varying magnetic field lines and determining large-scale current configurations in the magnetosphere.

Tropospheric ozone plays a key role in the oxidative chemistry of the troposphere and has an important impact on the radiative balance of the atmosphere. Understanding the processes that control the origin, trends, distribution, and effects of tropospheric ozone is a high priority in atmospheric chemistry research. Research continues toward understanding the production and loss of tropospheric ozone through remote sensing, in-situ measurements of trace gases and radicals involved in ozone photochemistry, and chemical and transport modeling studies.

Ocean Sciences

From 1995 through 1999 U.S. Navy submarines supported civilian scientists on cruises under

the Arctic Ocean ice cap. These cruises, known as Science Ice Experiments (SCICEX), were designed to support unclassified oceanographic research proposals funded by NSF and ONR. The missions were dedicated to improving our understanding of the Arctic Ocean and the nature of its seasonal variations.

The Arctic Ocean is the last frontier in oceanography. Important issues are related to the global carbon cycle and the distribution of biota, fresh-water balance, circulation, heating, transport of sediments and pollutants, and spreading of the sea-floor, as well as the volume, flow, and properties of sea ice. NSF and ONR have developed a new draft agreement to continue to use submarines to conduct science experiments when feasible.

The SCICEX submarine cruises have provided a unique synoptic snapshot of the configuration of the Arctic Ocean. They have revealed ice thickness distribution (which plays a major role in determining the overall heat and mass balance at the surface of the ocean). The front that separates Atlantic and Pacific waters appears to have moved from a position close to the Lomonosov Ridge to the Mendeleev and Alpha Ridges. This translates into a 20% increase of the area dominated by the Atlantic waters. In parallel the upper ocean temperature has increased, by 1°C in some regions. These observed changes in Arctic Ocean circulation and temperature may be due to an increase in the temperature and volume of the incoming North Atlantic water.

Gakkel Ridge, the active spreading center in the Arctic Ocean, is the slowest spreading portion of the mid-ocean ridge system. Gravity surveys carried out by the SCICEX program have revealed that the crust is very thin, probably less than 4 km.

A side-scan swath bathymetric sonar and a high-resolution sub-bottom profiler were mounted in 1998-99 on the submarine's external hull. This instrument, the Seafloor Characterization and Mapping Pod (SCAMP), provided an unprecedented opportunity to map the deep Arctic Ocean. SCAMP provided data necessary for the accurate digital terrain mapping required for modeling ocean circulation and for determining where piston coring or dredging should take place along the Arctic Mid-Ocean Ridge.

Earth Sciences

ANS supports research in a wide range of fields of geology, including paleoclimatology, glaciomarine sedimentology, permafrost, glacial geology/geomorphology, surficial processes, paleontology,

petrology, tectonics, and solid earth geophysics. The paleoenvironmental studies focus on understanding the past Arctic environments by examining the sedimentary and paleontological record of terrestrial coastal plain, continental shelf, and deep marine sediments.

The tectonic evolution of the Arctic Ocean Basin and the Bering Sea are major scientific problems that need to be addressed. Tectonic activity such as subsidence, uplift, and seafloor spreading have opened the basin since the mid-Mesozoic. New geological and geophysical studies will help our understanding of the evolution of the basin, which is a crucial missing link in understanding much of the Arctic history. Data collected using SCAMP has greatly improved our knowledge of parts of the Arctic seafloor, but substantially more mapping, geophysical measurements, and profiling need to be done before we have a complete picture of the basin.

Permafrost is ubiquitous in cold climates, and its occurrence and thickness increase during cold periods and decrease in warmer periods. Discontinuous permafrost is ice-rich permafrost that is thawing or degrading; its temperatures range from -5° to -2°C . Therefore, its occurrence and distribution are particularly sensitive to climate changes. Recent studies have shown that increases in air temperatures in the Arctic have been greater than increases in temperatures in the temperate climates. Such temperature increases should have been reflected in an increase in permafrost temperatures, but a number of other parameters such as the depth and duration of annual snow cover can also affect the permafrost. As a result, there is concern about the future of permafrost and response to warming trends.

Closely related to the concerns about the permafrost thawing is the role of the tremendous volume of clathrates or frozen gas hydrates that are associated with and found below the permafrost and off the shelf areas. Gas hydrates are frozen methane and water that can hold methane at concentrations approaching that of liquefied natural gas. Methane hydrates could have a major influence in stabilizing climate during periods of major cooling; more important is the concern over the stability of these deposits during a warming trend. Large releases of methane could increase atmospheric concentrations of methane. Furthermore they could also change the strength of sea floor sediments, which could affect seafloor stability.

Contaminants

The newest area of research in ANS is the study

of contaminants. ANS encourages research on the physical, chemical, and biological processes that sequester and disperse contaminants. Quantification of these processes for a variety of contaminants, including heavy metals, radionuclides, persistent organic pollutants (such as pesticides and industrial chemicals), hydrocarbons, ozone (and its precursors), and aerosols derived from various parts of the Arctic, is fundamental to appreciating and mitigating their impact on human physical and socioeconomic systems.

Environmental Research

The purpose of NSF's ANS environmental research is to understand the relationship between physical and chemical processes as they relate to the unique character of the Arctic environment. Research projects in this area include the history, biology, and dynamics of Arctic fauna and flora; the physical and biological geography of Beringia and the Arctic coastal regions; the microbial processes responsible for mineralization cycles such as carbon and nitrogen fluxes; biological adaptation to the Arctic environment; and the hydrography of freshwater drainages.

Climatic data obtained by ANS researchers studying changes in the permafrost indicate that Alaska is currently warming at a rate of about 2.4°C per century. Some of the discontinuous permafrost south of the Yukon River in Alaska has warmed by as much as 1.5°C .

The flora and fauna of tundra soils are among the least known components of Arctic biodiversity. Tundra soils are unique because of the presence of permafrost, highly acid or alkaline conditions, and repeated cycles of freezing and thawing. The soil biota are generally small and difficult to identify or even detect, but recent evidence suggests that the bulk of the biological activity in the Arctic is due to these organisms. Researchers have developed a rapid and innovative molecular-based technique that promises to characterize bacteria and viruses by probing unique sequences of their DNA. Special probes are bonded to a microchip and buried in the soil for a short time; subsequent laboratory analysis enables comparisons between known microbial DNA and that of microbes that live in the tundra.

Biological Sciences

Research topics span a broad range of biological disciplines, with several projects multidisciplinary and interdisciplinary in design. The biological sciences component of the Arctic Natu-



Controlled burn on the LTER site at Caribou-Poker Creeks, Alaska.

ral Sciences Program supports research in all aspects of Arctic biology, including biological oceanography and marine ecology as well as terrestrial and freshwater ecology.

Two Long Term Ecological Research (LTER) projects continue to provide insights into Arctic and near-Arctic habitat. Research at Toolik Lake in the northern foothills of the Brooks Range has identified a host of interrelationships between atmosphere, soil, water, and dominant biotic components. Large-scale tests of existing models have been conducted concerning the loss of carbon from land to rivers and lakes; these tests have confirmed that rates of carbon loss are approximately equal to net productivity on land. Research has produced the capability to measure the net primary production of an entire watershed based on measurements at a few well-chosen sites. Research has led to a rethinking of the basis for high levels of carbon dioxide in lakes and streams. This need for re-evaluation emerged from studies that indicated that metabolism within the lake could not account for the supersaturation of carbon dioxide in the lake waters. Further studies have pointed toward the metabolism of soil microbes as a likely major factor. Other work at Toolik Lake has involved the addition of phosphate to experimental streams, with concomitant significant effects on primary producers and subsequent changes in consumer communities. Studies on the growth rate of large fish in Arctic lakes have provided the basis for resource management decisions about lake trout fishing in this area. The results of the studies also

have implications for management of food resources for Native peoples, resources that may be significantly affected by climate changes.

The LTER project at the Bonanza Creek and Caribou-Poker Creeks watersheds has begun a long-term study of the effects of controlled, large-scale fires on the ecology of the latter watershed. The 900-acre burn (designated Frostfire) will be followed by detailed examination of nutrient changes and the long-term ecological effects. A substantial preburn database was accumulated and will provide a robust perspective on the nature of ecological changes that can be ascribed to natural and burn-related processes; measurements will be made of plant succession, species diversity, and population dynamics of organisms in the affected areas. The insights from this research will have importance from both a basic ecological perspective and for fire management planning, as this study is being done in close cooperation with the U.S. Forest Service.

One of the other ecosystem projects was designed to test the importance of geomorphology in determining food web (trophic) structure. This research, termed the geomorphic-trophic hypothesis, postulates that landscape characteristics, including lake outflow gradient, lake depth, and lake area, determine the distribution of fish species, which in turn controls the benthic and pelagic trophic structure. This proposed work has four major components:

- Assembling and interpreting a geographic information system database of lake area, lake depth, and outflow gradient for lakes in the vicinity of the Toolik Lake LTER site;
- Sampling a subset of these lakes in an experiment designed to evaluate landscape control of fish distributions and their impacts on benthic and plankton food webs;
- Sampling a group of experimental lakes, also in the context of the geomorphic-trophic hypothesis; and
- Constructing food web models to test whether the geomorphic-trophic hypothesis governs food web characteristics.

A second project was designed to improve the understanding of how carbon-nutrient interactions in soils might affect the responses of Arctic tundra ecosystems to global environmental change. This research was conceived in a global warming context that predicts that a global temperature increase would affect carbon-nutrient interactions at the ecosystem level. The central idea is that the primary production in Arctic eco-

systems is often strongly nutrient limited, with virtually all of the nitrogen made available to vascular plants in tundra ecosystems coming from microbial mineralization of soil organic matter.

Fundamental biological research with relevance to Arctic biodiversity continued to receive strong support for a substantial and diverse array of activities, including taxonomic investigations, population studies, community ecology, and ecosystem analysis.

Research supported through the NSF PEET program (Partnerships for Enhancing Expertise in Taxonomy), created to ensure continuity of systematic expertise in unusually important groups of organisms, has focused on a family of lichens (Cladoniaceae) that occupy widespread regions of northern forests and Arctic tundra but are also globally distributed. The northern members of this taxon are pivotal components of Arctic ecosystems, forming an important food resource for reindeer and caribou. The research is aimed at synthesizing the understanding of the taxonomic placement of these and related groups and has involved an international team of scientists and students in the application of molecular methods for the analysis of gene sequences to understand evolutionary relationships.

A similar clarification and correction of long-standing taxonomic differences among groups of Nearctic and Palearctic black flies have also been supported. This research has produced a number of monographic studies that promise to integrate disparate interpretations of the evolutionary history and relatedness of this large insect group so important for its ecological roles and health implications. U.S. investigators have collaborated closely with colleagues in Canada and Europe in this important, synthetic research.

Through its program aimed at encouraging surveys and inventories of regionally important biota, NSF has supported a study of the co-evolution of Beringian mammals and their parasites. This work seeks to discover the history of speciation of parasite and host as their mutual distributions have been affected by the rise and fall of Beringian sea levels. Comparison of this process with that occurring in mainland associations will help reveal the special influence of the Arctic insular environment on the nature and pace of evolutionary change. In addition, this research has produced a strong collaboration with Russian colleagues at the Institute of Biological Problems of the North in Magadan.

Another survey activity is focusing on the benthic marine algae of Alaska. The investigators

are developing Web-based databases for integrating their findings with those of other scientists working on the globally distributed group. More traditional products include a book called *Seaweeds of the North Pacific* and posters and presentations on the seaweeds of Port Valdez and Prince William Sound.

The potential effects of climatic warming on population-level responses are being examined through support of research on a circumboreal species of alpine cushion plant, *Silene acaulis*. Growth, survival, and reproduction of individual plants are being combined with measures of size frequencies of plants in different populations to examine how factors such as earlier snowmelt and higher summer temperatures affect the population biology of the plants. Data are being collected and analyzed in accord with the International Tundra Experiment protocols, making the results interpretable in a global context aimed at holistic understanding of the environmental effects of climate change.

Comparative ecological studies of Arctic tundra and north temperate ecosystems have demonstrated elevated growth rates and phosphorus contents of the common plankton species *Daphnia pulex* in Arctic habitats. This research is connecting changes in the proportional availability of carbon, nitrogen, and phosphorus with a reconstructed evolutionary history of target organisms to gain insight into how population-level traits can affect ecosystem function. Another project is measuring flux in carbon dioxide over several annual cycles in Arctic ecosystems to examine the net long-term effects of climate change and to compare long- and short-term ecosystem responses.

Another study of nutrient cycling in peatlands has uncovered what appears to be evidence of primary assimilation of nitrogen through the uptake of organic nitrogen by the ericaceous shrubs that inhabit this nearly 400-million-hectare circumboreal habitat. If demonstrated, this pathway of nitrogen absorption could change our understanding of the role of nitrogen in nutrient-poor ecosystems. The role of mycorrhizal symbionts in facilitating either organic or inorganic nitrogen uptake will also be examined.

The geomorphology of Arctic lakes on Alaska's North Slope is also being examined for its role in establishing the structure of food webs. The influence of lake depth, area, and outflow on fish community composition and the subsequent effect on the lakes' food webs will be studied in these lakes, which are free of human-introduced fish species.

Arctic Social Sciences

In FY 98 and 99, Arctic social scientists collaborated with the Arctic Research Consortium of the United States (ARCUS) with support from NSF to identify science needs in the North. The report, *Arctic Social Sciences: Opportunities in Arctic Research*, is available from NSF's Office of Polar Programs and is on the Web at <http://www.arcus.org>. Following are highlights of social science projects supported by NSF.

Health Care Delivery in the North

An international team of sociologists found that the introduction of competition and privatization in health care has had unintended effects for the northern regions of Norway, Sweden, and Finland. Many physicians in Norway, for example, are leaving the North to develop greater client lists in anticipation of the new fee-for-service system. Based on in-depth interviews with health care providers and citizens in the Arctic regions of all three countries, the study points up the consequences of policy changes for health care quality and accessibility in the rural North.

Whaling Communities in Alaska

Modern and ancient whaling practices reflect environmental changes in the Arctic. An interdisciplinary team of archaeologists, anthropologists, and geomorphologists documented past and present whaling practices from northern Alaska to the Bering Strait. They also worked with local elders and schoolchildren to develop an exhibit on the history of whaling for the Native village of Wales, Alaska, as part of its bilingual (Inupiaq and English) program. The exhibit will be shown in other villages in northern Alaska. The research team involved whaling communities in the archaeology projects through internships and through courses offered at Ilisagvik College in Barrow.

Traditional Knowledge and Indigenous People

A study on beluga whales demonstrated how traditional ecological knowledge, a system for understanding one's environment that is passed on from generation to generation, can be documented. Traditional ecological knowledge provides insights that are not available in the scientific literature. A series of semidirected interviews between social scientists and indigenous peoples documented the timing, location, and direction of local and migratory beluga movements; beluga behavior including feeding and calving; and environmental factors

that affect belugas, such as ice, fish, wind, and killer whales. Information was documented in text and maps. The project shows that indigenous knowledge of beluga whales is precise and consistent and that traditional ecological knowledge can be documented and made available to aid communities and scientists in research and decision-making. The results were shared with the Alaskan and Chukotkan communities in a series of village meetings; elders' suggestions for revisions were incorporated into the final report. Copies of the report were distributed widely throughout communities in western Alaska and the Russian Far East.

Social Science and Rural Education

A five-year longitudinal study of Alaskan high school students from villages, towns, and the state-supported boarding school indicates that students' aspirations are often incompatible with cultural traditions and village life. Aspirations are different for students educated in small village schools, compared to those in towns and boarding school, and girls are more likely than boys to migrate out of their home regions. Alaska Native students are less likely than non-Native students to leave rural Alaska for the predominantly non-Native worlds of colleges or cities. However, when parents or grandparents express positive attitudes toward college attendance, Native students are just as likely as non-Native students to leave rural Alaska for college. Results of the surveys and the longitudinal study were provided to each school district for use in evaluation and curriculum planning.

Education

NSF supports the integration of Arctic research and education. In FY 99, NSF contributed to the establishment of a vast educational network across remote villages of Alaska. The network enables village residents to pursue distance education courses from their homes. With NSF's assistance the University of Alaska purchased equipment to link villages with research stations at Toolik and Atkasuk via a smart classroom in Fairbanks. In FY 98 and 99, NSF continued to develop the network of high school teachers and students involved in Arctic research projects, to forge partnerships between educators and scientists through the Alaska Rural Systemic Initiative, and to provide linkages between Alaska Natives and the scientific community through the Alaska Native Science Commission.

Arctic Research Coordination

NSF supported a program of polar information and advisory services, provided support for the Interagency Arctic Research Policy Committee, provided funds for the Arctic Research Commission, and supported conferences, workshops, and studies to further develop and implement Arctic research planning and policy.

As required by the Arctic Research and Policy Act of 1984, a comprehensive Arctic Research Plan was prepared by the Interagency Arctic Research Policy Committee and submitted to the President in July 1999. The sixth revision to the U.S. Arctic Research Plan included two major sections. The first of these presented the Special Focus Interagency Research Programs:

- Arctic Environmental Change;
- Arctic Monitoring and Assessment;
- Assessment of Risks to Environments and People in the Arctic; and
- Marine Science in the Arctic.

The second major section was Agency Programs, which represents the objectives of Federal agencies, focusing on the period covered by this revision (2000–2004). They were presented in seven major categories:

- Arctic Ocean and Marginal Seas;
- Atmosphere and Climate;
- Land and Offshore Resources;
- Land–Atmosphere–Water Interactions;
- Engineering and Technology;
- Social Sciences; and
- Health.

The Interagency Committee also addressed issues related to logistics support for Arctic research and new opportunities for Arctic research. The biennial revision of the U.S. Arctic Research Plan serves as guidance for planning by individual agencies and for coordinating and implementing mutually beneficial national and international research programs.

NSF supports many other interagency planning and coordinating activities. Coordination with global change programs is an integral part of Arctic program development and implementation. Improved communication at all levels is encouraged through newsletters and journals.

Engineering and Technology

The Engineering, Geosciences, and Mathematical and Physical Sciences Directorates support research in engineering, material sciences, and permafrost. Research has included studies of the mechanical properties of ice, the hydraulic conductivity of frozen soils, metamorphism of dry snowpacks, and three-dimensional analyses of ice.

NSF also sponsors a program for science-based, high-technology small business firms, the Small Business Innovation Research (SBIR) program in the Engineering Directorate. SBIR is interested in research on advanced concepts in scientific or engineering areas, particularly where the research may serve as a base for technological innovation.

Department of the Interior

The Department of the Interior performs biological and physical research; conducts mapping, monitoring, and assessment programs throughout Alaska and its offshore regions; and manages department lands in Alaska. These activities are performed by services or bureaus, each with administrative and technical offices located in Alaska.

Minerals Management Service

The Minerals Management Service (MMS) has the statutory responsibilities to manage the mineral resources located on the U.S. Outer Continental Shelf (OCS) in an environmentally sound and safe manner and to collect, verify, and distribute mineral revenues from Federal and Indian lands. In support of these responsibilities, the MMS conducts two major programs of research that are relevant to activities in the Arctic. One, the Technology Assessment and Research (TA&R) program, focuses on engineering and technology issues. The other, the Environmental Studies (ES) program, focuses on issues related to assessing and predicting potential environmental and socioeconomic impacts.

Technology Assessment and Research Program

The MMS supports an active research program to understand the engineering constraints for offshore operations, especially as related to the structural integrity of structures and pipelines, the prevention of pollution, and the technologies necessary to clean up an oil spill should one occur. In essence, the program provides an independent assessment of the status of OCS technologies and, where necessary, investigates technology gaps and provides leadership in reaching solutions. The program also facilitates a dialogue among engineers in the industry, the research community, and the MMS in dealing with the many complex issues associated with offshore oil and gas operations.

The TA&R program supports research associ-

	Funding (thousands)	
	FY 98	FY 99
Technology Assessment/Research	3,480	3,200
Environmental Studies	3,335	3,700
Total	6,815	6,900

ated with operational safety and pollution prevention, as well as oil spill response and cleanup capabilities. It was established in the 1970s to ensure that industry operations on the OCS incorporated the use of the Best Available and Safest Technologies (BAST). The program comprises two functional research activities: Operational Safety and Engineering Research (OSER) and Oil Spill Research (OSR).

The TA&R program has four primary objectives:

- **Technical Support:** TA&R provides engineering support to MMS decision makers in evaluating industry operational proposals and related technical issues and ensuring that these proposals comply with applicable regulations, rules, and operational guidelines and standards.
- **Technology Assessment:** Industry applications of technological innovations are investigated and assessed to ensure that governing MMS regulations, rules, and operational guidelines encompass the use of the BAST.
- **Research Catalyst:** The program promotes leadership in OSER and OSR research by acting as a catalyst for industry research initiatives.
- **International Regulatory:** The program provides international cooperation for research and development initiatives to enhance the safety of offshore oil and natural gas activities and the development of appropriate regulatory program elements worldwide.

The TA&R program enhanced its research

capabilities in FY 99 through the establishment of a five-year cooperative research program with the Offshore Technology Research Center (OTRC) in College Station, Texas. This cooperative agreement provides direct research support to the MMS as well as providing a forum for identifying and jointly funding research projects with industry on a variety of topics.

In the past the program was motivated by the need to acquire basic engineering information necessary to oversee the general development of offshore operations. As a direct result of research funded by the TA&R program, regulatory changes were initiated on the design and operation of diverter systems, well control procedures and training requirements, the need for periodic platform inspections, methodologies for assessing the integrity of older or damaged platforms, the reduction of exhaust pollution offshore, and the development of oil pollution plans to ensure that the proper equipment, personnel, and procedures were available to respond to an offshore oil spill, should one occur.

However, the future has provided new goals and directions for offshore oil and gas research initiatives. This new emphasis is a result of past technology developments, economic constraints within the industry, and a continuing need to ensure that offshore oil and gas operations can be conducted safely without harm to the environment.

With a sound appreciation for the current state of offshore technology, the TA&R program will continue to focus its research efforts in the following four areas:

- Frontier areas of operations (both deep water and the Arctic), including safety issues as well as the integrity of structures and pipelines;
- Human and organization factors and how they can be addressed to mitigate accidents;
- The aging offshore infrastructure, including platforms and pipelines; and
- Spill mitigation measures, including cleanup and containment technologies for an oil spill, should one occur.

The TA&R program is a contract research program; that is, the research is not performed within the agency but is conducted by academic institutions, private industry, and government laboratories. Studies are performed in cooperation with the offshore industry or with other agencies or governments. This aspect of the program provided an important multiplier of funding support, but probably of equal importance is the discourse it provides with the industry. The ability to work

together to assess a particular technology or the rationale for future technical developments helps both industry and government. Such cooperation and dialogue help eliminate possible conflicts or misunderstandings concerning the engineering feasibility of an operational decision. As a result of this dialogue, a valuable exchange of information is provided between the MMS and the industry.

Operational Safety and Engineering Research

Arctic offshore operations have been hampered more by the lack of commercially economic discoveries than by technology. The industry has tended to develop onshore resources in the Arctic with just minimal exploration and development offshore. However, recently there has been increased interest by the oil and gas industry in Arctic offshore resources.

Sea ice is still the most severe environmental hazard posed by the Arctic relative to future offshore development. Such hazards include forces that moving sea ice may exert against offshore structures, icing of structures resulting from freezing spray, gouging of the sea floor by sea ice (which could interfere with buried pipelines), and interference with locating or cleaning up a potential oil spill. Engineering data for these hazards will become increasingly important as operations move from an exploration mode to a production mode and as structures are considered for deeper water, especially within the shear zone or pack ice.

The TA&R program has funded a variety of projects and major international workshops to develop a better understanding of the engineering constraints for operating in the harsh Arctic environment:

- International Workshop on Ice Scour and Arctic Marine Pipelines;
- International Workshop on Offshore Pipeline Risk Assessment and Management;
- Alaskan Arctic Pipeline Workshop;
- International Workshop on Corrosion Control for Marine Structures and Pipelines;
- Pressure Ridge Ice Scour Experiment (PRISE);
- Risk Assessment for Ice Damage to Seabed Facilities;
- An Engineering Assessment of Double Wall Versus Single Wall Designs for Offshore Pipelines in an Arctic Environment;
- Risk Assessment and Management Based Criteria for Requalification of Marine Pipelines;
- Appraisal and Development of Pipeline Defect Assessment Methodologies;

- Modernization of Tubular Collapse Performance Properties;
- The Banff/99 Pipeline Integrity Workshop;
- Optimization of Horizontal Well Completion; and
- Coiled-Tubing and Slim-Hole Technology, DEA-67 Phase III.

The objective of the International Workshop on Ice Scour and Arctic Marine Pipelines was to review ice scour effects relevant to the safe design and operation of marine pipelines offshore and to address the issues of damage control, oil spill cleanup, and risk management. The first international workshop was held in February 1998. The proceedings volume from that workshop is available from C-CORE. A second workshop was held jointly with the 15th International Symposium on Okhotsk and Sea Ice in February 2000 in Mom-betsu, Hokkaido, Japan. The general aim of the second workshop was to expand on the first event, exchange information through the review of progress and research since the last workshop, and relate issues of pipeline burial, protection, and damage control to current guidelines. The workshops were sponsored by the MMS, C-CORE, the Okhotsk Sea and Cold Ocean Research Association of Japan, the Sakhalin Oil and Gas Institute, and the oil and gas industry.

The primary goal of the International Workshop on Offshore Pipeline Risk Assessment and Management was to define alternative risk assessment and management approaches to maintain existing pipelines and to determine how they might be applied to marine pipelines. This workshop, held in Houston in November 1998, concluded that additional analysis of available data on offshore pipeline performance should cover current and evolving challenges and recommended that analytical models be verified. The workshop further recommended that projects be developed for synthesis of lessons from onshore experiences to offshore experiences; development of guidelines for inspection, maintenance, repair and operations plans; and development of procedures and guidelines that clearly demonstrate to management the benefits that both government and industry stand to gain from this effort.

In November 1999 a workshop on Alaskan Arctic Pipelines was held in Anchorage. The workshop was initiated and sponsored by the MMS through the TA&R program and coordinated by C-CORE. The objective of the workshop was to bring together members of the public and a group of experts with skills related to offshore pipeline

design, operation and maintenance, and inspection to examine the current state of practice for pipeline alternatives under consideration for Alaska offshore oil and gas reserves. The workshop was open to the public, and the speakers were urged to avoid highly technical discussions, formal lectures, and commercial overtones. Rather, speakers were asked to provide a candid presentation that would focus on their particular area of expertise in such a way that it could be seen how Arctic pipeline development is undertaken to address the concerns and interest of the public sector, the regulators, the designers, and the operators. The excellent response of all speakers towards meeting these objectives was a key reason why the conference was judged to be an outstanding success by the people who attended. When this workshop was being planned, it was expected that about 60–70 people would attend. The fact that 155 people registered is a clear indication of the level of interest and commitment among the public, regulators, design consultants, operators, and research agencies toward building safe and reliable pipelines with minimal environmental impact.

The Corrosion Control for Marine Structures and Pipelines Workshop was designed to define the state of the art of corrosion protection of marine structures and pipelines, to define the state of the art of testing for corrosion damage, to identify the technical and nontechnical barriers that hinder a fuller utilization of advanced methods for mitigating corrosion on marine structures and pipelines, and to identify research and development projects that would advance corrosion mitigation technologies. The workshop was held in Galveston, Texas, in February 1999. The marine structures that were discussed were offshore structures, harbor structures, and ship structures, and pipelines including those for gas and oil transmission over long distances. Internationally recognized corrosion experts, material specialists, inspection specialists, maintenance engineers, and designers participated. Industrial, university, regulatory, standardization, and certification leaders provided a breadth of knowledge and experience. The workshop will produce a hardbound proceedings volume.

The Pressure Ridge Ice Scour Experiment (PRISE) was a Joint Industry Project (JIP) headed by C-CORE. The most likely transportation mode for oil and gas in the Arctic and sub-Arctic offshore regions is a pipeline laid on or under the seabed. Marine pipelines in areas frequented by ice are threatened by grounding or scouring ice mass-

es, which occur periodically through the ice season. Pipelines must be manageable, economical, and protected by trenching or burial to a safe depth below the seabed. The major problem facing industry planners, regulators, and design engineers concerns the depth of burial required, or the trenching and trench backfill requirements.

Risk Assessment for Ice Damage to Seabed Facilities was a JIP with seven companies to assess risks associated with ice-seafloor interaction relative to Arctic oil and gas facilities. This JIP was also headed by C-CORE. The field data are being selected from available sites to be analyzed and compared to a recently completed model that digitally simulates data using stochastic methods. Efforts during this portion focused on setting the numerical model to conduct real-time simulations of ice keel behavior.

An Engineering Assessment of Double Wall Versus Single Wall Designs for Offshore Pipelines in an Arctic Environment is a project being completed by C-CORE for the MMS. The objective of the study is to accurately document the advantages and disadvantages (technical and nontechnical) of a robust, single, thick-walled design compared to a pipe-in-pipe design considering the constraints associated with an offshore Arctic pipeline project (ice cover, permafrost, scouring of the seafloor by ice, etc.) and based on supporting quantitative information. The information developed in this project would be essential to determine the adequacy of future pipeline installations in the Arctic. The project has four phases:

- Collection of background information;
- Design considerations (including a project update briefing to be held in Anchorage);
- Construction and installation consideration; and
- Operational considerations (including a final briefing to be held in Anchorage and a final report).

Risk Assessment and Management Based Criteria for Requalification of Marine Pipelines is a cooperative project between the MMS, Instituto Mexicano del Petroleo, and Ocean Engineering Services to develop a requalification method for pipelines in much the same manner as has been done for offshore platforms. The initial effort considered the results and recommendations of the recent workshop on risk management systems for pipelines and on how they affect the direction of the project. A database was compiled, and a pipeline model will be developed to include items of importance to a requalification process. A subse-

quent modification to the contract has been issued to investigate spatial currents on shallow water pipelines in the Bay of Campeche, Mexico.

Appraisal and Development of Pipeline Defect Assessment Methodologies is a project being completed by MSL Engineering Limited, U.K. This project will collect and evaluate all experimental data on the failure of defective pipe sections, including weld, corrosion, and mechanical damage defects. It will also assemble all current recommended practices for pipeline design and remaining strength calculations into one easy-to-follow document. The final product will describe the most appropriate methodology for the assessment of pipeline weld and metal loss defects.

Modernization of Tubular Collapse Performance Properties by Stress Engineering Services, Inc. will work to improve the accuracy of casing collapse performance properties. This improvement will allow an opportunity to substantially reducing tubular costs because the margins of actual collapse performance vs. API ratings have been found to be as high as 30–40%. The JIP will conduct physical testing on industry-wide sampling of API and proprietary casing grades and will review mill production techniques for both API and proprietary grades of casing. Data will be analyzed so that participating operators can immediately reduce tubular costs. A database will also be provided to API and the International Standards Organization for future standardization activity. The MMS will participate in this JIP to keep track of the changes in casing performance properties.

The Banff/99 Pipeline Integrity Workshop, held in Banff, Canada, is the fourth in a series of workshops that Natural Resources Canada has organized to address new pipeline technologies. The workshop reviewed the progress achieved from the 1997 workshop and carried out intensive group discussions on such topics as risk assessment and risk management, abandonment issues, and in-line inspections. Most of the topics presented dealt with the design, construction, maintenance, and repair of pipelines in cold or Arctic regions. The workshop was sponsored by Natural Resources Canada and a number of industry participants, including the MMS.

Optimization of Horizontal Well Completion was conducted by the University of Tulsa to develop guidelines to optimize horizontal well completions, develop user-friendly completion optimization software, and derive a completion pseudoskin expression for horizontal wells. In a horizontal well, depending on the completion method, fluids

may enter the wellbore at various locations along the well length. The pressure distribution in a horizontal well can influence the well completion and well profile design and have an impact on the production behavior of the well. Pressure drop versus flow behavior along the well and the relationship between the pressure drop along the well and the influx from the reservoir are being studied.

Coiled-Tubing and Slim-Hole Technology, DEA-67 Phase III is being conducted by Maurer Engineering as a JIP to review all aspects of coiled-tubing drilling, completion, production, and workover technology; update and maintain existing PC programs; and develop new PC programs needed by participants to overcome field problems. Information for the reports will be obtained from technical literature, field tests, service companies, operators, and laboratory tests. The objective of the project is to keep participants abreast of the latest technical developments in coiled-tubing technology and to assist them in implementing this technology into their operations.

Although these projects address critical areas for Arctic offshore facilities, additional research is still required to demonstrate fully that the technology is available to design, construct, and operate facilities in this ice-laden region. In addition to the development of numerical models, actual field programs are needed to improve the understanding of sea ice and the ice-structure interaction process. Research is also needed to improve probabilistic models for estimating year-round ice loads for permanent production structures. There are added load uncertainties due to the extended exposure periods of production structures, and these uncertainties must be considered in the design process. These areas will be addressed by the TA&R program in the near future.

Alaskan Arctic offshore oil and gas deposits may be one of the major undeveloped petroleum resources remaining in the U.S. The capability to drill exploratory wells in water depths up to 200 ft in the Arctic has been proven. The information gained as activities are extended into deep water and more hostile ice conditions, combined with extensive research, should provide a solid technological base for future operations.

Oil Spill Response Research

The MMS is the principal U.S. government agency sponsoring offshore oil spill response research. The MMS maintains a comprehensive international Oil Spill Research (OSR) program, which originated in the late 1970s to improve oil

spill response technologies and procedures. This program has expanded the existing capabilities to respond to an open ocean oil spill. The scope of the MMS OSR program was increased in 1986 by aligning the MMS program with Environment Canada and the National Institute of Standards and Technology. The MMS continues to leverage its program funds through this partnership. Many of the oil spill research projects are JIPs, where the MMS leverages its money by as much as 6:1. The OSR program complies with Title VII of the Oil Pollution Act (OPA) of 1990 and cooperates with the Interagency Coordinating Committee for Oil Pollution Research, as called for in the OPA.

The Technology Assessment and Research program is funding several projects to develop a greater understanding of the technologies required to detect, contain, and clean up oil spills in Arctic conditions.

The ALOFT (A Large Outdoor Fire plume Trajectory) model is widely recognized as a tool for computing and displaying smoke plume trajectories from in-situ burning. In the event of an emergency, it would be beneficial to rapidly access ALOFT predictions and other in-situ burning data to predict the likely effects of burning. The ALOFT model of smoke transport is capable of predicting time-averaged downwind concentrations of particulate matter from a large fire. Model assumptions include a uniform ambient wind blowing over relatively flat terrain. The model has been expanded to include the effect of varying wind velocity with altitude, and it can now calculate smoke plume concentrations as a function of time. The model has also been expanded to calculate the soot production from multiple smoke plumes over flat terrain.

Two model versions now exist: ALOFT-FT for flat terrain and ALOFT-CT for complex terrain. The flat terrain version is operational on workstations and can accommodate multiple fire sources. Development work on the three-dimensional complex terrain models has been completed. ALOFT-CT for personal computers has undergone two rounds of beta testing. Based on input from users, several significant new features have been added, including multiple fire sources, a fuel properties database that can be modified by the user, optional user-specified emission factors, and the ability to specify different wind fluctuations over water and land. This version is being prepared for general distribution to the response community. Work will continue on implementing ALOFT-FT and ALOFT-CT for personal computers. ALOFT-CT is not a

replacement for ALOFT-FT. ALOFT-FT is adequate in most areas except where smoke is expected to move into mountainous terrain. Large mountains, such as those found along the coast of Alaska, can have a substantial impact on the smoke plume trajectory. When the models have been reviewed by a larger group of users, the need for additional features and training will be considered.

Another joint project involves redesigning an existing, large, stainless steel fireproof boom to reduce its size, weight, and cost. The boom was designed, constructed, and tested in the early 1980s. It was built to survive for extended periods in steep Arctic waves, carry high loads, withstand impacts from ice, and operate in flames for long periods. Because of the rigorous performance criteria in the original design, the boom is expensive, heavy, and cumbersome to deploy manually. This project was completed in four phases:

- Redesign the existing stainless steel boom to reduce cost, size, weight, and handling problems and make it compatible with existing fireboom systems;
- Construct a 15-m (50-ft) prototype section of redesigned boom for testing purposes;
- Test the boom, with and without fire, at appropriate testing facilities; and
- Refine the design of the boom and produce detailed engineering drawings.

The engineering drawings are available free of charge on the Internet.

A catalog of oil properties was first compiled by Environment Canada (EC) in 1984. The MMS has jointly funded the catalog program since 1989. The catalog was started to provide, in one place, the physical and chemical data about oils relevant to oil spills. No catalog of this type existed, and data were found only by random searching of literature. The current (December 1999) catalog contains information on over 418 types of crude oils and petroleum products, including many Outer Continental Shelf (OCS) crude oils. The catalog is available in electronic format from EC's Web site at www.etcentre.org/spills.

The Behavior of Oil Spills (BOSS) project is designed to provide a comprehensive collection and review of data and concepts related to oil spill behavior. Topics include the behavior of oil spilled at sea but will also include the lesser-documented topics of oil on land, on fresh water, and in the ground. It will combine into one source the literature on oil spill behavior and findings from previous joint research projects. More than 5500 papers have been collected and initially reviewed to date.

Completion of this project will result in a series of volumes combining not only the review of literature, but also data tables and unpublished results. This will enable future re-evaluation of processes and use of data for model inclusion. The oil-in-ice review has been completed. Work is continuing on sections on solubility, evaporation, and emulsification.

The Mechanical Oil Recovery in Ice-Infested Waters (MORICE) program is designed to improve the equipment and techniques for mechanical recovery of oil spills in ice-infested waters. This project has demonstrated the potential to improve mechanical recovery in ice-covered waters. The results from this project may allow oil and gas activities to proceed off the coast of Alaska in broken ice conditions. The North Slope Oil Spill Response Steering Committee has endorsed this project, which will facilitate pending regulatory decisions for the Northstar and Liberty development projects. Phase 4 involved field testing the prototype skimmer during fall freezeup in Prudhoe Bay, Alaska, in October 1999. This is a JIP between the MMS, Alaska Clean Seas (ACS), Exxon Production Research Company, the Norwegian Pollution Control Authority (SFT), Norske Hydro, Statoil, and Saga Petroleum.

Alaska Clean Seas conducted an International Oil and Ice Workshop in April 2000 in Anchorage. The workshop assembled experts on oil fate and behavior, Arctic oil spill response, ice environments, and Arctic oilfield development to present the leading edge technologies in a seminar and field setting. Field experiments conducted as part of the workshop in the operations oilfield on the Alaskan North Slope added a level of realism to the key topics that could not be duplicated elsewhere.

At present the only known method of searching and detecting the presence of oil leaking at low rates from a marine pipeline in winter involves drilling holes in the ice at frequent intervals along the pipe to expose any oil that could be trapped in or under the ice. This method is expensive and labor intensive, and it exposes personnel to extreme weather. There is strong motivation within government agencies and industry to identify and develop a reliable and safe means of remotely detecting oil in and under ice. Phase 1 of this research study will establish a baseline of information that can be used to plan field trials with prototype systems to achieve this purpose. The primary goal of Phase 1 will be to gather and evaluate all available knowledge about the subject of oil-

More information about the International Oil and Ice Workshop can be found at the Alaska Clean Seas Web site (www.alaskacleanseas.org).

under-ice detection with the objective of identifying the most promising technology or process for future development and testing. If Phase 1 is successful and proceeds to Phase 2 (field testing), BP Exploration (Alaska) and Alaska Clean Seas have indicated that they would both consider participating as funding partners.

The MMS is seeking new and innovative methods and equipment for cleaning up accidental oil spills in ice-infested waters of the Alaskan Arctic. A new research contract has been developed to study the technology in the design and use of ice booms for recovering spilled oil in ice-infested waters. The objective is to determine the operating window in which an ice boom can be deployed when towing or pulling on a broken ice field. The work will also define the likely scenarios where an ice boom could be used effectively.

Another project will determine the fate and effects of chemically dispersed oil at sea in the context of an ecosystem approach to the management of the marine environment. It will compare the effects caused by exposure of several trophic levels to naturally and chemically dispersed oil as a function of time. This will provide a more complete assessment of the net environmental effects of using dispersants in different temperate environments to refine the dispersant use policy in Alaska and Great Britain. The goal is to develop a decision-making framework for determining the net environmental effect of using or not using dispersants in temperate offshore and near-shore locations. This is a joint project with the Alaska Department of Environmental Conservation, the U.S. Coast Guard, the Great Britain Ministry of Agriculture Fisheries and Food (MAFF), and the Maritime and Coastguard Agency (MCA).

The MMS TA&R program operates Ohmsett, the National Oil Spill Response Test Facility located in Leonardo, New Jersey. Ohmsett is the only facility in the world where clients can conduct full-scale oil spill response equipment tests with a variety of crude oils and refined petroleum products. Equipment tests are conducted under controlled, reproducible conditions and include the capability for variable, artificial wavemaking. Ohmsett provides a unique facility to conduct tests and develop new devices and techniques that detect, map, contain, and clean up oil spills. The primary feature of the facility is a pile-supported concrete tank with a water surface 203 m (667 ft) long by 20 m (65 ft) wide and with a water depth of 2.4 m (8 ft). The tank is filled with 9.84 million L of brackish water from nearby Sandy Hook Bay.

The tank has a movable, cable-drawn towing bridge capable of towing floating test equipment at graduated speeds up to 3.3 m/s (6.5 kt) for at least 40 s. The towing bridge is equipped to lay oil on the surface of the water several meters ahead of the equipment being tested, so that reproducible thicknesses and widths of test oils are achievable with minimal wind interference.

Alaska Environmental Studies Program

As the managing agency for the Outer Continental Shelf (OCS) leasing program in Alaska, the MMS Alaska OCS Region has conducted environmental studies to obtain information needed to make sound leasing decisions and to monitor the human, marine, and coastal environments. In Alaska, more than \$260 million have been spent on studies in 15 OCS planning areas in the Arctic, Bering Sea, and Gulf of Alaska subregions. These studies cover a range of disciplines, such as physical oceanography, endangered species, living resources, fate and effects, and socioeconomics.

Regional government leaders, traditional knowledge sources, environmental groups, oil and fishing industry personnel, studies contractors, other scientists, MMS components, and Federal, state, and local agencies help the MMS to identify environmental issues and information needs. Information transfer meetings and workshops are convened to bring together information from these key sources. The pooling of shared knowledge results in a synthesis of information that identifies studies needed to meet the current focus on post-lease and monitoring information requirements.

In 1998 the MMS renewed funding of the Coastal Marine Institute (CMI) at the University of Alaska Fairbanks (UAF) to benefit from its nationally recognized scope and depth of scientific expertise. Under a recently extended cooperative agreement, the MMS committed \$1 million per year for studies to be conducted by the CMI if matching state funds were available. The institute conducts research focused on environmental, social, and economic studies relevant to both Federal and state offshore oil and gas and mineral resource management issues. The UAF School of Fisheries and Ocean Science, internationally renowned for its coastal and marine expertise, manages the CMI. The institute creates an opportunity for the MMS and the state to accomplish research programs that could not otherwise be carried out. In addition to ten ongoing studies, eight

new studies are expected to be funded through the CMI in FY 99.

Endangered Species

The bowhead whale, an endangered marine mammal of high importance to Native cultures in the Arctic, migrates through areas in which oil and gas have been discovered. Efforts to define the migration corridors of bowhead whales and their responses to offshore operations continue through 1999 under the ongoing in-house Bowhead Whale Aerial Survey Project (BWASP). The BWASP provides real-time data on each fall migration of bowhead whales across the Alaskan Beaufort Sea for implementing overall limitations on seasonal drilling and geological and geophysical exploration. Both real-time information and annual BWASP reports provide background needed by the MMS to ensure that activities planned by the oil industry do not pose a threat of serious, irreparable, or immediate harm to the species. The information also helps ensure that planned activities will not have an unmitigable adverse effect on the availability of the bowhead whale to meet subsistence needs by causing whales to abandon or avoid hunting areas.

Analysis of BWASP data suggests that significant interannual differences exist in the mean distance of whales from shore and in the mean depth of water at the location of the sighting. In 1997 the migration corridor was significantly closer to shore in the eastern portion of the Alaskan Beaufort Sea (and not significantly different in the western portion) than in 1994 or 1995. Also in 1997, observers spotted record numbers of bowhead whales (1655), many of which were engaged in nearshore feeding activity.

An ongoing multiyear study, Bowhead Whale Feeding in the Eastern Alaskan Beaufort Sea: Update of Scientific and Traditional Information, is unique in the extent of its coordination with area whale hunters. Residents of Kaktovik, Alaska, have assisted and continue to assist in the study design, field implementation, technical oversight, and knowledge sharing needed to determine the importance of the eastern Alaskan Beaufort Sea area to feeding bowheads. Project scientists responded to concerns of subsistence hunters by not conducting vessel tows for zooplankton east of Kaktovik until the village had landed its second whale. Other ongoing study components include aerial photography, behavioral observations, isotopic analysis of baleen plates, stomach content analysis, and energetics modeling.

Living Resources

The final field season of a study monitoring the distribution and abundance of ringed seals in northern Alaska was completed in winter 1999–2000, and data analysis, interpretation, and preparation of manuscripts will continue through FY 01. This cooperative research effort with the Alaska Department of Fish and Game was designed to provide data for comparison with data from similar surveys that used the same protocols and were undertaken prior to 1987. Analyses should lead to detection of any significant population trends, which will be examined for correlation with natural factors and known development activities. Preliminary results indicate that ice type and deformation, meltwater, time of day, distance from shore and from the fast ice edge, and longitude all have an effect on observed densities. General information on relative abundance, relative density, and recruitment was also obtained.

A cooperative study implemented through the MMS/UAF CMI was designed to produce a correction factor for the proportion of ringed seals in the Beaufort Sea population that are not visible to aircraft-based observers during aerial surveys. Using information obtained during cooperative aerial surveys of ringed seals and observational data on the behavior of radio-instrumented seals, investigators will determine the proportion of seals that are occupying subnivean dens or are underwater and thus are not visible from the air. New information concerning seasonal changes in seal distribution and changes in group sizes associated with the breakdown of winter home ranges will also be useful for interpreting the results of strip-transect surveys.

The MMS and the USGS Biological Resources Division (BRD), through an FY 99 Intra-agency Agreement, initiated a monitoring study of Beaufort Sea waterfowl and marine birds. The goal of this study is to determine the abundance and density of various waterfowl and marine bird species in previously surveyed central Beaufort Sea “industrial” and “control” areas.

Another recent Intra-agency Agreement with USGS-BRD entitled Polar Bear Den Surveys is examining ways to better identify subnivean polar bear dens along the North Slope of Alaska. The immediate goal is a workshop on forward-looking infrared radar and other technologies for use in areas that might be vulnerable to disturbance by on-ice seismic exploration and other activity by the oil and gas industry. If shown to be effective, such technology might then be used to identify

and map subnivean polar bear dens prior to site-specific industrial activities.

Fate and Effects

In the first of three ongoing physical oceanographic modeling studies, a CMI study uses numerical models to address the generation, flux, and fate of plant particles and their interaction with physical processes along the ice edge on Alaskan Arctic shelves. The goal is to be able to predict the flux and fate of natural material on the shelves. In the second study, Rutgers University refined a coupled ice-ocean model of the Arctic Ocean. Products will include a CD containing new atmospheric data products, including a gridded 15-year wind record for modeling use and a 10-year hindcast simulation of Arctic ocean circulation and ice movement. In the third study, a CMI study documents how ice, ocean, and atmospheric circulation differ between two climate states. This study builds on a recent demonstration that the Arctic switches between two multiyear regimes, causing reversals in circulation and other environmental characteristics.

The first of two recently completed CMI studies compared three surface pressure fields used to derive hindcast winds in Chukchi Sea circulation models and recommended using European Center for Medium Weather Range Forecasting products. The second CMI study used a two-dimensional circulation model to examine the circulation of the northern Bering and Chukchi shelves. The model suggests significant features, such as a clockwise circulation around Wrangel Island that resolved from the sparse data for the region.

In the first of three oil behavioral model studies, the Alaska Region recently completed a study titled Update of the Coastal and Surf Zone Oil Spill Transport Model (COZOIL), which provides a desktop capability for projecting the trajectory and weathering of hypothetical oil spills in the surf zone. A second study evaluated the state of the art in oil weathering models and MMS needs in such modeling. As the result of this study, the MMS is obtaining a state-of-the-art weathering model and is participating in a consortium to improve the model.

In parallel with the modeling studies, the MMS has supported three CMI physical oceanographic studies. The first, recently completed, deployed moorings in cooperation with the Japan Marine Science and Technology Center and examined circulation on the data-sparse, north-central Chukchi Sea shelf. The mean circulation was northward

and eastward, parallel to the isobaths but opposite to the prevailing wind direction. The second and ongoing study examines circulation, thermohaline structure, and cross-shelf transport in the Alaskan Beaufort Sea using time-series measurements from moored instruments along the outer shelf and slope. A third study measures under-ice currents in the vicinity of Northstar and Liberty prospects on the inner Beaufort Shelf using innovative, bottom-mounted acoustic Doppler current meters. The study will provide the first long-term winter measurements of currents directly beneath the ice.

In the first of three monitoring studies, the CMI examines historical changes in trace metals and hydrocarbons in the inner shelf sediments of the Beaufort Sea prior and subsequent to petroleum-related industrial development. The study uses a combination of dated sediment cores, freshly collected surface sediment, 30 years of prior analytical measurements by the investigator, and data from the prior MMS Beaufort Sea monitoring program. Preliminary results suggest an increase in vanadium and barium, but not in other trace metals, since industrial development. A second monitoring study, Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA), was initiated in June 1999. This study examines impacts associated with the first anticipated Federal oil development on the Alaskan OCS—the Northstar and Liberty prospects. Phase I of the five-year study will monitor ambient noise, resuspension of sediments, and sediment quality and will develop additional monitoring tasks for Phase II. Phase II tasks will cover additional monitoring concerns as they develop. A third monitoring study examines sediment quality in surface sediments and dated cores from likely contaminant deposition areas in lower Cook Inlet and Shelikof Strait. Preliminary source fingerprinting for petroleum hydrocarbons and trace metals, toxicity bioassays, and biomarker analyses suggest no significant accumulation of contaminants or effects from 30 years from offshore and onshore oil development in the Cook Inlet watershed.

In the first of four combined laboratory and monitoring studies, a cooperative study implemented through the MMS/UAF CMI looks at the kinetics and mechanism of slow polycyclic aromatic hydrocarbon (PAH) desorption from Lower Cook Inlet and Beaufort Sea sediments. This study will lead to better predictive capability for the environmental fate of PAH in Arctic sediments. A second CMI study examines petroleum-degrading communities in Beaufort Sea sediments and will

compare the current community to that existing at the onset of coastal Beaufort Sea development in the late 1970s. A third, recently completed CMI study predicted high persistence of PAH in Cook Inlet sediments because of natural populations of hydrocarbon degraders and strong sorption of the PAH by the organic content of the sediments. A fourth CMI study found that humic acid content or properties do not affect sediment PAH concentrations in Cook Inlet and Port Valdez sediments, with the PAH level appearing to be more a function of opportunity (exposure).

Socioeconomics

A recent study titled Economic and Social Effects of Diminishing Oil and Gas Industry Activity on Alaskan Communities was completed in September 1999. According to the study report, by 1980, oil accounted for 90% of the State of Alaska annual unrestricted general fund revenue. Since 1980 the contribution has been at least 75%. This oil money affected many aspects of life in Alaska—employment opportunities, housing costs, utility costs, the availability and quality of education, health care, public safety, and even recreational and entertainment opportunities. While a pervasive force in state and local economies, the economic impacts of the oil industry have been unsteady and unpredictable. The oil industry contributed directly and indirectly to the quality of life for Alaskans through millions of dollars in philanthropic contributions. In the 1990s, as North Slope oil production began declining, Alaska has begun adjusting to a reduced role for the oil industry in the economy. Revenues to the State, pass-through funds to local governments, oil industry employment around the state, and philanthropic contributions have all declined. Thirty-two mitigation options are described in the study report. Some of the more important proposed options are to stabilize the economy, stage leases over time and geography, control rates of production, provide royalty relief, and diversify the economy.

The *Exxon Valdez* oil spill was likely the world's most studied tanker spill; in addition to published reports, there is a large amount of "grey literature." A study titled *Exxon Valdez Oil Spill Cleanup and Litigation: A Collection of Social-Impact Information and Analysis* collected, organized, and synthesized information about the oil spill cleanup and associated litigation. The final report also identified key social factors for analyzing this information to determine related effects on the human environment in local communities.

Examples of these social factors are social organization, cultural values, social health, access to subsistence resources, subsistence hunting, and use of subsistence resources. An interactive CD-ROM containing an annotated bibliography with abstracts, key social factors, and analytical findings is nearing completion. It will allow MMS staff, researchers, and the general public to rapidly access available information on the social impact information related to the oil spill.

Traditional knowledge is information gained from experience in living on the land and water. The Inupiat of the Alaskan North Slope are a source of traditional knowledge for marine and terrestrial ecosystems. However, because most of this knowledge, which has adapted to changes in technology and socioeconomic conditions, has been passed on orally from one generation to the next, little of it is in published form and even less is indexed. Some traditional knowledge has been written down, recorded, archived, and in some cases, published, but because this knowledge has not been indexed, it is often not available to scientists.

Collection of Traditional Knowledge of the Alaskan North Slope is an ongoing study that will collect, catalog, and organize existing information identified by Inupiat community elders, North Slope Borough subsistence coordinators, Inupiaq Language and Cultural Center personnel, and members of the North Slope Scientific Committee. The information will be attributed, abstracted, provided with key words, and geographically referenced in a database. The resulting information will be indexed and abstracted on a CD-ROM, and copies will be provided to Alaskan Native communities and Federal, state, and local government agencies involved in environmental research and decision making.

The extensive MMS social research in Alaska and the diverse study results accumulated over the past 20 years have warranted publication of a book synthesizing Alaska socioeconomic study findings pertinent to the Alaska OCS. A project titled *Synthesis of Information on Socioeconomic Effects of Oil and Gas Activities on the Alaska OCS* will synthesize the results of more than 160 MMS-funded studies on cultural, economic, regulatory, and monitoring topics. A CD-ROM version of the book will also be prepared for distribution. This important effort will provide a benchmark document in a peer-reviewed format, covering the broad scope of past MMS socioeconomic studies and resulting publications. It will provide a com-

prehensive reference for MMS staff, Federal and state agencies, local government, libraries, and the general public.

The study titled Update of Oil Industry Labor Factors for the Alaska Manpower Model was initiated in 1998 and is scheduled for completion in March 2000. It will update an existing in-house model that is based on labor factors in the early 1980s. The technology and efficiency of exploration, development, and production on the OCS has changed considerably since the 1980s. The updated model will yield more accurate projections of direct OCS employment. The updated Manpower Model will be linked with the IMPLAN model, which is an input/output model for sectors of the economy, originally developed by the U.S. Forest Service. The updated Manpower Model will also provide more accurate labor inputs to the Rural Alaska Model, which is used to make demographic projects for local areas. The forecasts from these models will be used in the economic sections of environmental impact statements. The improved accuracy is intended to enhance the confidence of stakeholders in the projections.

The MMS awarded a contract to LGL Limited during July 1998 to develop a GIS database of oil-and-gas-related and other human activities in the Alaskan Beaufort Sea between 1979 and 1998. The objective of this study is to compile detailed information describing the locations, timing, and nature of these human activities in the Alaskan Beaufort Sea. This information will be stored in Oracle/SDE, and an application will be developed

in ArcView to analyze and display this information graphically, particularly with regard to potential noise and disturbance associated with human activities. The MMS plans to use this database to analyze the potential effects of previous oil industry activity on subsistence whale hunting and to test hypotheses related to factors affecting bowhead whale distribution and relative abundance as described in the MMS Bowhead Whale Aerial Survey Program (BWASP) reports.

Information Transfer

Recently the MMS organized three Arctic workshops and meetings with other Federal agencies. The Arctic Seismic Synthesis and Mitigating Measures Workshop, which was convened in March 1997 in Barrow and sought the advice of Inupiat whale hunters, also included speakers from the National Marine Fisheries Service and Naval Research Laboratory. The Arctic Kelp Workshop and the Seventh Information Transfer Meeting were convened in Anchorage during May 1998 and January 1999, respectively. The latter three-day meeting, which had the theme "Focus on the Future—Alaska Environmental Studies" and was attended by about 200 people, included 50 presentations, nine of which were given by scientists from the U.S. Fish and Wildlife Service and Biological Resources Division of USGS. MMS study plans were presented for comment, and two discussion panels sought advice and information from community leaders, subsistence hunters, and government and university leaders.

Copies of the proceedings of the three Information Transfer workshops can be requested through akwebmaster@mms.gov or the Public Information Resource Center (Room 330), MMS, 949 E. 36th Ave., Anchorage, AK 99508-4363. Requests for copies of MMS Alaska OCS Region Annual Studies Plans or questions about specific studies discussed in this article can be referred to Dr. Cleve Cowles, Chief, Environmental Studies Section, MMS at 907-271-6617.

Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) conducts research, including inventories and monitoring, in the Arctic to generate information that will help meet its resource management responsibilities. These responsibilities include conservation of migratory birds, certain marine mammals, endangered species, anadromous fishes, and all biota inhabiting National Wildlife Refuges and other FWS lands. Although specific research programs are conducted by the Biological Resources Division (BRD) of the U.S. Geological Survey (USGS), FWS continues to conduct biological inventory and monitoring programs in the Arctic at both national and international levels.

	Funding (thousands)	
	FY 98	FY 99
Migratory Birds	2,889	3,484
Fisheries	3,879	3,894
Marine Mammals	1,568	1,568
Conservation of Flora and Fauna	185	185
U.S.-Russia Env. Agreement	0	75
Total	8,521	9,206

Ecological Services and Fisheries

Environmental Contaminants

Marine Mammals. Under the Marine Mammal Protection Act of 1972, the FWS is responsible for the management of polar bears, Pacific walrus, and sea otters. As stated in the act, the primary objective is to maintain the health and stability of

the marine ecosystem. When consistent with that primary objective, the goal is to obtain an optimum sustainable population, keeping in mind the carrying capacity of the habitat. All three species are important subsistence resources for Native Alaskans, and the FWS is further obligated to protect and maintain the availability of these species for subsistence purposes.

Potential adverse effects of contaminants on marine mammal populations have long been a concern. Since the 1970s relatively high levels of polychlorinated biphenyls (PCBs), DDT and its metabolites DDD and DDE, hexachlorocyclohexane (HCH), chlorobenzenes, dieldrin, endrin, and chlordane have been reported in fat tissues of marine mammals. Some marine mammals have relatively high concentrations of potentially toxic metals in their tissues. The occurrence of relatively high levels of anthropogenic contaminant levels with relatively large-scale die-offs of marine mammals in Europe and North America have raised concern about the role of contaminants in these events. A further concern is the exposure of those who depend on these species as a subsistence food source.

The FWS's polar bear biomonitoring program was initiated in 1995 to determine if contaminant levels in polar bears from the two Alaskan population stocks were of concern. The Chukchi/Bering Seas and Southern Beaufort Sea population stocks in Alaska are shared with Russia and Canada, respectively. Compared to Canada, Greenland, and Norway, relatively little recent information on heavy metal and organochlorine contamination has been collected on polar bears in Alaska and Russia. Polar bears have been identified by the Arctic Monitoring and Assessment Program (AMAP) as a key species for monitoring environmental contamination in the Arctic ecosystem because of their wide distribution, position at the top of the Arctic marine food chain, and value to Native subsistence users. The initial goals of this program were to establish baseline levels of trace elements in liver, kidney, and muscle, and organochlorine pesticides in fat tissues of adult male polar bears in Alaska; develop and maintain a contaminant database for polar bear tissues in Alaska; and determine if there are significant differences in contaminant levels between the two Alaskan populations. Because of variations in contaminants between sex and age classes, the project goals are to collect samples from 60 adult males, the minimum required for statistical analysis. Males are harvested by Native subsistence hunters at approx-

imately twice the rate of females, so obtaining samples from adult males will be quicker and will not encourage hunting of adult females, the most important age class with respect to population dynamics. The acquisition of samples from adult male polar bears, 16 to date, has been slower than expected. Late-forming ice during the last two winters has kept bears offshore and unavailable to Native subsistence hunters. Additionally, fewer adult males are harvested than subadults because the adults tend to stay farther offshore, require more work to process, and generally are less desirable with respect to the quality of fur and meat.

Levels of PCBs in adult male polar bears from Alaska analyzed to date are relatively low compared to the levels found in polar bears in eastern Hudson Bay and Norway. The average levels of HCH in Alaskan bears are among the highest levels reported in the Arctic. However, the role of these relatively high HCH levels with respect to the health of polar bears, human consumers, and the Arctic ecosystem is not known.

Relatively high levels of toxic elements such as mercury, cadmium, copper, and lead have also been documented in many Arctic marine mammals. Preliminary results from 11 bears indicate that mercury levels in Alaskan polar bear livers (both population stocks combined) are lower than those reported for western Canada in 1986, but concentrations of cadmium and copper in Alaskan polar bears were somewhat higher than those from western Canada.

Samples have also been collected for long-term storage with the Alaskan Marine Mammal Tissue Archival Project (AMMTAP) to use in future analyses as analytical techniques improve and to assist in determining spatial and temporal trends of contaminant levels in the Arctic. Standardization of quality assurance and quality control procedures will help reduce past limitations that have hindered making meaningful comparisons among various data sets. The contaminant data collected from the polar bear biomonitoring program has been used for interlaboratory comparisons, as well as physiological studies on contaminant accumulation and effects on polar bears, uptake between trophic levels in the Arctic ecosystem, and the health of local consumers. FWS will continue sampling until tissues from at least 60 adult males have been obtained.

Walrus are benthic feeders (specializing on bivalve mollusks), and contaminant loads in their tissues reflect pollutant concentrations in the sediments of the Chukchi and Bering Seas. In recent

times, plans for oil and gas development and mining have increased within the range of the Pacific walrus. Potential contamination of walrus from these activities and the effects on the health of marine mammal and human populations of the Bering and Chukchi Seas are of concern. In light of these concerns the FWS has collected tissue samples to assess baseline levels of contaminants in walrus from throughout the region.

Studies of organochlorines and aliphatic hydrocarbons conducted in the late 1980s found only extremely low levels of these compounds in walrus blubber collected from five Alaskan coastal locations (50 animals) and various sites in the Bering Sea (3 animals) during 1981–1984. More recently FWS biologists have found levels of these compounds to be largely below detection levels in blubber collected from 25 walrus taken in the Bering Sea during a 1991 research cruise. A report summarizing these results is being prepared for publication.

Heavy metals can come from natural sources or anthropogenic events such as spills or run-off associated with mining or other activities. Previous FWS work evaluated contaminant levels in walrus harvested by Alaska Natives in northwestern Alaska from 1980 to 1989. A positive correlation between cadmium and age was found in both liver and kidney. Similar relationships were found between age and concentrations of zinc (kidney) and arsenic (liver and kidney). In several instances, cadmium concentrations exceeded the level thought to interfere with organ function in some mammals. To determine if a relationship exists between metals and organ function, paired samples from 170 animals were collected from Gambell and Diomedé (1992–1994) for metal analysis and histopathology. Histopathological examination indicated that the metals present in the kidneys and livers did not cause discernable effects. The FWS plans to synthesize its heavy metal contaminants data for walrus into a journal publication and will continue to contribute walrus tissue samples to AMMTAP. Contaminant residues in walrus should be evaluated on a periodic basis to ensure that levels are not increasing over time.

Sea otters inhabit the nearshore environment and may be particularly vulnerable to contaminants because of their proximity to source areas of contaminants, their relatively high trophic status, and the tendency of organochlorine compounds to bioaccumulate. Sea otters and their principal prey (benthic invertebrates and coastal fishes) are comparatively sedentary, which limits their exposure

to contaminants present in their local environments. Thus, the presence of contaminants in sea otter tissues can provide documentation of hazardous materials in the food chain within the near-shore marine environment. Such information provides an opportunity to examine the large-scale spatial variation of contamination in environments where sea otters occur.

Early contaminant sampling in Alaska documented elevated organochlorines (mainly PCBs) in sea otter livers from Adak Island (Aleutian Island chain), while tissues were relatively “clean” in most areas sampled in southeast Alaska. Recent FWS sampling included organochlorine and heavy metals analyses of livers and kidneys collected from 65 sea otters throughout Alaska. These analyses are in progress; preliminary results have identified several otters with low levels of PCBs, beta-BHC, and dieldrin. The source of these contaminants is unclear, and the extent of contamination cannot yet be determined given the limited sample size. Physiological effects of contaminants on the sea otter population are also unknown. The majority of the samples are from sea otters harvested by Alaska Native sea otter hunters. Since sea otters are hunted primarily for their fur, the organs are voluntarily provided to the FWS as part of a biological monitoring program conducted jointly with the Alaska Sea Otter Commission (ASOC), a statewide coalition of Alaska Natives. This results in an opportunistic geographic distribution of samples based on voluntary participation of Native subsistence hunters.

Sea otter populations are believed to be growing in most areas of southeast and south-central Alaska. However, localized subpopulations in certain island groups in the Aleutians have undergone a precipitous decline in the past decade. Possible factors include increased predation by killer whales, over-exploitation of food resources, emigration, or contaminant-related morbidity or mortality.

Threatened and Endangered Species. The Fish and Wildlife Service and the National Marine Fisheries Service share responsibility for administration of the Endangered Species Act. Generally the National Marine Fisheries Service deals with those species occurring in marine environments, while the Fish and Wildlife Service is responsible for terrestrial and freshwater species, anadromous fish in freshwater and brackish water areas, and migratory birds. The FWS’s efforts include protecting endangered and threatened species and restoring them to a secure status in the wild. The

FWS has studied endangered Arctic species to determine the role that environmental contaminants may play in their decline and recovery.

The FWS has monitored populations of the Arctic peregrine falcon and the American peregrine falcon in northern and interior Alaska, respectively, since 1978. Peregrine falcon populations declined dramatically following World War II as a result of contamination with organochlorine pesticides, particularly DDT. The principal metabolite of DDT (DDE) prevented normal calcium deposition during eggshell formation, causing females to lay thin-shelled eggs that often broke before hatching. The peregrine falcon was first listed as endangered in 1970. The use of DDT and other organochlorine pesticides such as aldrin and dieldrin were restricted in Canada and the U.S. in the early 1970s. The population of peregrine falcons began to increase during the late 1970s, and by 1984 the FWS reclassified the Arctic peregrine falcon as threatened. This subspecies was delisted by the FWS in 1994. The American subspecies is still listed as endangered, but a proposal to delist this species was published in the *Federal Register* in August 1998.

During the early 1980s, FWS endangered species and contaminants biologists collaborated to develop an egg monitoring program to track changes in organochlorine residue levels through time and to measure eggshell thickness. The study design involved collecting 10 eggs from each subspecies every five years. Samples were collected in 1984, 1989, and 1995, and another round of sampling is proposed for the 2000 field season. To date, 187 eggs representing 153 clutches have been analyzed (with roughly equal numbers from the two subspecies). Initially, only concentrations of organochlorine pesticides and their metabolites were determined, but in later years some heavy metals were added to the analysis. The data are being analyzed, and a report will be published in 2000.

Satellite tracking and banding data indicate that virtually all of these falcons winter in Central and South America, where organochlorine pesticides are still used. Residue analyses have detected DDT (not just DDE, the metabolite) in eggs as recently as 1995, suggesting recent use of DDT within the peregrine's range. Residue studies are proposed as part of the post-delisting monitoring plan for both Arctic and American peregrine falcons, because of the important role of organochlorine contamination in the decline and subsequent recovery of this species.

Declines of spectacled and Steller's eiders, both designated as Federally threatened species, have raised concerns about contaminant exposure and biological effects within these species. Several contaminant surveys of these and other eider species in Alaska and Arctic Russia have shown that although organochlorine levels were very low, some elements including cadmium, copper, lead, and selenium were surprisingly high compared to published values. Lead appears to be entering the U.S. breeding population via ingestion of lead shot. The sources of other elements have yet to be established. Furthermore, it is unclear what physiological effects, if any, might result from such high concentrations of these other elements. Studies are underway to correlate elemental residues in eiders with physiological responses. Contaminant levels in spectacled eiders have been fairly well characterized, but routes of exposure have not yet been elucidated. Analysis of key spectacled eider food items for these elements should be pursued in the future.

The threats of petroleum and chemical spills to eiders are also being assessed. A preliminary review of marine spill threats to spectacled eiders has been performed. This review qualitatively assessed the petroleum products commonly found in these areas and compared known vessel traffic, spill histories, and environmental conditions (such as wind, current, and ice cover) to eider distributions at critical times during the year. Alaskan populations of spectacled eiders spend much of their time in close association with marine habitats of the Bering and Chukchi Seas and congregate in molting and wintering areas. Catastrophic population impacts are a real possibility if these eider groups are exposed to marine petroleum spills. Updated information continues to be gathered to improve predictive capability.

Very little is known about contaminant burdens in the short-tailed albatross. This species is currently listed as endangered throughout its range. Contaminant residue information may enhance our knowledge of why this species has declined and might contribute to its recovery.

Species Declines and the Bering Sea

A primary goal of the FWS is to prevent listing of additional species under the Endangered Species Act. To accomplish this goal, continued emphasis must be placed on investigating reasons for ongoing species declines. A number of species in the Bering Sea have declined over the past two decades, particularly the Steller sea lion; colonial

seabirds and sea ducks have also been affected to different degrees. Some species have declined dramatically throughout the Bering Sea region, while others have demonstrated inconclusive or localized trends, with declines observed only in certain areas. Many of these species fall under the jurisdiction of the FWS because they are migratory birds or because they are present within National Wildlife Refuges. Reasons for the declines have not yet been established; several mechanisms may be affecting such a wide range of species. While fishing pressure, climate change, and food-web changes are most commonly cited as causative factors, little research has focused on the role of contaminants in these changes.

An interagency cooperative effort to develop methods for collection, handling, transport, and long-term storage ("banking") of seabird eggs from the Bering Sea, Chukchi Sea, and Gulf of Alaska was initiated by the National Institute of Standards and Technology, the Alaska Maritime National Wildlife Refuge, and the Biological Resources Division of the U.S. Geological Survey during 1998. Common murre eggs were collected from two Bering Sea and two Gulf of Alaska sites, and thick-billed murre eggs were collected from one Chukchi Sea site for evaluation of collection, handling, shipping, and archival techniques. Long-term storage of specimens under the Arctic Marine Monitoring and Trends Assessment Program will allow retrospective analyses of chemical residues and other parameters in the future. Additional seabird species will be considered for inclusion in the specimen bank in the future. This research should update our current knowledge of seabird egg and tissue contamination within this region, in addition to archiving specimens for the future.

National Wildlife Refuges

National Wildlife Refuges were first established in Alaska in the early 1900s to protect seabird nesting islands. In the ensuing years additional lands were added to existing refuges and new refuges were created. Currently there are sixteen refuges in Alaska, encompassing about 92 million acres of land.

Lands within the National Wildlife Refuge system in Alaska have had a varied and interesting history. While large tracts remain in near-pristine condition, past uses of refuge lands have also included oil exploration and drilling, mining, establishment of runways and support facilities for aircraft, and use by the military for various operations including military installations, staging

areas, supply depots, radar or communication facilities, training grounds, and even a historic battlefield on Attu Island in the Aleutians. After these operations ceased, sites were often abandoned. Entire facilities were commonly left intact or minimally cleaned because of the costs involved with transporting wastes and debris from remote sites in Alaska. At other sites, hazardous materials were spilled with no subsequent cleanup. In many areas there are concentrations of abandoned 55-gallon drums and similar containers, including many that released their contents to the surrounding environment. A number of sites are scheduled for remediation by the Army Corps of Engineers, the Department of the Navy, or the Department of the Air Force. The FWS in Alaska has devoted considerable effort over the past two decades to identifying potentially contaminated sites and working with responsible parties to ensure cleanup of these sites.

The FWS has also conducted numerous contaminant studies on refuges within the Arctic zone, establishing baseline conditions or investigating impacts on trust species. These investigations will continue to be necessary for determining significant changes through time and for responding to new issues as they are identified.

Oversight of Assessment and Cleanup Activities

Many of the active and inactive military facilities in Alaska contain chemical and physical hazards to humans and wildlife, including PCBs, chlorinated organics, petroleum hydrocarbons, heavy metals, and unexploded ordnance. Because many of these sites are located on refuge lands or pose threats to migratory birds, the FWS has been integrally involved in overseeing many of the site investigations and cleanup activities at these facilities. While military sites are spread across Alaska, most sites on FWS lands are located in the Aleutian Islands (including Adak, Amchitka, Attu, and Shemya), on the Alaska Peninsula, in western Alaska, or on Alaska's North Slope, including DEW-line stations.

In the Alaska Maritime National Wildlife Refuge, bald eagle tissues collected from the remote Aleutian Island of Adak were analyzed for metals and chlorinated organic compounds. The resulting information will assist in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) investigations of existing military facilities on Adak.

The FWS has participated with other agencies in collecting data from Amchitka Island (Alaska Maritime NWR) over the last several years and has

has provided oversight of contaminants investigations conducted by military and Department of Energy contractors. Interpretation of wildlife data from Amchitka Island and comparison to previous surveys is ongoing and will aid in assessing the level of contaminant risk to wildlife. A final report is anticipated in FY 00.

National Wildlife Refuge Studies

The FWS has published a series of baseline contaminants reports for studies on National Wildlife Refuges within the Alaskan Arctic. These include the Koyukuk, Nowitna, Selawik, Innoko (Northern Unit), and Kanuti National Wildlife Refuges. These studies measured ambient concentrations of metals in water, freshwater sediments, and fish tissues at several sites in each refuge. Similar data have been collected for Tetlin, Yukon Flats, and Innoko (Southern Unit) National Wildlife Refuges. Reports for those studies are in preparation and should be completed in mid-2000.

A more extensive data set has been collected from the Arctic NWR, and the first two of three volumes have been published. Sampling included water, sediment, fish, and terrestrial vegetation for metals, hydrocarbons, and persistent organic chemicals such as organochlorine pesticides and PCBs. The third volume should be published during 2000. A separate study compared metals concentrations (particularly mercury) in snow from the Arctic NWR, Prudhoe Bay, and Barrow, Alaska.

Samples of liver from burbot were collected for determination of concentrations of organochlorine pesticides, including toxaphene. Samples were collected from three National Wildlife Refuges in interior Alaska and the Tanana River near Fairbanks, Alaska. The results of the analyses are pending, and the report on these data should be published during 2000. High concentrations of toxaphene have been reported in burbot from two lakes in Yukon Territory, Canada, and consumption advisories have been issued at these sites.

A number of active and abandoned mining operations exist on refuge lands or may be affecting trust resources. Only a small percentage have been inspected for contaminants, and additional inspections and investigative studies are necessary to determine what impacts mine tailings and mine effluents may have on trust resources.

Summary

The FWS continues to conduct a wide variety of research and management-oriented studies within the Arctic zone. These investigations pri-

marily focus on trust species or are conducted on National Wildlife Refuge lands. Some of these data are compatible with the AMAP design and will be included in the next AMAP report. Continued support for these efforts is needed over the next five years to maintain ongoing projects and to allow study of trust species that have not been sampled for contaminants in the past.

Fisheries

FWS fishery research in the Arctic focuses on Yukon River salmon shared by the U.S. and Canada. Allocation of the harvest has been an international issue. The FWS continued research on using state-of-the-art enumeration techniques to quantify salmon abundance and monitor resource health and on applying genetic stock identification techniques to quantify genetic diversity and to determine what portion of U.S. harvests are of Canadian origin.

Bilateral talks between Canada and the U.S. stalled in 1998 as Canada ended discussions to reach a long-term agreement on the allocation and conservation of salmon stocks originating from the Yukon River in Canada. With no formal working arrangement between the U.S. and Canada in place in 1999, the FWS needed another process to disburse Yukon River Salmon Restoration and Enhancement funds. Congress originally appropriated the funds for projects that contributed to the restoration of Canadian-origin, Yukon River salmon. Lacking an agreement with Canada, the FWS Fairbanks Fishery Resources Office issued a call for proposals from local fishers, local governments, nongovernmental organizations, and agencies on the U.S. side. Representatives from the FWS, Alaska Department of Fish and Game, and local users of Yukon River salmon selected 14 projects for funding. Projects included research on salmon life history; escapement monitoring, including the use of video recorders to monitor fish passage; test fishing for run timing and strength; and coded wire tag recovery. Successful applicants included individual fishers, local governments, and Alaska Native NGOs, as well as the FWS and the U.S. Geological Survey. This represents an excellent example of the ecosystem management approach by involving local users in a unique partnership to facilitate decision-making, monitoring, and management for a resource of international significance. Bilateral talks on Yukon River salmon between the U.S. and Canada resumed in April 2000, and the next negotiations

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are planned for October 2000. The Alaska Region of the FWS resumed its role in providing leadership and technical expertise in support of the international negotiations.

In 1998 and 1999 the FWS continued studies in support of in-season management of Yukon River salmon. As part of this effort the Fairbanks Fishery Resources Office and FWS Fish Genetics Laboratory, in cooperation with the National Marine Fisheries Service, continued a combined mark-recapture, genetics, and radiotelemetry study. To date, this study has provided fishery managers with information on run strength of fall chum salmon in the upper Yukon River drainage. Some Yukon River fall chum salmon travel more than 3500 km before spawning, the longest freshwater salmon spawning migration in the world. The telemetry portion of the study was fully implemented in 1999, with 1000 tags deployed at the Rampart study site. Information from the mark-recapture portion of the study and radiotelemetry work conducted in 1998 confirmed that existing escapement monitoring sites account for most of the fall chum salmon run in the upper Yukon River. Radiotelemetry and genetics work conducted in 1999 will provide new information on stock composition, run timing, and locations of undocumented spawning areas.

The FWS continued to use weirs and sonar technology to enumerate salmon escapements on four Yukon River tributaries. Escapement information collected at sites on the Chandalar, Gisasa, South Fork Koyukuk, and East Fork Andreafsky rivers was used to schedule fishery openings along the Yukon River and to ensure stock conservation on National Wildlife Refuges. The FWS pioneered the use of split-beam sonar technology to enumerate riverine populations of adult salmon and uses floating weirs spanning 100 m to count salmon in Yukon River tributaries. Escapement monitoring projects of the FWS confirm poor returns of chinook salmon and summer and fall chum salmon in the Yukon River in 1998 and 1999. These poor returns continue to create economic hardships for local users of salmon in the Yukon River drainage.

The FWS Fish Genetics Laboratory completed laboratory processing of samples for two genetic stock identification projects in 1999. In the first project, laboratory staff used molecular genetic methods to construct a genetic baseline to improve stock discrimination of Yukon River fall chum salmon. This project supports interjurisdictional efforts to rebuild fall chum salmon stocks and enhance the ability of managers to allocate the

salmon run among users. The laboratory evaluated the suitability of three classes of genetic markers for stock discrimination, with special emphasis on separating U.S.- and Canadian-origin stocks of fall chum salmon. The new genetic baseline comprises data from nine populations analyzed with 12 microsatellite markers. Results from preliminary analyses indicate that the new genetic baseline will improve stock discrimination.

The second genetic project, initiated in 1997, was a three-year study to develop a genetic baseline for coho salmon. The new baseline will provide fisheries biologists and managers with a tool to conserve genetic diversity and provide for sustained harvests. FWS staff and partners sampled fish from more than 80 spawning stocks from locations throughout Alaska, including the Yukon River. Molecular genetic methods permitted staff to use nonlethal sampling methods and greatly simplified field logistics. Thirteen genetic markers, representing two classes of genetic markers, were used in the baseline. Preliminary tests indicate that the new baseline can discriminate among populations from major geographic regions with greater than 90% accuracy. The results of this project will have application not only in Alaska, but throughout the geographic range of coho salmon.

Marine Mammals Management

In Alaska the FWS is responsible for managing three species of marine mammals: polar bears, Pacific walrus, and northern sea otters. Of these species, polar bears and walrus are characteristic of Arctic regions. Walrus and polar bear populations are shared with Russia, and one polar bear population is also shared with Canada. Research on these populations is designed to provide information essential for international actions that are necessary to conserve populations. Research seeks to develop improved methods of defining and monitoring populations in order to detect or prevent region-wide population declines or depletion. The harvest of walrus and polar bears at sustainable levels is an important issue because both species are subject to subsistence harvest. Another issue addressed by research is the identification of important habitat areas and the potential impact of human activities on areas that may be essential for the stability of populations.

Polar Bears

International Activities. The FWS participates in a number of international forums to promote the

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conservation of trust resources, such as the Polar Bear Specialist Group (PBSG). The PBSG was established in 1968 in response to concern for overharvest of polar bears and comprises scientists and resource managers from the five Arctic nations that manage polar bears. A major function of the PBSG is to coordinate research and management activities between countries and to ensure consistency with the 1973 international Agreement on the Conservation of Polar Bears. The twelfth working meeting of the PBSG was held in Oslo, Norway, in February 1997 to discuss the status of polar bears in territories of the member nations. Proceedings, which were published in 1998, provide an overview of ongoing research and management activities on polar bears. Some of the action items addressed through resolution at the meeting include:

- Development of cooperative management agreements for shared polar bear populations;
- Special protection for adult females and emphasis on harvest management practices that select for males and young animals;
- Conservation consequences of Native-guided sport hunting in Canada under a quota system;
- Collection of data necessary to meet basic requirements for sound conservation management practices;
- Need for conservative management strategies and harvest levels in the absence of reliable scientific data;
- Management of human activities to minimize disturbance of polar bears in areas where they congregate and in maternity denning areas; and
- Coordination of an international study on the levels and effects of radionuclides on polar bears throughout their range.

Population Assessment. In 1999 the U.S. Coast Guard, as part of their commitment to provide a "ship of opportunity" platform for scientific investigations, approved inclusion of a polar bear population survey project aboard their icebreaker *Polar Star*. The project involves using the vessel's two Delphine H-65 helicopters to conduct aerial surveys for polar bears over pack ice habitat. Unexpected mechanical problems aboard the *Polar Star* led to postponement of the survey until the summer of 2000.

In 1998 the FWS began a cooperative effort with the U.S. Geological Survey, Biological Resources Division to develop a Leslie-matrix transformation model to address stock management issues such as predicting growth rates and

recovery times from environmental perturbations such as an oil spill. The model incorporates the best available life history and harvest data for the southern Beaufort Sea stock of polar bears. Age-specific rates of reproduction and mean litter sizes were based on capture data; age-specific survival rates were based on radiotelemetry. Harvest records from Alaska and Canada provided estimates of the size and composition of the harvest. Multiple iterations of the model have been run; results were used in part to assess potential impacts from offshore oil and gas activities proposed in the southern Beaufort Sea. The model shows great flexibility to incorporate a range of existing data but is limited by the data available on the southern Beaufort Sea polar bear population. Additional refinement of the model is necessary and is expected to be completed in 2000.

Harvest Monitoring. During 1997–1999 the FWS continued to collect information regarding polar bears harvested by Native hunters in coastal villages for subsistence purposes. The majority of polar bears are killed during the winter months, when advancing pack ice brings bears into contact with coastal Alaska Natives. The Alaska harvest during the 1997–98 harvest years totaled 57 animals: 27 males, 21 females, and 9 sex unknown. The harvest was the second lowest since monitoring began in 1980. The relatively low harvest may have been due in part to the late arrival of the pack ice near shore, reducing the availability of bears to hunters. In 1998–99, a total of 92 bears were harvested in Alaska: 60 males, 27 females, and 5 of unknown sex. The majority of the harvest (83%) was reported from villages in the Bering/Chukchi Seas region of western Alaska. Premolar teeth for aging were also obtained from subsistence-harvested bears. Teeth from the 1997–98 and 1998–99 seasons have not been completely aged at this time. A manuscript was developed on the genetic verification of sex of harvested polar bears. The sex of harvested bears was determined by analyzing chromosomal DNA to assess the accuracy of the hunters' reports. The results indicate that a proportion (19 of 139, or 13.7%) were incorrectly sexed and that the numbers of female bears harvested were underestimated. Based on the current estimated population size and harvest levels, the misidentification of sex does not result in an overharvest of females. However, male bias in reporting could result in an overharvest of females if harvest levels increase or population levels decrease. An additional study on the comparison of sex and age characteristics of harvested

polar bears to the population, as determined through mark and recapture programs, is ongoing.

Habitat Monitoring. The Incidental Take Program is another ongoing monitoring effort underway in Alaska. The purpose of the program is to monitor the activities of industrial development in polar bear habitat and help minimize impacts to polar bears, their habitat, and their availability for subsistence use. Oil and gas exploration and development may pose risks to polar bears and other wildlife. The Marine Mammal Protection Act of 1972, as amended, required the FWS to develop regulations that authorize the incidental, unintentional take of small numbers of polar bears during oil and gas operations. Operators contact the FWS to discuss proposed activities and their potential impacts on polar bears and their habitat. The FWS issues Letters of Authorization (LOA), which include conservation, monitoring, and reporting requirements. Additionally each operation is required to develop an approved Polar Bear Interaction Plan and conduct environmental orientation training for all on-site personnel to minimize negative polar bear-human interactions. A total of 17 and 35 LOAs were issued in 1998 and 1999, respectively.

In August 1997 the FWS completed a report called *Collection of Local Knowledge Regarding Polar Bear Habitat Use in Alaska*. This report summarizes information collected from Alaska Native polar bear hunters regarding areas used by polar bears for denning, feeding, and seasonal movements. A database was developed that includes all known locations of dens based on radiotelemetry, traditional knowledge, and other anecdotal sources of information. This information is used for land use planning activities with the oil and gas industry and other ongoing activities in the Arctic. The project also served as the basis for a polar bear habitat use study initiated in 1998 by the Alaska Nanuq Commission and the Union of Marine Mammal Hunters of Chukotka under the National Park Service's Beringia Program.

Local knowledge of polar bear use of coastal beaches and barrier islands alerted scientists to the importance of marine mammal carcasses as a food source for polar bears. Marine mammal carcasses represent tons of potential food for polar bears and may be particularly important for the survival of females with cubs and younger bears during the fall. To document the distribution and abundance of marine mammal carcasses, aerial surveys were conducted in 1995–1997 along the Alaska coast from Nome to the Canadian border. A summary

report entitled *Distribution and Abundance of Marine Mammal Carcasses Along Beaches of the Bering, Chukchi, and Beaufort Seas, Alaska, 1995–1997*, was completed in 1998. Additional studies are proposed to investigate the age and sex composition of polar bears feeding on marine mammal carcasses and to assess their energetic value to polar bears.

Pacific Walrus

Harvest Monitoring. The Pacific walrus population is a shared resource of the U.S. and Russia and is an important component of the subsistence lifestyles of the Native peoples of Alaska and Chukotka. Reliable harvest estimates are critical to walrus management and maintaining the walrus population at a healthy level. In 1998 and 1999 the FWS continued its Walrus Harvest Monitoring Project (WHMP), which monitors the size and structure of the subsistence walrus harvest in the primary walrus hunting villages in Alaska. FWS and village technicians work together to collect information on the size and demographics of the spring harvest by conducting hunter interviews and obtaining biological samples. This information is used to assess the size and composition of the harvest and to study aspects of walrus population dynamics and life history. Samples collected through the WHMP include teeth for age determination, adult female reproductive tracts to determine reproductive status, and occasionally anomalous tissues to identify specific pathologies.

Assessing Productivity and Survivorship. Over the past few years there has been a growing body of evidence that changes in the walrus population are occurring. Subsistence hunters are reporting that they have been seeing fewer newborn calves in recent years. The information supplied by these hunters is consistent with recent reports from scientists who have been surveying the ice pack in the Chukchi Sea between Alaska and Russia to assess the age and sex composition of walrus herds. In 1998 and 1999, shipboard surveys of the pack ice in the Chukchi and Bering Seas were used to visually sample the age and sex composition of walrus herds in order to investigate productivity and juvenile survival rates. Preliminary results of the surveys indicate that the numbers of calves, one year olds, two year olds, and three year olds per 100 adult females were lower than expected, suggesting that productivity and/or juvenile survival among Pacific walrus has been low for at least five years.

The cause(s) of the suppressed productivity

and/or juvenile survival rates of Pacific walrus is unknown and warrants further investigation. The FWS has contacted the USCG Arctic Icebreaker Committee to propose conducting ice-edge walrus surveys in 2000 and 2001. Information on ice conditions, depth, and locations of walrus herds may also be useful for planning future large-scale population surveys.

Haulout Monitoring. Each summer, Bristol Bay, Alaska, provides critical feeding and resting habitat for thousands of male Pacific walrus. From May through October, walrus congregate in the bay and rest at terrestrial haulout sites at Round Island, Cape Pierce, Cape Newenham, and Cape Seniavin. In 1998 and 1999 the FWS participated in walrus haulout monitoring activities in Bristol Bay with the Alaska Department of Fish and Game and the Bristol Bay Native Association. Several incidences of human-caused disturbances were recorded during the monitoring period. Increased numbers of walrus at Cape Seniavin and decreased numbers at Round Island and Cape Pierce in recent years seem to indicate that the haulout dynamics may be shifting. In 1999 the FWS also provided financial support for walrus haulout monitoring studies in the Gulf of Anadyr, Russia.

Refuges and Wildlife

Alaska Maritime National Wildlife Refuge

Seabird Monitoring. A major focus for the Alaska Maritime National Wildlife Refuge is the long-term monitoring of the status and trends of seabird populations. Every year, seabird productivity, primary prey, and environmental conditions are monitored at ten sites representing different geographic areas and seabird species. Population trends are tracked from index plots at these ten sites at three-year intervals. Geographic gaps are filled as needed by periodic observations at other sites. Information collected at these sites is used as a basis for identifying potential resource management issues and for interdisciplinary studies of ecosystem processes. One issue being examined is the differing effects of climatic processes (such as El Niño) on the reproduction of plankton-eating and fish-eating seabirds.

Seabird, Marine Mammal, and Oceanography Coordinated Investigations. The Alaska Maritime Refuge currently works in partnership with the National Marine Fisheries Service, the Biological Resources Division of the U.S. Geological Survey, and the Institute of Marine Sciences, University of

Alaska to describe and monitor the nearshore marine ecosystems surrounding seabird and Steller sea lion monitoring sites. The partners conduct surveys of the distribution and relative abundance of seabirds and marine mammals and their potential prey (forage fish) within 40 km of breeding colonies. Forage fish surveys use hydroacoustic and test fishing techniques to sample surface, mid-water, and bottom habitats. Contents analyses of seabird stomachs and marine mammal feces validate prey species of these animals. Oceanographic characteristics are described through measurements of water temperature, salinity, and density. This ecosystem approach provides information on trends of seabird and Steller sea lion populations and tracks possible environmental correlates.

Using Pacific Halibut to Assess Forage Fish Abundance. Because of the difficulty and expense of studying forage fish at sea, the refuge is assessing the feasibility of using Pacific halibut as indicators of the relative abundance of various species of forage fish. Halibut are opportunistic feeders and take whatever forage fish are present. After promising results of a preliminary study based in Homer, Alaska, the refuge expanded the program to include the Pribilof Islands, where the local Fisherman's Association cooperates by providing halibut stomach samples. Researchers are correlating the relative abundance of important seabird and marine mammal prey species such as capelin and sand lance found in halibut stomach samples with seabird and mammal population information. Relationships between these factors may emerge that help to identify the ecosystem processes that influence seabird and marine mammal populations.

Changes in Populations of Marine Birds and Marine Mammals at Bogoslof Island. Observations of recent population changes in marine fish, mammals, and birds in the eastern Bering Sea region have led to concerns about deleterious changes in the marine ecosystem, especially the possibility of the reduction in these populations relating to diminished prey availability. The refuge is using Bogoslof Island, a recently active volcano, as a natural laboratory in a unique study to address this question of carrying capacity. Significant recent volcanic activity on Bogoslof has made new habitat for seabirds and marine mammals that should support population increases if food is not a limiting factor. In the early 1990s, the refuge and the National Park Service began to gather baseline data on seabird use of the island. The National Marine Fisheries Service gathers

similar data on marine mammals. In 1999 the refuge, the University of Alaska, the University of Washington, the Biological Resources Division of the U.S. Geological Survey, and Dalhousie University, Nova Scotia, initiated research to evaluate the changes in seabird and marine mammal populations on Bogoslof Island.

Wildlife Associated with the Runways at Eareckson Air Station, Shemya Island. In a cooperative project with the U.S. Air Force's Animal, Plant, and Health Inspection Service, the refuge conducts wildlife surveys near the airport on Shemya Island. Although the primary purpose of the study is to develop a bird strike hazard plan for aircraft, the information is also providing a baseline wildlife inventory for the island, which is part of Alaska Maritime National Wildlife Refuge.

Alaska Peninsula/Becharof National Wildlife Refuges

Plant Community Assessment of the Alaska Peninsula. Through comparative transect studies, the FWS is investigating plant species and ecosystem diversity of the Alaska Peninsula and Becharof National Wildlife Refuges in relation to utilization by caribou, a FWS trust species and important subsistence resource. A team of internationally known specialists from the fields of plant taxonomy (including vascular plants, lichens, and mosses), vegetation ecology, and soils is participating.

This assessment is the first quantitative plant community study of the central and eastern Alaska Peninsula intended to identify key ecological characteristics important within these diverse northern ecosystems. The goal of this ecosystem field survey is to establish a hierarchical classification of plant community resources and gather location-specific baseline data from representative sites that are important correlates of caribou productivity. Particular attention will be given to lichen abundance and utilization by caribou within various habitats.

Field surveys were completed during the summers of 1998 and 1999. This phase of the investigation focused on identifying longitudinal and elevation gradients in species composition of plant communities. In the upcoming analytical phase of the study, the researchers will classify the plant communities into community types by ecosystem; correlate plant species abundance with environmental characteristics including landform, substrate type, elevation, soil pH, and soil conductivity; and relate lichen abundance and utilization by

caribou to the diversity of plant community types in the landscape.

The results of this study will improve assessments of wildlife populations dependent on mountain ecosystems by identifying significantly different groups of ecosystems characteristic of distinct regional types. For managers these data will be powerful tools to facilitate the evaluation of caribou production potential through plant indicator species and environmental variables.

Caribou Herds of the Alaska Peninsula. The cyclic nature of caribou numbers in the far north has sometimes frustrated attempts of managing agencies to provide a stable resource to the public. The Alaska Peninsula herds, living in a maritime climate on a 400-mile peninsula with little opportunity to expand their range, provide a unique challenge to management. The northern and southern Alaska Peninsula caribou herds are among the most important subsistence resources to 17 communities along the Alaska Peninsula and provide popular recreational opportunities to sport hunters who are often assisted by professional guides.

In recent years, Alaska Peninsula/Becharof and Izembek Refuges have worked closely with the Alaska Department of Fish and Game (ADF&G) and others to monitor the status of the herds and better understand the mechanisms affecting population change. ADF&G has kept long-term records of herd numbers and age/sex composition through aerial surveys during summer and fall. Recent efforts have expanded to include monitoring the reproductive success of known-age females, studying causes of neonate calf mortality, and documenting body condition and prevalence of disease and parasites in calves.

Isolated southwest of Port Moller, the southern herd peaked in 1983 at about 10,000 caribou. The subsequent decline reached a low near 2,000 in 1996. Occupying the remainder of the Alaska Peninsula, the northern herd peaked near 20,000 caribou from 1984 through 1989. During this period the northern herd began crossing the Naknek River to use ungrazed winter range to the north, an indication of inadequate winter range to the south. A decade later the herd's slow decline had reduced it by half; 1998 and 1999 counts were only about 9,000 caribou. Consequently the Alaska Board of Game severely restricted harvest and limited permits to residents who could demonstrate long-term dependence on the herd. Concurrently the Federal Subsistence Board closed Federal lands to hunters from outside the area.

Although mortality caused by predators and

hunters gains more attention, the data show that inadequate nutrition may be the primary cause of these declines, as indicated by relatively low pregnancy rates, young cows beginning reproduction about a year later than normal, and low calf weights. Bears, wolves, and eagles took up to 20% of the calves during the first two weeks after birth; nevertheless, comparable losses have been seen in herds that are increasing. What was more worrisome in the northern herd was that high mortality continued into the third week of life as weakened calves succumbed to other causes. As the northern herd declined, the incidence of pneumonia and lung worms increased among calves; depressed resistance may result from malnourishment. Surveys of the caribou range indicate that lichens, an important caribou and reindeer forage in the Arctic interior, are scarce on the Alaska Peninsula yet abundant on ungrazed offshore islands. These observations might suggest conditions of overgrazing on at least part of the caribou's range. In 1999, weights of newborn calves increased in the southern herd, an indication of improving nutrition in one of the herds.

Arctic National Wildlife Refuge

Long-Term Monitoring of Recovery of Trails from Winter Seismic Exploration. The Arctic National Wildlife Refuge, the northernmost of all wildlife refuges, encompasses one of the most spectacular assemblages of Arctic flora, fauna, and landforms in the world. It was established for the primary purpose of conserving wildlife habitat, including that of the Porcupine caribou herd, migratory birds, polar bears, grizzly bears, muskoxen, wolves, and wolverines. The vegetation is a carpet of low-growing plants, dominated by dwarf shrubs, sedges, and mosses. Permafrost is continuous. The area has very low winter temperatures and short, cool summers. Annual snowfall is low, and the snow cover is shallow and variable because of redistribution by high winds.

Plans for the use of the Arctic coastal plain of the refuge are perennially debated by the U.S. Congress, with proposals ranging from designating the area as wilderness to leasing it for oil and gas development. The Alaska National Interest Lands Conservation Act of 1980 requires studies on the possible biological effects of such development before Congressional actions are taken.

Preliminary seismic exploration of subsurface geologic structures was conducted on refuge lands during the winters of 1984 and 1985 to assess 600,000 hectares of potential oil development area

in low Arctic tundra on the coastal plain between the Beaufort Sea and the Brooks Range. Approximately 2000 km of seismic line were completed in a 5- × 20-km grid. Collection of seismic data along each line required multiple passes by tracked vehicles. Additional trails were created adjacent to the seismic lines by D-7 Caterpillar tractors pulling ski-mounted trailers (cat trains) between camps. FWS monitors attempted to limit habitat disturbance by routing vehicles through less-sensitive vegetation types and areas with greater snow cover.

In 1985, FWS initiated a long-term monitoring program to document levels of habitat disturbance and natural recovery associated with the 1984-85 seismic exploration activities. Color-infrared aerial photographs were taken of 20% of the trails in 1985 and 1988, and disturbance levels were photo-interpreted at thousands of points. Two hundred randomly selected plots on the trails were established and sampled in 1986, 1989, 1993, and 1998. Each plot was visited and rated for disturbance and degree of trail visibility (landscape scarring).

To date, FWS studies determined that the amount of initial disturbance and subsequent recovery depended on snow cover, vehicle type, traffic pattern, and vegetation type. Snow depths of at least 25 cm significantly decreased the initial disturbance. Heavier vehicles (higher ground contact pressure) caused more initial damage and less recovery than lighter ones, and camp-move trails were more disturbed than seismic trails. Multiple vehicles on a single narrow trail caused more disturbance than dispersed tracks. Trails with low levels of initial disturbance improved over time, while those with medium to high disturbance levels (approximately 25% of the trails) did not.

Vegetation type was an important factor affecting the level of initial disturbance and the speed of recovery. Trails crossing shrub-dominated ice-wedge polygons caused ruts, bare ground, and decreased shrub cover, which have not fully recovered after over 14 years. On gentle slopes of moist sedge-*Dryas* tundra, a common vegetation type with numerous frost boils, some trails subsided due to melting of the permafrost. At some of these sites the trail became a trough, and large ponds formed over melting ice lenses by 1998. Trails on tussock tundra recovered well if the initial disturbance was low. On tussock tundra sites with higher disturbance, trails became depressed and revegetated with nontussock sedges, and they remained very visible from the air in 1998. Trails in flat, sedge-dominated tundra generally recov-

ered well by 1998, except where high initial disturbance had caused trail subsidence due to melting of the permafrost.

The depth of the summer-thawed soil layer remained greater on about 50% of the disturbed plots compared to controls for the first ten years (1985–1995). By 1998, differences were still significant in only a few of the wet graminoid, tussock tundra, and riparian vegetation types. In contrast, 50% of the plots characterized by moist sedge-*Dryas* tundra still had significant differences in the summer thaw level in 1998. Moist sedge-willow plots were prone to subsidence and change to wet sedge tundra; 25% of these plots still had differences in thaw level. These observations indicate disruptions of the soil thermal regime, with unknown, long-term recovery times. Arctic vegetation depends on the soil thermal balance, so complete vegetative recovery is unlikely to occur until the thermal regime stabilizes.

In conclusion, habitat recovery was not complete 13–14 years after the initial disturbance, and impacts are expected to remain for another decade or more. The results are relevant because the types of vehicles used during the 1984–85 seismic exploration in the Arctic National Wildlife Refuge are still used every winter on the North Slope of Alaska. Each summer, new trails and older ones in various stages of recovery are visible from the air and the ground. Current exploration west of the refuge produces a much denser grid of trails than that conducted earlier. Despite the magnitude of this activity, the cumulative impacts of many years of exploration on the North Slope have not been addressed.

Muskoxen Monitoring Program. In 1998 and 1999 the Arctic National Wildlife Refuge continued a long-term study to monitor a re-established population of muskoxen. Muskoxen disappeared from Alaska by the end of the 19th century, and efforts to restore the species began in the 1930s. In 1969 and 1970, muskoxen were released into regions of former range near the Arctic NWR in northeastern Alaska. From 1982 to 1999, population trends and animal distribution were determined by annual censuses, ground composition counts, and seasonal relocation of radiocollared muskoxen. As the population expanded and muskoxen began to disperse into regions beyond the Arctic NWR, cooperative monitoring efforts were initiated with the Alaska Department of Fish and Game, the Department of Renewable Resources of the Yukon Territory Government, and Parks Canada. Analysis of information collected during the

17 years of this study, combined with data from earlier surveys, showed that numbers of muskoxen in regions first occupied in the Arctic NWR grew rapidly for over a decade but stabilized as calf production declined and predation and dispersal of muskox groups increased. During the course of the study, muskoxen have expanded their range into north-central Alaska and northwest Canada, indicating a successful return of the species to regions formerly occupied by muskoxen.

Steller's Eider Studies. FWS continued a long-term study of the natural history of the threatened population of Steller's eiders at Barrow, Alaska, in cooperation with the North Slope Borough and the Ukeavik-Inupiat Corporation. The wetlands in the vicinity of Barrow are the only place in the U.S. where this little-known seaduck breeds with any regularity. The research is focusing on acquiring information on the distribution and abundance, timing of nesting, and productivity of Steller's eiders, as well as trying to understand factors that influence nesting success. Preliminary results suggest that there are complex relationships between eiders, microtine abundance, and the presence and absence of various predator species such as foxes and jaegers that may profoundly influence eider abundance and productivity. FWS is also working closely with its local partners to explore various conservation strategies for Steller's eiders in the vicinity of Barrow, a town that needs to expand to meet the needs of its growing human population. The goal is to accommodate the growth of Barrow while minimizing impacts to nesting eiders.

Innoko National Wildlife Refuge

Moose Habitat Capacity Analysis. Innoko NWR encompasses the middle portion of the Innoko River and its tributaries in the Yukon River valley. It is dominated by river floodplain, muskeg, and bogs. Extensive wetlands are important moose habitat and provide nesting habitat for over 100,000 waterfowl and shorebirds annually.

Moose, wolves, and bears have been studied extensively in Alaska, but the capacity of the land to support these animals has not. Based on information from the top of the food web only, some conservation agency officials report that predators maintain moose populations below the carrying capacity of the land throughout much of Alaska, an assumption that has resulted in controversy over the control of wolf populations and restrictive regulations for hunting moose. A recent study conducted on the Innoko National Wildlife Refuge, in cooperation with the University of Alaska and the

Yellow-cheeked vole, part of a mark-recapture study of the effects of wildland fires on mammal communities, Koyukuk National Wildlife Refuge, Alaska.



Alaska Department of Fish and Game, suggests that, in this locale, moose habitats are much smaller, food availability is much lower, and the use of available food is much higher than previously thought.

Based on moose surveys conducted in the winters of 1994, 1996, and 1998, only about 5% of Innoko NWR, which is known for its large moose populations, is suitable habitat for moose in winter. Forage quality and quantity are lowest in winter, and deep snows often reduce food availability. Individual food plants (the willow species *Salix planifolia* and *Salix alexensis*) were tagged and their architecture measured during late summer; they were re-evaluated in late spring to determine winter use. Based on five years of studying forage availability and use, from 50% to over 80% of available forage (all the plants can sustain) is eaten each winter by moose. During a series of years with favorable weather, moose populations increased to a point well beyond that which is sustainable during periods of unfavorable weather. The implication of this work is that predator limitation of moose populations, with respect to the long-term capacity of the land, may not occur. Publication of this study is expected in the near future.

Koyukuk/Nowitna National Wildlife Refuges Wildland Fire and Yellow-Cheeked Vole Populations in Interior Alaska. Wildland fires are primary agents of disturbance in Alaska's boreal

forest, initiating successional patterns that impact a variety of plant and animal species. Years of fire produce a mosaic of seral stages, each of which supports a unique system of flora and fauna. Vegetative characteristics of post-fire seres have been well examined and classified. However, the effect of wildland fires on mammal species has only more recently been investigated. Among such species is the yellow-cheeked vole, a large colonial microtine rodent that inhabits moist grassy areas and early post-burn seral stages within the boreal forest. Although yellow-cheeked voles are known to be important prey items for marten, raptors, and other predators, little is known about the species' specific habitat requirements. During the summers of 1997 and 1998 a mark-recapture study was conducted on the Koyukuk and Nowitna National Wildlife Refuges to investigate yellow-cheeked vole populations in several recent burns. Two 250-square-meter grids of 100 live traps each were established within three areas: 1988 burn, regenerating white spruce; 1988 burn, regenerating black spruce; and 1985 burn, regenerating black spruce. Voles were trapped at each site for four days each month during June, July, and August, and in June 1999. Vole abundance increased throughout each summer and was highest within the regenerating white spruce stands. Vegetation surveys showed that white spruce areas had greater cover of fireweed, horsetail, and grasses, which are preferred forage species for yellow-cheeked voles.

Yukon Flats National Wildlife Refuge

Moose Calf Mortality Studies. Prompted by local concerns over a low-density moose population in the western half of the Yukon Flats NWR, the refuge staff began investigating environmental factors that limit this population. A study to examine the causes of death in moose calves was initiated in 1998. Cooperators in this study include local villages and the Alaska Department of Fish and Game. Biologists captured and radiocollared 30 adult cows near Beaver, Alaska, in March 1998. This effort was necessary to ensure success in locating calves later in the spring. Cow back fat was measured using ultrasound, revealing that cows were generally in good health. During calving in late May, all but six of the 30 cows gave birth to calves, for a birthing rate of 80%. Over 70% of these cows had twins. This high proportion of twins was another indicator that cows were in good physical condition going into calving.

From May 20 to June 4, 1998, 29 moose calves were captured and collared near Beaver. Calves



Radio-tagged cow moose resighted from a helicopter as part of an ongoing study of moose mortality patterns on Yukon Flats National Wildlife Refuge, Alaska.

were in good health, with an average weight of 16.8 kg. The movements of the radiocollared calves, as well as noncollared calves with 10 radiocollared mothers, were monitored daily. Calf mortalities were determined by listening to the pace of the transmitter signal. Each calf kill site was examined to determine the cause of death. Mortality rates were high. Examination of kill sites revealed that 17 calves were killed by bears, 3 drowned, and 13 died of unknown causes. Only six of the calves survived a year (15%). This is one of the lowest survival rates recorded for moose calves. Survival rates from other studies in Alaska and Canada have ranged from 19 to 56%.

The study continued in 1999. Beginning in mid-May, radiocollared cows were located daily, and collars were placed on their calves shortly after birth. All the radiocollared cows had given birth by early June (birthing rate of 100%), with over 60% giving birth to twins. In 1999, 29 collared calves and 12 noncollared calves with radiocollared mothers were monitored. Studies will continue through the spring of 2000 to provide a second year of data on annual survival rates of calves. As of September 30, 1999, only seven of the radiocollared calves and four of the noncollared calves remained alive. Bears were the primary cause of mortality.

International Circumpolar Activities

Area V

Since 1972 the U.S. and Russia have been involved in international negotiations regarding the protection of nature and the organization of reserves. In 1994 the U.S.-Russia Environmental

Agreement was signed (renegotiated from the 1972 U.S.-U.S.S.R. Environmental Agreement). Under this agreement, conservation agencies and other organizations in both countries actively sponsor exchanges of American and Russian specialists in rare and endangered flora and fauna, protected areas, migratory birds, marine mammals, fish husbandry, and marine/terrestrial ecosystem biodiversity. Joint projects have made significant progress in the protection and management of shared species.

The FWS is involved in a number of Area V initiatives. The Conservation of Wild Species of Fauna and Flora and the Protection of Natural Areas project's primary goal is to promote conservation of individual species or groups of species (particularly migratory) and their habitats. Biologists from both countries exchange expertise and collaborate in studies to contribute scientific knowledge and promote effective management approaches. Six activities comprise the work of this project:

- Implementation of the 1976 U.S.-Russia Convention Concerning the Conservation of Migratory Birds and Their Environment, which monitors and promotes the study and protection of more than 200 bird species;
- Study and conservation of cranes, raptors, and other rare birds, including the establishment and maintenance of stable, reproducing populations, both in the wild and in captivity;
- Study and conservation of rare and endangered mammals;
- Study and conservation of protected natural areas, including military-civilian cooperation in land management, and a small grants program where the U.S. awards small grants for technical assistance to nature reserves, parks, and other protected areas of Russia;
- Cooperation among zoos in the captive breeding of endangered species; and
- Conservation and management of marine birds.

Another Area V initiative that FWS leads is the Aleutian Chain Biodiversity Project, which focuses on joint studies of species occurring in National Wildlife Refuges of southeastern Alaska, the Alaska Peninsula, and the Aleutian Islands, and the nature reserves of northeastern Russia, the Kamchatka Peninsula, and the Commander Islands.

In 1999, FWS, the Alaska Department of Fish and Game, the National Park Service, and the U.S. Forest Service cosponsored a bilateral workshop

for Alaskan and Russian protected areas and wildlife management specialists to enhance communication networks, explore instruments of sustainable support for protected areas, further the Sister Refuge program, and increase focus on the study and protection of transboundary species and ecosystems.

Cooperative studies of the biology, ecology, and population dynamics of marine mammal species are also underway. FWS species studied under Area V are polar bears, Pacific walrus, and sea otters. Recognizing the need to unify management and research activities for the shared polar bear population of the Chukchi and Bering Seas, the U.S. and Russia began developing a bilateral conservation agreement in 1992. In February 1998, after several years of negotiations and public review, representatives from governments of both countries signed the U.S.–Russia Bilateral Agreement on the Conservation and Management of the Alaska–Chukotka Polar Bear Population. Final treaty language awaits approval by the officials of both governments. A primary component of the agreement is the development of sustainable harvest allocation quotas between Alaska and Chukotka, Russia. However, before a science-based harvest program can be implemented, a reliable population estimate is required. Conducting population surveys in this area is problematic because of the extreme remoteness of polar bear habitat and the logistical difficulties associated with thoroughly censusing the area. Therefore, no population surveys have been conducted in the region to date.

The routine exchange of publications and harvest information between the U.S. and Russia has advanced understanding of Pacific walrus biology and has helped the FWS track the status of the population. However, recent economic issues in Russia have resulted in the deterioration of harvest monitoring programs in Chukotka. In 1999 the U.S. Fish and Wildlife Service, the Eskimo Walrus Commission, and the Alaska Department of Fish and Game sponsored a pilot walrus harvest monitoring project in Chukotka, Russia. The project was designed to collect walrus harvest information from the six primary walrus-hunting villages in Chukotka by using a network of local Native harvest monitors. In May, Russian harvest monitors traveled to Gambell, Alaska, to observe and participate in U.S. walrus harvest monitoring training. At the training session the harvest monitors were provided with data forms and field equipment necessary to carry out harvest monitoring activities in

their villages. Between May and August 1999 a total of 366 walrus were recorded by Russian harvest monitors in the villages of New Chaplino, Siriniki, Enmelen, Lorino, Uelen, and Inghoun. The American side and the Russian side exchanged their respective harvest monitoring reports in May 2000 and continued preparations for future monitoring.

The Animal and Plant Ecology Project focuses on cooperative research into the ecology of single species and communities of flora and fauna in the U.S. and Russia. Activities include studies of:

- Rare and endangered species of plants and the introduction of exotic species in both countries;
- Northern migratory waterfowl, specifically snow geese, Aleutian Canada geese, and spectacled and Steller's eiders;
- Holarctic mammals;
- Chemical senses and communication in animals;
- Application of contemporary technology, such as sea ice mapping and distribution, in studies of large mammals such as polar bears; and
- Wildlife health and disease, such as the effects of lead poisoning in waterfowl.

The Area V Ichthyology and Aquaculture Project seeks to improve fisheries management practices, increase productivity through intensive fish culture, restore natural fishery resources, and exchange information on the physiology, nutrition, diseases, genetics, and reproductive biotechnology of shared fish species.

The FWS also leads the effort to facilitate cooperation in control of wildlife trade and other law enforcement activities to provide technical assistance and training for the conservation of protected species in the Russian Far East. Additionally, increases in conservation education efforts, such as the Sister Schools Shorebird Program, are enhancing public awareness of, and commitment to, conservation of wild species and their habitats.

Conservation of Arctic Flora and Fauna

The FWS Alaska is the lead U.S. agency for the Conservation of Arctic Flora and Fauna (CAFF), an international, circumpolar initiative that falls under the umbrella of the Arctic Council. CAFF is one of four broad initiatives sanctioned through the Arctic Council, which was adopted by Canada, Denmark/Greenland, Finland, Iceland, Norway, Sweden, Russia, and the U.S. in 1991. The FWS participates on the CAFF Working Group, which was established in 1992 and consists of scientists,

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conservation managers, and indigenous peoples of the Arctic. CAFF provides a circumpolar forum in which a wide range of Arctic conservation issues are discussed. CAFF's focus is preserving biodiversity, promoting habitat conservation, conserving species through an ecosystem approach, and bringing indigenous people's knowledge and concerns into the work of CAFF.

Under FWS lead, CAFF published the *Atlas of Rare Endemic Vascular Plants of the Arctic* as CAFF Technical Report No. 3 in 1999. Specialists from eight Arctic countries surveyed the vascular flora of the Arctic to identify rare taxa endemic to those lands beyond latitudinal tree line, establish an annotated list of these taxa, and determine the level of protection currently afforded these plants.

Ninety-six rare endemic taxa are identified. The information compiled for each taxon includes taxonomy, geographic distribution, habitat preferences, biological characteristics, estimates of endangerment, and citations of supporting literature. To determine the relation of rare taxa to protected areas, gap analysis is used as a conservation tool. Taxa are grouped into three categories: unprotected (no occurrences are within protected areas); partially protected (some occurrences are within protected areas); and protected (all occurrences are within protected areas). The results indicate that 47% of the rare endemics are unprotected, 23% are partially protected, and 30% are protected. Using the World Conservation Union (IUCN) Red List threat categories, 19% of the taxa are vulnerable, 29% near threatened lower risk, 26% least concern lower risk, 1% endangered, and 24% data deficient. The majority of rare endemic taxa (61%) occur outside IUCN protected areas (categories I-V); 25% occur within strict nature/scientific reserves (IUCN category I); 12% are in managed nature reserves/wildlife sanctuaries (IUCN category IV); and 1.6% are in national parks (IUCN

category II). The report was written by an international team from the U.S. (S.S. Talbot, U.S. Fish and Wildlife Service, Anchorage; D.F. Murray, University of Alaska Museum, Fairbanks); Russia (B.A. Yurtsev, Komarov Botanical Institute, St. Petersburg); Canada (G.W. Argus, Canadian Museum of Nature, Ottawa); Denmark (C. Bay, University of Copenhagen); and Norway (A. Elvebakk, University of Tromsø).

In October 1999, FWS hosted a workshop to develop ways to enhance the support and sustainability of Russia's Arctic Protected Areas. Partners in the workshop included the National Park Service, the U.S. Forest Service, the Alaska Department of Fish and Game, and the University of Alaska. Ten Russian natural resource managers from Moscow and the Russian Far East participated with Alaskan National Wildlife Refuge managers and representatives from a variety of state and Federal agencies and private organizations. A protocol to increase cooperative bilateral work in conservation and protection of shared ecosystems and transboundary species was signed.

Other ongoing CAFF programs include:

- Continuing implementation and further development of the *Circumpolar Protected Areas Network Strategy and Action Plan*;
- Completing a circumpolar Arctic vegetation map;
- Implementing the International Murre Conservation and Action Plan and the International Eider Conservation Strategy and Action Plan; and
- Preparing recommendations for CAFF and the Arctic Council concerning incidental mortality of seabirds in commercial fisheries in the Arctic region.

Future work of CAFF will be directed by the *Strategy for the Conservation of Biological Diversity in the Arctic Region*.

National Park Service

The central mission of the National Park Service (NPS) in Alaska is no different than for the rest of the United States. The NPS preserves, unimpaired, the natural and cultural resources under its stewardship for the enjoyment, education, and inspiration of present as well as future generations. As an adjunct to this central mission, the Service is also charged with cooperating with

	Funding (thousands)	
	FY 98	FY 99
Cultural Resources	1,400	1,400
Natural Ecology	2,486	2,486
Total	3,886	3,886

partners to extend the benefits of natural and cultural resources conservation and outdoor recreation throughout the U.S. and the world.

The unique aspect of the NPS's mission in Alaska is provided by the Alaska National Interest

Lands Conservation Act (ANILCA). Among other things, ANILCA ensures the continuation of traditional subsistence pursuits in most of the park areas and allows sport hunting in the national preserves. The vast size of the Alaska parks, combined with their ecological complexity, presents great management challenges. As recently demonstrated by the *Exxon Valdez* oil spill, the parks are not free of threat and degradation from the impacts generated by the modern industrial world. They remain vulnerable, and the wise management of these lands depends on the knowledge and information that can only be supplied by solid and well-thought-out research and monitoring programs.

Recent organizational restructuring within the agency, coupled with the creation of the U.S. Geological Service, Biological Resources Division (BRD), has changed the way natural resources research is accomplished within the NPS. Today, in the more decentralized NPS, park staffs have assumed significantly greater responsibilities for charting and carrying out both natural and cultural research activities. And in keeping with current Department of the Interior policy, the NPS has turned to the BRD for assistance with the larger and more complex biological research issues that face the parks. Moreover, in step with the intent of the Arctic Research and Policy Act, the NPS has actively sought the involvement and partnership of other Federal agencies, the State of Alaska, adjacent northern nations, Native groups, educational institutions, and other interested parties in cooperative natural and cultural research endeavors.

The research objectives in the NPS are driven and guided by its major mission goals. These goals were reaffirmed by the NPS's National Leadership Council in the 1997 *National Park Service Strategic Plan*. The specific goals that give general direction to NPS's natural and cultural resource programs in the North are as follows:

- Natural and cultural resources and associated values are protected, restored, and maintained in good condition and managed within their broader ecosystem and cultural context.
- The National Park Service contributes to knowledge about natural and cultural resources and associated values; management decisions about resources and visitors are based on adequate scholarly and scientific information.
- Park visitors and the general public understand and appreciate the preservation of parks and their resources for this and future generations.

Shared Beringian Heritage Program

The Shared Beringian Heritage Program recognizes and celebrates the biological and cultural aspects of a heritage shared by Russia and the U.S. on both sides of the Bering Strait. The program seeks local and international participation in programs designed to understand and preserve natural resources and to sustain the cultural vitality of Native peoples in the central Beringia region. During the 1998-99 fiscal years, the Shared Beringian Heritage Program, with the assistance of the Beringia Panel, has been successful at enhancing local support and involvement for the program and encouraging a "Russian component" in academic and community-based projects. One of the functions of the Beringia Panel, in which Native leaders play a major role, is to review the many project proposals that come to the Beringian Program each year. Projects range in scope from cultural celebrations to educational opportunities for the village young people. The Far Eastern Branch of the Russian Academy of Sciences is becoming increasingly involved with the Shared Beringian Heritage Program and has signed a letter of intent with the NPS to become an active player in the Beringia region. The Academy and the NPS plan to work on joint projects to prepare a science plan for the proposed international park.

Another avenue for increasing cross-border awareness and appreciation of the unique natural and cultural resources of the region is the annual Beringia Days conference held by the NPS each fall in Anchorage. The 1998 and 1999 conferences provided American and Russian park managers, scientists, Native groups, nongovernmental organizations, and others interested in the region an opportunity to get acquainted with ongoing projects, receive current information on Beringian research, and establish important local and international contacts.

Among the ongoing projects, the Alaskan Nanuq Commission is working with the Russian Union of Marine Mammal Hunters Native organization in conducting habitat studies and conservation education on polar bears in Chukotka, Russia. The NPS staff provides assistance in the production of conservation material for this project.

Determining the routes of human expansion into the New World is one of the most difficult questions in archaeology. In a project on chert artifact fingerprinting, Natalia Malyk-Selivanova conducted a comparative structural analysis of

chert artifacts collected in Alaska and Russia in order to discover the ancient pathways of trade and contact once prevalent in the Beringia region.

In FY 98 and 99 the village of Deering conducted archaeological training for area residents in conjunction with the testing and excavation of a highly significant Ipiutak archeological site discovered during work on a local sewer project. This project funds the construction of traveling display boxes to be used as educational aides in sharing information about the Deering project with surrounding villages.

The Eskimo Heritage Project is a collection of approximately 1000 oral history tapes produced in the Bering Strait region from personal interviews and elders conferences. NPS is assisting Kawerak, a local Native corporation, with the process of transcribing and translating the tapes and preparing the information for schools, communities, and research.

Dr. Gary Laursen and other scientists are conducting a study comparing the fungi of the Seward Peninsula and Kobuk Valley in Alaska with the fungi of the Chukotka Peninsula in Russia. Earlier work resulted in the discovery of species previously unknown in the region and the description of an entirely new species. Fieldwork in 1998 took place on the Seward Peninsula. In 1999 work was conducted in Kobuk Valley National Park, and a final year of field studies is planned for eastern Chukotka in the summer of 2000.

During the summers of 1998 and 1999 the Golovin Village Corporation and the local school conducted an archaeological field school to train students in their local culture and archaeology. In addition to classroom training, students participated in fieldwork, conducted by University of Alaska Fairbanks archaeologists and museum specialists, on prehistoric sites on village corporation lands.

The UAF Native Language Institute is working on a dictionary for the Naukan Eskimo language of Chukotka, Russia. NPS's part in this project is to help UAF gather data from visiting Native speakers from Russia by assisting with logistics and publication of the final product, the dictionary.

The main product of a two-year project on the organization of Inupiaq national life is the publication of Volume VI in the series of the Cultural and Natural Heritage of Northwest Alaska. In this volume Dr. Ernest Burch comparatively documents the political life of traditional Inupiaq nations of the nineteenth century.

An early-man archaeological expedition called

Paleoindian Adaptations in Arctic Alaska focused on the Tuluak Hill site in northwest Alaska. Preliminary radiocarbon dates of 11,130 and 11,180 indicate that Tuluak Hill is one of the oldest known sites in Arctic Alaska. A two-year multidisciplinary research program focused on mapping surface artifacts, locating buried cultural materials, and identifying suitable deposits for obtaining paleoenvironmental data.

FY 98 was the third and final year of a multidisciplinary study of the Kobuk Sand Dunes. It includes climate history, fire and biological processes, local area usage, and ecotourism potential.

A photographic and fine arts project called Portrait of a Divided Maritime Family is documenting Siberian Yu'pik elders in a traveling exhibit and collection. Residents of Nome and Savoonga in Alaska and New Chaplino and Sireniki in Chukotka are being depicted.

The North Slope Borough, together with the Yu'pik Eskimo Society of Chukotka, the Provideniya Museum of Regional Studies, and the Naukan Native Cooperative of Lavrentiya, documented the subsistence activities in selected villages in Chukotka. Their work in 1999 was the final year of the three-year research that resulted in a series of reports. In 1999 they published *Preservation and Development of the Subsistence Lifestyle and Traditional Use of Natural Resources by Native People (Eskimo and Chukchi) in Several Coastal Communities (Inchoun, Lorino, New Chaplino, Sireniki, Enmelen) of Chukotka in the Russian Far East*.

The NPS and the Northeastern Scientific Research Institute in Magadan worked cooperatively in standardizing and radiocarbon dating archaeological artifacts from various sites in the Russian Far East.

The main goal of a project called Ten Years After—Documenting the Human Landscape is to record changes and people's expectations that resulted from opening the border between Alaska and Chukotka, Russia, since 1988. Principal investigator Sue Steinacher is interviewing village residents from St. Lawrence Island to Barrow and in Chukotka on how the open border has affected their lives.

A project headed by Caleb Pungowiyi is a study of the traditional use and knowledge of neighboring seabird colonies by the Native residents in the villages of Sireniki and New Chaplino in Chukotka, Russia. Beringia-funded work in 1996 and 1997 was completed on St. Lawrence Island and included the villages of Gambell and

Savoonga. A companion project with the USFWS completed a biological census of the seabird colonies on the island.

The Shared Beringian Heritage Program has recently published the English translations of three major works of Russian anthropology. A follow-up to the publication of N.N. Dikov's *Asia at the Junction with America in Antiquity* is a volume entitled *Mysteries in the Rocks of Ancient Chukotka*, Dikov's seminal study on the rare petroglyph panels of Pegtymel. Another important publication in archeology translated in 1999 is *An Early Culture of the Northwest Bering Sea* by A.A. Orekhov. It covers the archeology of the little-known coastal Kerek people. Lastly the National Park Service was privileged to publish the long-awaited translation of G.F. Debets's *The Paleo-Anthropology of the Early Eskimos (Ipiutak and Tigara)*. This volume is potentially of great interest to physical anthropologists around the globe.

Another 1999 Beringian project is a broadcast-quality videotape of elders telling folktales in two traditional Inupiaq subdialects. Elsie Weyiouanna recounts the story "Two Young Men Visit Iyat" at her homeland of Serpentine Hot Springs, and Gideon Kahlook Barr tells "Ilaganiq Protects the People" at his boyhood home of Ublasaun, both in Bering Land Bridge National Preserve. The video will be distributed to local schools for use in Native heritage curricula and will help preserve part of the rich oral tradition and the language itself.

Cultural Resources

Denali National Park and Preserve

In the past two years there has been a significant increase in the number and complexity of cultural resource investigations at Denali, implemented by park staff, cooperating state agencies, and university personnel. In cooperation with the State of Alaska, Division of Subsistence, work continued on an ethnographic overview and assessment of the park and preserve as a whole. Work on a Native place names map involves several neighboring tribal groups, park staff, and scholars at the University of Alaska Fairbanks. A study of the subsistence use of trapline cabins, conducted by the University of Washington, was also completed. Finally, a reconnaissance-level archeological investigation, conducted on the south side of the Alaska Range, focused on providing information for future park development. This survey was conducted in cooperation with the State Office of History and Archeology.

Wrangell-St. Elias National Park and Preserve

A historical archaeological project involves the machine shop at Kennecott National Historic Landmark. Kennecott, a significant example of an early 20th century copper mining complex, was abandoned in 1938 after the mining operation closed. The machine shop is located in the industrial complex of the mill town. Inventory and analysis of the 2921 artifacts remaining at the site provide an excellent opportunity to study abandonment and post-abandonment processes at a large, corporate, industrial site situated in a remote location. The foundation area of the machine shop contains thousands of industrial hardware items and mining equipment and is one of the only remaining extant assemblages of material culture at Kennecott.

A second project, done in cooperation with the University of Alaska Fairbanks, was an archeological field school conducted at a prehistoric stratified site near Ptarmigan Lake. The identification of a wedge-shaped microblade core pushed back the date for known prehistoric occupation in the park by at least a millennium or possibly much more. Following two previous field seasons that identified more than 100 sites in this little-known area of the park, the cooperative effort has focused on shedding light on prehistoric occupations before and after the eruptions of Mt. Churchill at 1890 and 1250 years BP.

Multi-Park Units and Projects

The Lake Clark-Katmai Studies Center was established in 1999. It is a research and curatorial facility for natural and cultural resource collections from Aniakchak National Monument and Preserve, Alagnak Wild River, Katmai National Park and Preserve, and Lake Clark National Park and Preserve. The center also houses the cultural resource program for those parks, directing a multidisciplinary research agenda emphasizing history, ethnography, archeology, and paleogeography.

Extensive oral historical data from the Lake Clark and Katmai regions have been digitized and placed on CDs by the Elmer E. Rasmuson Library Language Center at the University of Alaska Fairbanks in cooperation with the NPS. Begun in 1996 the project is now complete and ready for distribution to 12 village schools. The CDs link oral history recordings to a series of historic photographs, maps, and place names. The historic themes represented are Native and non-Native subsistence, early education, reindeer herding, trails/trade, early 20th century population transitions, early industry, sport

hunting and fishing and local perspective on these activities, early settlements, people, aviation, and landscape changes.

Bristol Bay Alaska from the Hinterlands to Tidewater: A Grassroots Pictorial 1885–1965 was published in 1999. This historic “photo scrap-book” contains over 300 historic photographs from private collections pertaining to the Lake Clark and Katmai area.

Aniakchak National Monument and Preserve

The third year of a five-year archeological inventory project in Aniakchak was completed in 1999. Approximately 2700 acres have been surveyed with subsurface testing in high-probability locations. Thirty-six archeological sites dating from 2000 years BP to the historic period have been documented, including 15 prehistoric, 14 historic, and 7 with both historic and prehistoric components. Several of these sites are sizeable villages, one with 43 house depressions and another with an intriguing depression over 20 m in diameter. Ongoing geoarchaeology is revealing a pattern of human occupation dramatically impacted by regional volcanic events. Mid-Holocene human populations appear to have been exterminated twice by regional pyroclastic flows from caldera-forming eruptions, while late Holocene data suggest that cultural hiatuses in the last 1200 years may correspond to later tephra falls and periods of beach berm building.

Puyulek Pu’irtuq! The People of the Volcanoes, Aniakchak National Monument and Preserve Ethnographic Overview and Assessment, published in 1999, reports the results of the first

ethnographic study in Aniakchak. The book contains chapters on Aniakchak-associated villages, regional culture history, commercial exploration, 1867–1900 resettlement of the Alaska Peninsula, village descriptions from 1880–1920, industrialization, fisheries, mining and oil exploration, fox farms and trapping, resource use, Inupiat immigration, and recommendations for future research. The book, which features several historic and landscape photographs and detailed maps, has been very well received in park-associated villages.

Alagnak Wild River

In cooperation with Igiugig Village Cooperation, the NPS collected a large assemblage of Paleoarctic artifacts from a dune field along early shorelines of Kukaklek Lake. The lithic assemblage includes microblades, depleted microcores, projectile points, scrapers, and lithic debitage. This large collection is probably related to the Koggiung phase, the earliest archeological components in the Katmai area.

Katmai National Park and Preserve

A third season of data recovery excavations was conducted in 1999 at the stratified Mink Island site within the Takli Archeological District on the Katmai coast. This exposed and severely eroding site is the oldest known site along the Katmai coast. The well-preserved stratigraphy, including occupation floors and a rich faunal record dating from 7200 years BP to 500 years BP, will enable the NPS to define the cultural history for the Katmai coast. Detailed recording of the microstratigraphy and recovery of sediment peels will assist in identifying human and natural taphonomic processes recorded in the site sediments. The well-preserved vertebrate and invertebrate assemblages provide a record of the paleoclimatic history of the area for much of the Holocene including the hypsithermal and Little Ice Age. The response of nearshore marine ecosystems to paleoclimatic changes will also be interpreted.

An ethnohistorical study of three Katmai coastal villages and village life in the nineteenth century was initiated in 1996 and will be completed in 2000. The research conducted by the University of Alaska Fairbanks examines data from clergy registers, baptismal and burial records, confessional lists, Russian–American Company records, and Alaska Commercial Company records. The final report will compile all primary source information about village life in Kaguyak, Katmai village, and Kukak during the 1800s, describing village demo-

Archeological data-recovery excavations of a 7000-year-old maritime site on Mink Island off the coast of Katmai National Park and Preserve. The entire grassy knoll to the right of the excavations is a product of repeated human occupations. The spidery structure over the excavations, when covered in plastic, protects the excavations during the frequent rainstorms. Excavations were undertaken to save data threatened by vandalism and coastal erosion



graphics and social structure, trade goods and routes, foods and procurement areas, essential material culture, and important events.

Investigations at the sites of proposed developments near the Brooks River Archeological District National Historic Landmark yielded information about prehistoric land use of the Brooks River drainage. Systematic subsurface testing along the Beaver Pond terrace located one mile south of the river produced negative results, suggesting that the prehistoric inhabitants focused mainly on resources available within the river corridor.

Building in an Ashen Land, a historic resources study for the park, is now in press and represents a two-year archival research effort focused on understanding the history of commercial, Russian, Native American, early American, and scientific activity in the Katmai region.

Lake Clark National Park and Preserve

Research conducted over the past three years in the Kijik National Historic Landmark (NHL) has resulted in the acquisition of color aerial photography and a series of detailed topographic maps. These products were used in a geomorphological study of the landscape history and an assessment of flooding hazards and potentially catastrophic beaver dam failure to identify risks to archeological sites. Paleoshorelines, former terraces, and abandoned drainage channels have been identified and analyzed, with implications for the present distribution of natural and cultural resources. Archeological field research identified new sites, and testing recovered radiocarbon samples for constructing a chronology for the 17 known Dena'ina settlements within the NHL. The research addresses questions about the origins of the Dena'ina in the area, the relationship among sites within the NHL, the role of trade in European goods, and the co-occurrence of abundant food resources in aggregating the Kijik settlements. Analyses of trade beads and historic ceramics and radiocarbon analysis of 52 wood charcoal samples show a range in the occupation of Kijik from AD 1170 to 1900. Three lake cores have been recovered and will help develop an understanding of the glacial and paleoclimatic history as well as the history of salmon run establishment and size at Kijik. A popular book synthesizing the landscape, archeological, and ethnographic history of the Kijik NHL, entitled *Qizhje: A History of the Land and People in the Kijik National Historic Landmark, Lake Clark National Park and Preserve*, is currently in press.

The NPS worked with the Newhalen Tribal

Council and the Newhalen School in 1998 and 1999 to document two large archeological settlements in the Newhalen area adjacent to the park. Radiocarbon age determinations of calibrated AD 1275–1410 and calibrated BC 810–210 artifact assemblages and house forms suggest that the sites represent Norton culture sites later reoccupied by Dena'ina Athapaskan people. Artifact analysis and additional radiocarbon analyses will yield additional information on these two sites to address the question of Yup'ik and Dena'ina cultural history in this traditional boundary area. The Newhalen senior class has produced an interactive interpretive CD and a video, *Newhalen Culture Heritage Project: A Culture in Motion*.

Bering Land Bridge National Preserve

In 1998 a survey along a 55-mile stretch of eroding barrier-beach system between Shishmaref and the tip of Cape Espenberg resulted in the documentation of 60 archaeological sites, including 39 new sites in previously unexamined areas of the coastline. Crews also completed the final surveying and postmark photography for photogrammetric mapping of the Cape Espenberg beach ridge site complex. This mapping will greatly assist in future inventory and monitoring efforts along the preserve coastline. In 1999, archaeological surveys were conducted in the vicinity of the Trail Creek cave sites and along the shores of Imuruk Lake. The Trail Creek survey located and documented nine new archaeological sites, including cairns and historic scatters. Only one prehistoric site was located. Two new historic sites were located on the east shore of Imuruk Lake, and two other historic sites were located in the vicinity of the Noxapaga River. The condition of a previously reported Late Prehistoric village (approximately 300 years old) and Denbigh encampment at Kuzitrin Lake (approximately 4000 years old) was monitored.

Another park project is a biography of Dr. David Hopkins, Professor Emeritus of Quaternary Studies, University of Alaska Fairbanks. The book, authored by Dan O'Neill and entitled *The Man Who Built the Land Bridge*, is a history of Arctic science and the importance of Hopkins' scientific contributions to Alaskan national parks. This NPS-funded biography will go to press in 2000.

Cape Krusenstern National Monument

In 1998, NPS crews monumented, paneled, and surveyed an array of aerial targets for a Department of Defense satellite imagery project. Work

also continued on the excavation of an Inupiaq house at the site of Atiligauraq. Documentation of the site also included a three-dimensional Autocad map of the structural details of this feature. The Atiligauraq excavations were completed in 1999. The artifact inventory indicates the site was occupied at the end of the 19th century and reveals predominantly traditional tool kits augmented by limited Euro-American items (almost exclusively rifle cartridges and glass trade beads).

Kobuk Valley National Park

In 1998, fieldwork focused on Kaklikuvik (the area around the confluence of Kavet Creek and the Kobuk River). Crews completed surface mapping of six previously known sites, as well as locating and mapping eight new Late Prehistoric winter village sites. House pits tested at one site revealed a rich faunal assemblage dominated by fish remains. Another focus of the survey was the Kobuk Dunes, where two known sites were remapped and recollected in order to understand the dynamics of sand movement with associated cultural material. Survey transects in the Kobuk Dunes in 1998 identified 26 new prehistoric sites, all apparently over 5000 years old, concentrated in an area of the dunes most frequently visited by tourists. The Kobuk Valley Gold Rush project documented 13 gold-rush-related sites within the boundaries of the park. The inventory and testing

of these sites advanced our knowledge of the way in which newcomers adapted to the harsh winter climate of the area and the ways in which the native Inupiat responded to the influx of prospectors and their material goods.

Noatak National Preserve

Fieldwork in 1998 consisted of two major projects: the Wrench Creek Archaeological Survey and the Irwin Sluiceway Site Evaluation. The survey crew collected baseline data from 37 new and 17 previously recorded prehistoric sites in the Wrench Creek area. Two new sites in the vicinity of the Tuluaq Quarry Site produced typologically early spear points. Radiocarbon assays of 11,110 and 11,180 radiocarbon years, taken from a soil test at one of the sites in 1998, are associated with cultural remains and suggest that the Tuluaq Hill Site is one of the earliest known in Alaska. A charcoal sample recovered from site assessment excavations in 1999 indicated a radiocarbon age of 11,200 years. The lithics recovered from the site document the complete manufacturing sequence of massive, bipointed spearpoints first identified at the Irwin Sluiceway Site in the upper Noatak drainage and known as Sluiceway points.

In 1999, a reconnaissance-level survey of the headwaters of Wrench Creek was completed. Twenty-eight new archaeological sites were identified, none of which are considered older than the Mid-Holocene. Limited typological comparison indicates that the majority of the sites were occupied less than 4000 years ago.

Test excavations were completed in 1998 at the Irwin Sluiceway Site in collaboration with D.J. Stanford of the Smithsonian Institution. One of the test units revealed a hearth, charcoal from which indicates radiocarbon ages of 9,550 and 10,060 years. Testing of two sites in the vicinity of the Irwin Sluiceway Site in 1998 permits the provisional delineation of new Early Holocene assemblages. At the Last Day Site (dated to 8,830 and 8,540 radiocarbon years), wide microblades and a large wedge-shaped core are tentatively associated with a Nim-11 type corner-notched projectile point. Three 1- × 1-m test units at the RBS Site, dated to 8,240 radiocarbon years, produced a range of narrow and wide microblades, large and small wedge-shaped microblade cores, and the base of a Kayuk-like projectile point. Until the within-site distribution analyses of these Late Pleistocene/Early Holocene Noatak drainage sites are completed, artifact associations must be considered tentative. The use by prehistoric campers

Student using a string grid while collecting artifacts at the Tuluaq Site, a paleo-Indian site along Wrench Creek in Noatak National Preserve, northwest Alaska.



of fossil wood, available in the vicinity of all of these sites, must be considered. Multiple charcoal samples from single hearths from several of the sites are being prepared for species identification and radiocarbon assay.

V.V. Pitulko of the Institute for the Study of the History of Material Culture in St. Petersburg, Russia, collaborated in the investigations in 1998 at the Irwin Sluiceway Site. In 1999, Pitulko joined the team at Tuluq Hill, along with D. Guerasimov, also of the Institute.

In 1999, T.D. Hamilton (USGS emeritus) and J. Esadale began mapping the surficial geology and outlining the glacial history of the western portion of the preserve. The preliminary maps were completed last year, and fieldwork will resume in the summer of 2000.

Gates of the Arctic National Park and Preserve

A remote sensing archeological survey was initiated to develop techniques for using classified high-resolution remote sensing satellite imagery to locate and do preliminary analyses on archeological sites. The park began the process of obtaining classified imagery, prepared a research design and archeological background material, and partnered with the University of Alaska Fairbanks' Quaternary Center to move ahead with this project. Revisions are being made to the first draft of an archaeological overview and assessment for the park.

Natural Resources

Denali National Park and Preserve

Scientific research in Denali National Park and Preserve is critical to understanding and documenting resource conditions, providing information for park management decisions, and resolving threats to natural conditions. The park provides a unique opportunity for comparative studies that look at environmental response in pristine areas versus intensively manipulated areas. Denali is a vast wilderness of over 6 million acres; documentation of the presence and condition of resources is a massive task.

To accomplish this task the NPS conducts and supports a substantial interdisciplinary natural resource inventory, monitoring, and research program. This program is implemented through efforts by park scientific staff, cooperating state and Federal agencies, and various academic institutions. During any given year, there are nearly 100 studies or projects underway.

Wildlife research has been an important activity

in Denali since 1926, when the first thorough inventory of wildlife in the park was started. Examples of 1998 and 1999 projects include the ecology of moose (USFS), the nesting ecology of migratory golden eagles (NPS), the ecology of grizzly bears (USGS-BRD), and investigations into predator-prey (caribou-moose-wolf) relationships (USGS-BRD). Information related to wolf management, one of the most controversial resource issues in the park, continued to be developed through an extensive monitoring program using radiotelemetry. A major examination of the habitat use of bears on the south side of the Alaska Range was undertaken by the NPS during this reporting period. Other studies continued in 1998 and 1999 included documenting wildlife behavioral response to vehicular use along the park road. For example, a final report on the effects of vehicular use on Dall sheep migratory routes (USGS-BRD) and a report on monitoring large mammals in the park road corridor were completed (USGS-BRD). Finally, during 1999, some attention was focused on examining the nature and extent of winter use by humans in the park and the environmental impacts of that use.

Denali's Long-Term Ecological Monitoring (LTEM) program continues to be developed jointly by park staff and USGS-BRD. Studies from this program are contributing to a fundamental understanding of park resources. Watershed-based studies for this program are wide-ranging in scope and have focused on such resources as soils, water chemistry, small mammals, birds, and vegetation. Other LTEM studies parkwide were aimed at monitoring weather and determining the regional effects of climate on glaciers. Particular emphasis was placed on development of the park's vegetation monitoring program and discussions about modeling techniques and model application to the LTEM program.

Recent studies have reflected a shift in interest to learning more about the park's abiotic resources. Examples of such projects include investigating the characteristics of the Cantwell formation volcanics unit. The park's limited paleontology program was reviewed by the NPS's paleontology expert. A study of the phenomenon of surging glaciers continued on the Muldrow Glacier. Studies dealing with roadside impacts (trail development) and road dust were also continued. Closely related studies on the environmental fate and impact of dust palliatives were conducted and largely completed. Air quality sampling efforts including ultraviolet B monitoring continued. Investigations

related to other park issues and threats included assessing channel response to stream restoration, monitoring gravel extraction from alluvial floodplains, and documenting the freeze-thaw transition on a regional scale in boreal forests using satellite data (NASA).

Significant emphasis has been placed on the development of resource information in the form of resource inventories. Ongoing projects include wetland mapping to National Wetland Inventory standards for selected areas in the park, soils mapping over the entire park, landcover mapping for the entire park, and geographic and geologic mapping of selected areas. During these two years, the park staff has also started a comprehensive floristic inventory. Initial work has identified many species previously unknown in the park and has documented extension in the range for many species.

The park is a vast and often forbidding area in which to conduct research and monitoring. This vastness has been made far more manageable by park staff through the application of global positioning systems and geographic information systems. ArcInfo and ArcView software is used by many of the park staff involved in research efforts; this program is supported by a full-time geographic information system (GIS) specialist. Additionally efforts are being directed at automating all resource data and information, as well as developing and cataloging traditional information such as specimens, maps, and written records. A data management position was added to the park staff in late 1999.

Wrangell-St. Elias National Park and Preserve

The park has completed a three-year project to analyze the effects of a spruce bark beetle infestation at a stand and landscape level. One hundred and twenty-six forest inventory plots were sampled for stand structure, vegetation, and site characteristics. These data were used to develop a vegetation classification for the area, to model vegetation change due to infestation, and to model the risk of infestation. A vegetation and infestation map was developed to characterize the extent and distribution of vegetation and infestation in the affected area. A GIS was used to quantify the extent of vegetation and infestation by land ownership so that better ecosystem management could be achieved in the Copper River Basin. GIS was also used to extrapolate the models across the landscape. The final report and all data sets were made available on CD-ROM at the end of 1999.

A collaborative research effort studying the

Mentasta Caribou Herd (MCH), begun in 1993, continued between the USGS-BRD, the park, and the Alaska Department of Fish and Game (ADF&G). The herd calves and summers in the park/preserve and winters over a wide area ranging from Mt. Drum to north of Tok. It numbered approximately 3200 animals in 1987 and has declined to less than 500 in 1999. The research indicates that predators (wolves and grizzly bears) are preying on young calves and severely limiting the number of calves that grow to reproductive age (generally three years for caribou). Although management options on NPS lands do not include reducing predator populations, the park is continuing to monitor the herd to see how movements and population dynamics change as the herd continues to decline.

The MCH research allows regional biologists to determine predator response to changes in caribou density, changes in calf survival rates when caribou numbers become low and calving is dispersed, changes in bull:cow ratios, seasonal movements of Nelchina and Mentasta bulls, genetic differences between regional herds, natal philopatry of young Mentasta cows, winter forage competition between Nelchina and Mentasta, the effect of calf loss on maternal body condition and survival, and patterns of weight gain and condition of calves that do survive. Data from the MCH are being compared to similar data from several other herds, including the Nelchina, Denali, and Chisana caribou herds.

In September 1999 the park began a radiotelemetry study of bull caribou to investigate their movements and behavior in relation to cows and calves. This will be one of the first studies of bull caribou ecology conducted and should explain the high bull:cow ratios seen in fall surveys.

Katmai National Park and Preserve

Human activities along the park coastline have increased steadily in the last decade. These activities primarily involve bear viewing and photography. Most tourists arrive by floatplane and spend less than an hour at Hallo Bay. Other tourists come to Hallo Bay via boat, and these people tend to stay for 1–5 days. The NPS initiated a study in 1998 to assess if increased human use has an effect on coastal grizzly bears. The research is investigating the effects of human activities on habitat use, activity budgets, and the bears' foraging efficiency. The primary food resources available to grizzly bears at Hallo Bay are vegetation, clams, and salmon. The bears graze heavily on

sedges and forbs until salmon move into the streams to spawn. Overall, clams constituted a small percentage of their total diet during the summers of 1998 and 1999. Clams, however, may be an important food resource for certain individual bears. Over 500 scan samples and 400 focal samples were collected. The scan samples provide a “slice-in-time” sketch of bear habitat use and activities. The focal samples, of a half-hour duration each, record all activities, habitat use, and distances from the observed bear to the nearest bear and the nearest human in that half hour. The study will provide valuable information on whether bears are being displaced from highly desirable habitat that is crucial to their long-term survivability and whether any additional management intervention is required to assure their continued well-being.

Concerns have been raised about the health of prized rainbow trout populations in the Alagnak River and its upstream tributaries. Because of limited knowledge of basic life history characteristics, it is difficult to assess the impacts of increasingly popular sport fisheries. Beginning in 1997 a five-year study was initiated to increase basic understanding of the population dynamics of Alagnak watershed trout and to improve technical capabilities for assessing the overall health of Alaska rainbow trout populations in general. In cooperation with the USGS-BRD and the Alaska Department of Fish and Game, NPS is studying the fundamental population structure of rainbow trout populations of the Alagnak drainage. The study is designed to address whether the rainbow trout in various rivers, lakes, and tributaries of the watershed are represented by a single, well-mixed population, with readily mixed spawning aggregations, or whether there are discrete populations having independent spawning groups. A radiotracking study was completed in 1999 to study detailed patterns of movement or population intermixing. Results suggest that extensive seasonal migration is occurring, but that individual rainbow trout return to previously used overwintering areas. Initial genetic results indicate that despite the tendency of individuals to return to the areas where they previously overwintered, there is no genetic structuring of the population among spawning sites. Additional genetic analysis is planned.

Relocation of the Brooks Camp developed area within Katmai is planned. A study was conducted to:

- Determine the extent to which the Beaver Pond Terrace (BPT) site is being used by

brown bears;

- Determine the site’s value to bears in comparison to other potential Brooks Camp relocation sites;
- Develop site measures needed to reduce the impacts of construction to bears; and
- Develop site measures to maximize the separation of bears and people.

The location and intensity of use of bear trails in the vicinity of the BPT was mapped using GPS, and track plots were established and monitored in three locations along the Naknek Lake shoreline to obtain information on the timing and relative intensity of bear use and movement patterns. Preliminary results indicate that the BPT development site proper does not exhibit a significantly greater amount of bear activity than other potential development sites within the area, but it does have significantly less bear activity than the current Brooks Camp developed area, as evidenced by much lower numbers of bear trails and day beds at the site. However, a number of potential areas of conflict between bears and people at the BPT site deserving preconstruction consideration were noted, including the effect of proposed roads on bear movements and the challenges the narrow shoreline on Naknek Lake presents for accommodating the mix of bear and human traffic.

Lake Clark National Park and Preserve

Lake Clark is a complex, deep, freshwater lake that receives turbid glacial water, clear cold groundwater, warm bog water, and possibly thermal warm waters from nearby volcanoes. In 1999 the University of Alaska Fairbanks initiated a limnology study to gain an understanding of the behavior of the lake—how temperatures and chemistry vary and how those differences affect microscopic plants and animals and ultimately juvenile sockeye salmon. Five sampling stations were established where water temperature is recorded throughout the year, even below thick winter ice. At each station, water chemistry at various depths and the amount of chlorophyll *a*, an indicator of microscopic plant life, were measured weekly throughout the summer. Zooplankton, microscopic organisms that are important food for juvenile sockeye salmon, were sampled vertically through the water column. The results of this two-year study will be available in 2001.

Six major tributaries, five of them glacial, flow into Lake Clark. A tributary study was begun in 1999. It has two primary objectives: determine the amount of water contributed to Lake Clark from

the various rivers, and determine the basic chemistry of the major rivers. A recording gage was set up near the mouth of the Tlikakila River to continuously measure water level, flow, water temperature, and specific conductance. Water samples collected monthly during the summer were analyzed for suspended sediment, nutrients, organic carbon, and major ions. On the other five tributaries, measurements of flow and basic water quality were also collected monthly (June–October). Since June 1999, inflow to the lake has ranged from 8,800 to 26,500 cfs. The Tlikakila, a sediment-laden glacial river, is the main contributor to the lake, providing about half the inflow during July. The change in stage on the Tlikakila was nearly 3 m throughout the summer. USGS will be analyzing the river flow data to determine a water budget for the lake.

Water quality samples were collected from the Johnson River in 1998 and 1999. In 1998, an ecological survey of the Johnson River was done to describe the physical habitat of the river. Bed material samples were collected and analyzed for trace elements and semivolatile organic compounds. Water quality samples were collected and analyzed for nutrients and suspended sediment. In 1999, water quality sampling took place from May through October to describe how water quality varies with flow. Samples were analyzed for trace metals, nutrients, major ions, organic carbon, and suspended sediment. These data will provide useful baseline information for park managers if development occurs on a private inholding within the park.

A moose study to determine productivity, mortality, and calf survivorship is nearing completion. A total of 44 cow moose were instrumented with radio collars in 1996 and 1998. Park staff have obtained 1758 locations between November 1996 and October 1999. Data analysis and a final report including movements of moose subpopulations, cow survival, a comparison of landscape factors affecting calf survival, and recommendations for harvest management will be completed by the summer of 2000.

Recent low returns of sockeye salmon to the Bristol Bay system have raised concerns over the health of salmon populations in the region. A joint USGS-BRD/NPS five-year study of sockeye salmon biology began in 1999. Important migration routes and spawning habitats of sockeye salmon are being determined by radiotagging individual fish entering Lake Clark and following them to their final spawning sites around the lakeshore and

into tributaries. Body measurements and tissue samples from fish at their spawning locations will be used to distinguish genetically discrete populations of sockeye salmon. These genetic “fingerprints” will allow identification of Lake Clark salmon as distinguished from other Bristol Bay sockeye populations. This information will help biologists understand Lake Clark sockeye salmon movements in the ocean, their harvest rates in Bristol Bay, and their relative success of returning to Lake Clark to spawn.

USGS-BRD and Moscow State University studied surfbirds on their breeding grounds at Turquoise Lake from 1997 to 1999. A pool of 42 individually marked adults, including 15 equipped with radiotransmitters, was followed daily in 1997 and 1998 from arrival during the first week of May until departure, usually by mid-July. Severe storms in 1998 delayed breeding by about 10 days compared to 1997 and resulted in almost no production of young in 1998. Nesting birds showed strong site and mate fidelity. As many as 20 and 15 pairs may have attempted to nest on the study area in 1997 and 1998, respectively. Within preferred habitats, birds nested in densities of about 3.0 pairs/km². Nests were constructed between 900 and 1000 m elevation on sparsely vegetated ground associated with lateral moraines. Most nonincubating members of pairs flew great distances to forage, usually along the lakeshore. Shortly after broods hatched, adults moved them to higher elevations into habitats that appeared to be richer in insect prey. The departure of adult females from the area appeared to be related to date and not age of the brood. Males generally remained with chicks until shortly after fledging.

Kenai Fjords National Park

The black oystercatcher inhabits rocky coastal shorelines of Alaska and western North America. Alaska is its primary breeding habitat. The surrounding steep mountains of Aialik Bay restrict the amount of suitable nesting habitat, causing oystercatchers to use the same well-defined breeding territories perennially. Humans, as well as numerous natural predators, regularly use the same beaches where nests are located. Continual human disturbance poses a major threat to breeding pairs. Previous studies in other areas indicate that oystercatchers often abandon nests, refrain from nesting, or completely evacuate the location due to human disturbance. These facts raise concern about the sensitivity of this shorebird population in Kenai Fjords.

To determine how human interaction affects the nesting behavior of the black oystercatcher, the park initiated a study applying a controlled human disturbance to nesting pairs of oystercatchers. The disturbance consisted of two kayakers that set up an overnight camp 100–150 m from the nest. Observations were made during three similarly proportioned time periods: predisturbance, disturbance, and postdisturbance. The data quantify bird behavior and human behavior in order to determine any correlation between the two.

In addition to behavioral observations, the park conducted an inventory of nesting pairs, determined nesting success and productivity for as many nests as possible, and attempted to develop a habitat model to predict nesting locations and densities.

Noatak National Preserve

Preserve moose populations have continued to decline in number because of high adult mortality and low calf recruitment, while the demand for consumptive use by both sport and subsistence hunters has increased. During 1998 and 1999, daily moose locations were obtained using aircraft for approximately 50 radiocollared cows to determine calf productivity and survival. A two-year investigation was also initiated to determine habitat characteristics of moose birthing sites and the associated behaviors of cow moose prior to and during parturition. The hypothesis is that calving site characteristics in combination with cow behavior will ultimately be related to calf survival. During 1999, 31 calving sites were visited.

Dall sheep hunting resumed in the Baird Mountains area of the preserve for the first time in eight years. Aerial survey data from 1998 showed that full-curl ram numbers were high enough to support a quota-limited harvest. Subsistence sheep hunters harvested 16 full-curl rams during the winter of 1998–99. Survey data obtained during July 1999 showed that winter mortality of these older-age-class rams, in combination with the hunt, had reduced full-curl rams to a level that would not support a hunt during 1999–2000. Overall, adult numbers continued to increase slowly, and above-average lamb production was recorded for the past five consecutive years since the population decline. In 1999, funds were obtained to begin a four-year project to develop an aerial survey method to determine population size and to investigate the population dynamics of Dall sheep.

During March and April 1999, 11 wolverines in the upper Noatak River valley were radiocollared

to test the feasibility of long-term population monitoring. Nine VHF transmitters and two satellite-transmitting collars were deployed. The efficacy of satellite radiotelemetry is being tested to study the vast movements and dispersal characteristics of juvenile wolverines. The satellite transmitters operated less than two months. Design and battery flaws probably prevented long-term transmissions. NPS has worked with the manufacturer to correct these problems and will redeploy 12 transmitters during 2000. Currently the movements of five wolverines are monitored at least twice monthly using aerial radiotelemetry.

Gates of the Arctic National Park and Preserve

Off-road point count surveys were conducted in Anaktuvuk Pass for neotropical migrant birds in June 1999 using variable circular point count techniques. Established survey routes in the upper Noatak River drainage and the Middle Fork of the Koyukuk River drainage were not run in 1999 because field staff was not available. The objectives of this long-term monitoring program are to:

- Identify resident or breeding bird species in three distinct areas of the park;
- Collect baseline information on bird species abundance in these three areas; and
- Obtain habitat use information for bird species in these areas.

Fifteen species were identified on the route, and there was one unidentified sandpiper; five more species were detected in 1999 than in 1998. Overall, 26 species of birds have been identified on the route since 1993, with 12 of those species being passerines.

A Dall sheep project is being conducted within park subsistence areas surrounding Anaktuvuk Pass. The project objectives are to:

- Examine the movement patterns of Dall sheep in the Anaktuvuk Pass area;
- Determine the sex and age composition of the population; and
- Examine the harvest characteristics for the community of Anaktuvuk Pass.

Movement patterns are investigated with radiotelemetry. Eighteen Dall sheep were captured with a net gun and radiocollared in March 1998. Three additional sheep were captured in March 1999 to replace animals lost during the first year. Sheep were located 19 times during the first year. By late 1999, none of the radiocollared animals had crossed a major drainage or valley. Home range size has averaged 11.2 square miles and varied from 4.05 to 22.41 square miles. The sex and age

structure of sheep populations are investigated by aerial and ground-based surveys. In the 358.5 square miles that were surveyed from the air in both years, 386 sheep were observed in 1998 and 181 were observed in 1999. This 53% reduction may be more a result of a change in sheep sightability than an actual population reduction. Lamb:ewe ratios have been high in both years, with 26:100 in 1998 and 33:100 in 1999. Ram:ewe ratios were comparable between years, with 27:100 in 1998 and 24:100 in 1999. The success of ground-based surveys has been poor during the last two years because of poor sightability and small sample sizes.

Muskox sightings are becoming more frequent with each passing year. Muskox are indigenous to the park but were extirpated in the late 1800s. Interest in muskox range expansion is important to park staff and local residents. Aerial muskox surveys were conducted in the major river drainages on the north and west sides of the park in April and June 1999. No muskoxen were observed in either survey. The muskoxen database for the park continues to grow, with a total of 30 observations. Eleven of these observations have been in the past year. The majority of observations have been in the Noatak River Valley (53%) and near Anaktuvuk Pass (17%). It is likely that one or two muskoxen account for multiple observations in each of these areas. Based on timing and location of observations, a minimum of six muskoxen occupied the park during the summer of 1998 and three muskoxen occupied the park in the summer of 1999.

A cooperative agreement was put in place with the Alaska Department of Fish and Game for a wide variety of wildlife work, including assisting with developing a new bear survey technique in Game Management Unit 26B in spring 2000, and caribou and sheep radiotelemetry in the park.

The third annual snowshoe hare track counts were conducted near Wiseman west of Nolan during February and March 1998. The 11 transects established in 1997 in six vegetation types were re-located. Tracks were counted on five days to get an index of how many hares were in the area. Browsing of vegetation by hares was also noted in each vegetation type. The results indicate that the population increased slightly between 1997 and 1998, and the population is suspected to be at or near its peak.

A resource inventory was conducted in the Castle/Fortress Mountain Unit of the park in July 1999. The objectives of the inventory were to:

- Compile vegetation species lists;
- Collect and prepare plant specimens;
- Locate and document archaeological sites;
- Identify human impact sites;
- Determine small mammal presence and abundance within a study site at May Lake; and
- Identify future logistical issues for conducting resource management projects in the unit.

The unit was traversed from the Kiruktagiak River to May Lake, during which plant, mammal, and bird species lists were compiled, plant specimens were collected, and potential archaeological sites were identified and visited. A 50- × 40-m small-mammal trapping grid was also deployed at the northwest corner of May Lake for 45 trapping hours. Of the many potential archaeological sites visited, positive findings were found at one. Two small mammals were captured throughout the trapping period, *Microtus miurus* and *Sorex tundrensis*, both considered uncommon species. It was surprising that a more common species was not captured. Low temperatures, snow, rain, and sleet during the trapping period likely affected success, making any conclusions drawn on presence and abundance erroneous. Trap results warrant future small mammal research.

A study was initiated in 1995 to evaluate all-terrain vehicle (ATV) impacts on tundra vegetation in drainages surrounding Anaktuvuk Pass. Data were collected in impacted and nonimpacted sites within different vegetation types to monitor the resistance and resiliency of vegetation communities to ATV use. Results from this study will serve as a general resource database for the area and will be used to make management decisions regarding ATV use. In 1996 and 1997, data were collected in areas not yet affected by ATV use. During the 1998 and 1999 field seasons, plots were established in ATV-affected areas.

In 1996 the park adopted the Arctic National Wildlife Refuge's recreational impacts monitoring program. Northwest Areas National Parks (Bering Land Bridge National Preserve, Noatak National Preserve, and Kobuk Valley National Park) also adopted this monitoring program in 1999, which was then renamed the Brooks Range Impacts Monitoring (BRIM) project. The BRIM project is an attempt to manage for acceptable levels of environmental change while balancing public desires for recreation without irreversible loss to the wildland resource. This will allow park managers to determine and allow levels of human use that park resources can withstand without impairing their integrity or condition. The project will

quantify the current state of impacted sites and will help to assess the future effects of human use and site recovery. The goals of this project are to:

- Determine levels of impacts in high-use areas;
- Establish new study sites and revisit established sites to detect changes over time; and
- Provide a baseline for determining the limits of acceptable change in high-use areas.

Yukon-Charley Rivers National Preserve

A comprehensive bird inventory project began in the preserve in 1998. Project objectives are to:

- Collect and summarize all existing information on bird distribution and abundance;
- Obtain geographic data layers needed to characterize habitat (vegetation, hydrology, fire history, and ecological subsections);
- Determine bird abundance associations by species and habitat characteristics during the breeding season;
- Estimate parkwide abundance and distribution;
- Examine distribution and relative abundance for wintering birds;
- Document owl species presence or absence by ecological subsection; and
- Design a bird monitoring program for the preserve.

A fall waterbird staging survey was also conducted. Project objectives were to determine fall waterbird staging areas, determine waterbird species composition of fall staging aggregations, and estimate numbers of waterbirds during fall staging. Low-level flights were conducted along the Yukon River corridor to count and classify waterbirds during September 1999. Six survey flights were conducted. A mean of 994 birds per flight was observed. Bird numbers varied between flights in response to migration movements. In addition to the surveys, a database and annotated bibliography on historical bird species information were completed for the preserve. An interagency agreement was established with the USGS to obtain technical assistance for project development and statistical analysis.

An ecological subunit map and GIS data layer were developed to aid sampling for wildlife studies in the preserve. The objective was to delineate regions within which there is a consistent geographic pattern of ecological conditions. Ecological units were delineated on 1:250,000-scale USGS topographic maps. Unit boundaries were formed by qualitatively interpreting and synthesizing topographic information with high-altitude color-infrared photographs, geologic maps, fire

history maps, and land cover maps.

The third annual neotropical bird monitoring survey was conducted out of Coal Creek Camp in June 1999 using variable circular point count techniques. The objectives of this long-term bird monitoring program are to identify resident or breeding bird species in boreal forest habitat, collect baseline information on bird species abundance, and obtain habitat use information for bird species. Two transects were surveyed: Woodchopper Road and the high road to Slaven's Roadhouse. Twenty-one bird species were identified on the Woodchopper transect and 20 species on the high road to Slaven's Roadhouse transect. Fifteen species were common to both transects.

The social impacts of military overflights were examined in Alaska Military Operations Areas within the preserve. This project is funded by the U.S. Air Force under an Interagency Agreement with the NPS. The principal investigators are with USGS-BRD and the University of Washington. Data collection was to begin in 1999, but the Kosovo crisis pre-empted all major flying exercises and hence all planned project fieldwork for 1999. However, pretest activities were conducted in July and August 1999 and included the following:

- Testing visitor contact means and interview instruments at Chena State Recreation Area;
- Conducting unstructured qualitative interviewing at Chena Recreation Area and the preserve;
- Pretesting administration and construction of preserve river trip diaries and on-site interviews in Circle, AK; and
- Pretesting the use of diaries for campground hosts.

Dall sheep ewes were outfitted with global positioning system/VHF radiotelemetry collars in March 1999 to investigate the impacts of military flying activity within the Military Operations Areas. Collars were put on ten sheep in the Cirque Lakes area within the preserve and ten sheep in the West Point area to the west of the preserve. Cirque Lakes is an area that is mitigated for the impact of military overflights and West Point is not. Weights of sheep were taken during the capture operation, and a blood sample was drawn for pregnancy determination. Horn annuli were counted for determining age. Aerial surveys were conducted in June 1999 in both locations. Habitat and noise investigations within the study areas did not begin during this first year of the study. Occurrences of scheduled flying exercises were uncertain because of the U.S. involvement in the Kosovo

conflict. Resumption of normal flying patterns will allow all aspects of this study to progress in the upcoming year. Additional sheep were collared in March 2000.

The objectives of a Dall sheep study initiated in 1997 are to:

- Determine seasonal movement patterns of sheep;
- Improve the timing of surveys;
- Quantify the co-mingling of sheep from discontinuous areas of habitat;
- Identify lambing and rutting areas; and
- Develop a long-term monitoring plan.

A total of 18 sheep are being monitored with conventional VHF radiocollars. Sheep often move between mountains and river bluffs, with the frequency of movements decreasing during the winter. There is a significant amount of movement among areas frequented by sheep, and there do not seem to be specific lambing or rutting areas within the preserve. Given the homogeneous distribution of sex and age classes and the potential for significant movements throughout the study area, future sheep surveys will need to cover most of the Charley River drainage to produce a representative estimate of the preserve's sheep population. An annual report was completed in the winter of 1999.

A wolf radiotracking project was initiated in 1993. The objective is to examine the demography of wolf packs in the preserve. Identified preserve wolf packs receive protection from the sterilization predator control program implemented by the State of Alaska on its land. The wolf control effort is in response to the decline of the Forty-Mile caribou herd. Twenty collared preserve wolves that make up eight packs are being monitored to maintain their exempt status from the control effort. Pups have been seen with seven of the eight packs in 1999. Snow conditions in the winter of 1998-99 were poor, so snow tracking was not possible for

locating and radiocollaring new packs. Identifying and marking all preserve packs is important to ensure their protection from sterilization when on state land. The known preserve wolf harvest was one individual in 1998-99.

During the 1999 fire season, approximately 120,000 acres within the preserve were burned by wildfires. Fifteen randomly located permanent plots were established within the burned black spruce woodland of the Yukon River Corridor between Nation Bluff and four miles east of Kathul Mountain in September 1999. All plots were located within one kilometer of the Yukon River. The objectives of these long-term plots are to monitor vegetation recolonization rates and succession, determine post-fire changes in permafrost depth, and determine changes in soil chemical composition. Measurements of the depth of the active layer (the depth to permafrost) and point-intercept vegetation sampling were completed along two perpendicular subtransects within the 20-m-diameter circular plots. Fire intensity was determined, four permanent photo points were established, and the numbers of live, standing dead, and downed dead trees were tallied. The establishment of this long-term monitoring project will provide information on black spruce fire ecology in the preserve.

A military F-15C fighter jet crashed in the headwaters area of the Charley River in 1995. The impact resulted in a fire that severely scorched roughly 300 square meters to mineral soil. An unknown quantity of type A jet fuel contaminated the area, and wreckage debris littered the site. Cleanup efforts conducted by the NPS and the U.S. Air Force removed the majority of the wreckage, but the site is still littered with some debris. Site revegetation has been monitored annually since the crash and will continue every three years. Soil and water quality will be tested in the future.

Bureau of Land Management

The Federal Land Policy and Management Act of 1976 gives the Bureau of Land Management (BLM) responsibility for managing the land and resources of the public lands of the U.S., including those in Arctic Alaska. Management is based on principles of multiple use and sustained yield, a combination that takes into account the long-term needs of future generations for renewable and nonrenewable resources. These resources include

	Funding (thousands)	
	FY 98	FY 99
Natural Ecology	2,700	1,700
Minerals Research	115	115
Cultural Resources	250	200
Pipeline Monitoring	550	550
Fire Control	350	380
Mining Administration	300	300
Total	4,265	3,245

soils, recreation, range, timber, minerals, watersheds, fish and wildlife habitat, wilderness, and natural, scientific, educational and cultural values.

Research is typically site specific to address identified problems, as opposed to research for the sake of expanding knowledge.

Cultural and Paleontological Resources

A BLM field crew conducted a paleontological reconnaissance in July 1999. The reconnaissance focused on the southern end of a large Cretaceous basin in western Alaska. Nine drainages were surveyed at low level by helicopter. The field crew took samples from nonmineralized and unfolded sedimentary Cretaceous beds. The upcoming pollen analysis will contribute to understanding the paleo-ecology of Cretaceous beds in Alaska.

Botanical Surveys

Floristic inventories were conducted in the relatively unexplored areas of the Nulato Hills of western Alaska and the Lime Hills/Lyman Hills complex of south-central Alaska. The crews visited sites representing all upland and alpine habitats and sites suspected of supporting rare plants. The collections are curated at the University of Alaska Museum Herbarium, Fairbanks, and information about them has been entered into a database.

Several significant floristic finds resulted from these surveys. *Ranunculus auricomis*, the Goldilocks buttercup, was found at two sites, the first known records for this northern Eurasian species in North America. Both populations were small, and a critically imperiled (S1) ranking is expected to be assigned to this plant by the Alaska Natural Heritage Program. Over 12 taxa ranked as critically imperiled to rare (S1–S3) were documented, and many of these records represent considerable extensions of their known range.

In a very localized flora effort at the Bering Glacier, University of Alaska personnel discovered one new plant species and one range extension. Expansion into other areas is needed. The BLM is now looking for support to expand this flora inventory.

Mineral Assessments

Upper Koyukuk Mineral Assessment

The BLM is continuing a mineral resource assessment of the upper Koyukuk River. The 11.6-million-acre study area includes Federal, state, and Native lands in the Koyukuk Mining

District. The program is a comprehensive study of past and current mining activity and the potential for future mining development. Study objectives are to identify the type, grade, and size of mineral resources in the area and to perform mining feasibility studies, using hypothetical mine models on mineral deposits with economic potential.

The study area is drained by the upper Koyukuk, Kanuti, Alatna, John, and Wild Rivers. The region has over 400 mineral sites, including those containing placer and lode gold, copper, zinc, tungsten, antimony, chromite, tin, and coal. The five-year program includes literature and mining records searches, construction of an extensive mineral database for the district, and field investigations. In a cooperative effort with the Alaska Division of Geological and Geophysical Surveys, an airborne geophysical survey was conducted over a 530-square-mile area in the northeastern portion of the district. The results of the survey were made available to the public in the spring of 1998.

During the 1998 and 1999 field seasons, 316 mineral sites were visited. These included historic and active placer gold mines, copper and tungsten skarns, copper porphyries, stibnite-gold vein systems, and podiform chromite occurrences. Anomalies resulting from the 1997 airborne geophysical survey were examined to determine possible sources. A total of 1207 samples of rock, pan concentrate, stream sediment, and soil were collected. Mine operators were interviewed to determine area mining costs. Information from the interviews will be used for mine feasibility studies of the major deposit types in the district.

Tests were made using ground-penetrating radar (GPR) as a tool to determine the thickness of frozen fluvial gravel over bedrock in the district. Traverses at four sites in the Wiseman area where depths to bedrock were known showed that GPR could penetrate to depths of approximately 30 ft. This technique could prove useful to placer mining operations, as prior knowledge of overburden thickness and buried channel configuration are determining factors in the viability of most area placer deposits. A report with the results of the first two years of fieldwork in the upper Koyukuk River area is due for release in the fall of 1999. Fieldwork will continue into FY 00, and the final reports for the study are due in 2001.

Mineral Investigation of Native Land Selections

During FY 98 the BLM completed the last year of fieldwork on a two-year mineral assessment of

Ahtna, Inc., selections within the Wrangell–St. Elias National Park and Preserve, Alaska. The assessment was conducted to provide Ahtna the necessary minerals information to finalize their regional selections within the park (as requested by the National Park Service).

Through a literature search and field investigation, the BLM identified 127 mineral occurrences within a three-mile radius of the Ahtna selections in the southern Wrangell Mountains. Mines, prospects, and occurrences were sampled to aid in determining the type, amount, distribution, and economic viability of mineral deposits located on Ahtna-selected lands within the park boundary. An open-file report was completed in the second quarter of FY 99.

During FY 99 the BLM compiled a three-volume final report from data collected during a mineral assessment of Ahtna selections within the Wrangell–St. Elias National Park and Preserve, Alaska.

Tongass National Forest Mineral Assessment

Studies of the mineral development potential of mining districts in southeastern Alaska are continuing at the request of the U.S. Forest Service. The objectives of the studies are to identify the type, amount, and distribution of mineral deposits, determine ore reserves, complete economic feasibility studies, and address the economic and environmental effects of mineral development.

A mineral assessment of the Chichagof and Baranof Islands area, initiated in 1995, has been completed. A final report summarizing the mineral endowment of the area was released in early 1999. An economic feasibility report was completed also. It focused on grade and tonnage requirements for developing two deposit types found in the area: vein gold, and magmatic nickel, copper, and cobalt.

The Stikine area mineral assessment, encompassing the Wrangell and Petersburg areas of central southeastern Alaska, was started in 1997. A report on the assessment was released in 1998. A second report is in progress covering the work that was completed in 1997 and 1998. It includes detailed prospect descriptions, as well as background information on land status, geology, and mining history. Fieldwork in the Stikine area has been completed, and the report will be published before the end of FY 00.

Geophysical Surveys in Alaska

The BLM has coordinated three regional airborne geophysical surveys to augment its mineral

assessment responsibilities on public lands in Alaska. In 1997 a survey of approximately 1100 square miles of mineralogically prospective land in central southeast Alaska was conducted. In FY 98, data from a similar survey were released for lands in the Wiseman area of north-central Alaska. Later in FY 99, survey data were released for approximately 850 square miles in southeastern Alaska near Ketchikan. In each survey, total field magnetics and induced electromagnetic conductivity data were acquired to aid in geologic interpretation, with the aim of furthering mineral exploration.

The Ketchikan survey was unique in the diverse array of project participants. Federal, state, and municipal governments were involved along with a regional Native corporation. The BLM, the Ketchikan Gateway Borough, and the cities of Thorne Bay and Coffman Cove contributed funding for the survey. Sealaska Regional Native Corporation contributed existing geophysical data from their land holdings adjacent to the areas surveyed. The State Mental Health Land Trust Office paid for surveying their land holdings in the area. The Alaska Division of Geological and Geophysical Surveys (ADGGS) provided contract administration and management. The intent of many of the participants was to promote economic activity by spurring mineral exploration in the area.

A fourth airborne geophysical survey is planned for a mineralogically prospective area on the lower Kuskokwim River in southwestern Alaska. The area to be surveyed holds the potential for large, low-grade gold deposits associated with Cretaceous to Tertiary felsic intrusive rocks. This project is funded by the BLM, with contract administration handled by the ADGGS.

North Slope Research Camps

Research on the North Slope is expanding. An estimated 300 researchers, many of them university-affiliated, conducted research on BLM-managed public lands on the North Slope during the 1999 field season. Research work encompasses studies ranging from the greenhouse effect to snow cover, and from aquatic plants to ground squirrels.

Approximately 90% of all research is done within the boundaries of three Areas of Critical Environmental Concern (ACEC). The largest of these—the 82,000-acre Toolik Lake ACEC—includes the Toolik Lake Field Station, an important logistic base for Arctic biological research and the only such base located within the U.S. The

Institute of Arctic Biology, University of Alaska Fairbanks, established the field station in 1975 under a special use permit issued by the BLM. The field station serves scientists from about 30 universities and 20 nations. The BLM, through its membership in the Toolik Lake Steering Committee, works closely with the Institute of Arctic Biology, the National Science Foundation, and the research community to manage this ACEC.

Other Arctic research is ongoing in the Galbraith Lake ACEC, located along the Dalton Highway, and in the 19,000-acre Iteriak ACEC, located in the northern foothills of the Brooks Range. During the 1998 and 1999 field seasons, the BLM permitted the Polar Ice Coring Office of the University of Nebraska to establish a logistic base camp at Iivotuk for its researchers working in the Iteriak ACEC, which is accessible only by air during the summer.

Arctic Char in the Kigluaik Mountains

In FY 98 and 99, researchers at the University of Wisconsin, Milwaukee, and the BLM continued a cooperative project to study Arctic char on the Seward Peninsula in western Alaska. The study was initiated in 1997. Researchers are using nuclear and mitochondrial DNA genetics analysis to determine the taxonomic status of isolated, relict populations of lake-resident Arctic char in the Kigluaik Mountains. Preliminary results indicate that char from some of the lakes differ from other Alaska char. As many as three different species or subspecies of char may inhabit many of the more than 50 glacially formed lakes in the study area.

National Petroleum Reserve—Alaska

The 23-million-acre National Petroleum Reserve—Alaska (NPRA) is the largest block of public land managed by any U.S. agency. Cooperative projects with a variety of agencies and special interest groups were conducted in FY 98 and 99.

The U.S. Geological Survey's (USGS) Global Change and Climate History Program, which monitors earth temperature changes using oil and gas test wells, is supported by the BLM with logistics and personnel. This program has operated for more than 40 years. During the last five years, small, remote meteorological stations, adjacent to test wells, were set up to monitor surface climate changes.

A second cooperative project with the USGS

involves sampling hydrocarbons from test wells. The U.S. Navy has drilled test wells in the NPRA since the 1940s. Hydrocarbon shows in a few wells have not been sampled and analyzed since their drilling. As these old wells are inspected, plugged, and abandoned, researchers are attempting to collect samples for analysis by modern techniques.

The BLM is in the planning stage of a joint land use study with the students of Atkasuk Village School 3 of the North Slope Borough School District. The project will document historic use of area lands. The environmental condition of a trail used during the 1940s to 1950s for hauling coal to Barrow is of particular interest.

During the summer of 1999 the BLM conducted an aerial raptor survey throughout most of the NPRA, with a focus on peregrine falcons and terrain supporting nesting habitat. This survey covered large areas that had not been comprehensively surveyed since 1977. It will provide information on changes in the population status of four species: peregrine falcons, gyrfalcons, rough-legged hawks, and golden eagles. The BLM also contributed funds to the annual surveys of raptors by boat along the Colville River. These surveys have provided excellent long-term data since 1978, with fewer observations dating to 1952. The diversity and density of nesting raptors along the Colville River is matched by only a few other areas on earth.

In the northeastern portion of the NPRA, where oil and gas leases were recently awarded in FY 99, the BLM began a long-term study of the impacts to vegetation by winter seismic exploration. This study will assess the impacts to all land cover types and disturbance levels. The study will describe the recovery from disturbance by the land changes or species composition and the time required.

The BLM and Ducks Unlimited, Inc. (DU) correlated their earth cover classes map within the NPRA with the locations of seven waterfowl species collected by the U.S. Fish and Wildlife Service (USFWS). Since 1992 the USFWS has conducted aerial surveys of spectacled eider populations within the Arctic coastal plain and has also collected valuable information on 35 other avian species. The earth cover map was created by DU and the BLM using Landsat thematic mapper (TM) and System Pour l'Observation de la Terre multi-spectral (SPOT XS) satellite imagery. The project area included all of the NPRA to the west and east but extended south to the limit of the waterfowl

surveys conducted by the USFWS, which roughly corresponds to the Arctic coastal plain physiographic province. The first phase of the analysis found a correlation between the distribution of observed spectacled eider locations and earth cover types, and the second phase modeled resource selection. A logistic regression function was used to produce the relative probability of occurrence surfaces by the spectacled eider. The results of the resource selection analyses led to the conclusion that the NPRA earth cover data can be used with waterfowl point data to study the distribution of waterfowl across the Arctic coastal plain.

The possibility of expanding petroleum and natural gas exploration and development is being analyzed for a portion of the NPRA. Baseline earth cover and wildlife data provide a basis for multiple-use management planning of this vast and remote area in the event of expanded development in the Arctic coastal plain. Study methods provide a relatively fast and efficient way to analyze the baseline data in a macro-analysis of this Arctic landscape.

Land Cover in Western Alaska

The BLM, in partnership with DU, the USFWS, the Alaska Department of Fish and Game (ADF&G), the USGS, and the National Park Service, has completed field ground-truth mapping on 26 million acres from the Nulatto Hills and Norton Sound to the Kilbuck Mountains. Computer processing by DU will provide land cover mapping for more than 20 vegetation and land cover categories. Data will be used to develop predictive models, quantification of land cover types, land cover base data for climate change detection, and a landscape-level tool to analyze and direct land use decisions.

Hydrologic Monitoring

The BLM's hydrologists are monitoring streamflow in interior and Arctic coastal Alaska. These rivers have important anadromous fisheries. Water level recorders are located on Clear Creek, a tributary to Hogatza River, and on Jim River. Recorders have also been installed on rivers in the National Wild and Scenic River System, including Beaver Creek, Birch Creek, and Fortymile River. Peak streamflow and channel morphology sites are located at numerous drainages in the Circle, Fortymile, and Tolovana mining districts. Recorder sites provide information that is used for designing

channel and floodplain reclamation on Federal mining claims and evaluating earlier reclamation results. Nine rivers and 30 lakes were inventoried for water quality and quantity during a reconnaissance survey of the northeast area of NPRA. Snow surveys and climate monitoring continue along the Dalton, Steese, and Taylor Highways, as well as at remote locations in the Interior.

Neotropical Migratory Bird Surveys

The BLM-Alaska wildlife biologists have participated in the Neotropical Migratory Bird (NTMB) program during FY 98 and 99.

In an effort to monitor trends in North American bird populations, 10 breeding bird surveys and 7 off-road breeding bird point count surveys were conducted annually in northern Alaska. Survey routes were initiated in 1992 and 1993. The surveys provide a source of standardized data on populations of breeding birds throughout the U.S. and Canada. Breeding habitats in Alaska are largely intact and provide an opportunity to clarify the importance of breeding habitat versus migration and wintering habitats for many species of long-distance migrants. Many species detected on these routes are identified by Alaska's Boreal Partners In Flight (BPIF) working group as having a conservation priority. These include the olive-sided flycatcher, Hammond's flycatcher, gray-cheeked thrush, varied thrush, Townsend's warbler, and white-winged crossbill.

Mining impacts to breeding birds were monitored within mined and undisturbed portions of a Birch Creek National Wild River tributary during FY 98. This project was initiated in 1995 using area search protocol and incorporating vegetation surveys. Preliminary results suggest that disturbance to the birds extends beyond the actual footprint of the mining operation.

Breeding bird survey routes were conducted on the Unalakleet and Anvik Rivers in western Alaska. At 50 points along the river corridor, all birds seen and heard within a quarter mile during a three-minute count were tallied. The species tallies are reported to the Biological Resources Division of USGS. A trend analysis statistical procedure is used to estimate the population change for each species or trend each year. Thirty-five species have been recorded on the Unalakleet route, and 42 on the Anvik survey since the routes were established in 1996. The species include resident birds and long-distance migrants from Central and South America.

In conjunction with the breeding bird survey, three bird banding stations were established to inventory breeding landbirds in FY 98 and 99. In June of both years, birds were banded at the Old Woman public use cabin on the Old Woman River. An off-road point count transect was also established on Old Woman Mountain to supplement banding efforts. The Old Woman River is part of the watershed of the Unalakleet River, which drains into Norton Sound. Bird banding stations were also established on the upper reaches of the Anvik and Bonasila Rivers, which drain into the Yukon River near the village of Anvik. Four shorebird and 17 landbird species were captured in the two years, with 231 individuals banded using mist nets. Northern waterthrushes were the primary species captured, followed by Swainson's thrushes, Wilson's warblers, and myrtle warblers.

A fall migration bird banding station was established at BLM's Campbell Tract in Anchorage in 1997 and continued in FY 98 and 99. Migrant birds were captured and banded with mist nets and released annually from mid-August through September. Twenty-six species were captured, with 413 individuals banded in 1997, 961 individuals banded in 1998, and 1010 individuals banded in 1999. Slate-colored juncos were the primary species captured, followed by Wilson's warblers, orange-crowned warblers, and ruby-crowned kinglets. The capture of an Arctic warbler on September 6, 1999, represented the first record of this species in the Anchorage Bowl. Additional avian sightings provided records of 30 species.

Game Birds

The BLM and the Alaska Fire Service are cooperating with the U.S. Army Alaska on a ruffed grouse habitat enhancement project. Prescribed fire will be used to encourage aspen suckering to maintain a mosaic of age classes or control grass invasion. A rotation of prescribed burns will be conducted within ruffed grouse habitat in the study area to maintain stand diversity.

Vegetation surveys for this project were completed in FY 98. The first prescribed burn is planned for FY 00. Vegetation response and grouse use will be monitored.

Fortymile and Ray Mountains Caribou Herds

The BLM joined state and Federal agencies and a citizen team to plan for the recovery of the

Fortymile Caribou Herd (FCH) in response to requests from subsistence hunters throughout Alaska and the Yukon Territory, Canada. Important to subsistence hunters throughout the ages, this herd once occupied 220,000 square kilometers of Alaska and the Yukon. Today the herd ranges within less than a quarter of that area and rarely migrates into the Yukon. Calf survival is poor. Years of research show that wolf predation limits calf survival.

A plan was carefully crafted by subsistence and sport hunters, wildlife enthusiasts, animal rights advocates, environmental advocates, ecotourism representatives, and agency representatives from Alaska and the Yukon. Implementation of the plan includes reduced harvest, monitoring of land use within the FCH range, fertility control of alpha wolves, and translocation of subordinates wolves. The BLM has formed a partnership with the ADF&G to monitor calf survival and population growth during the implementation of the project.

The Ray Mountains Caribou Herd, a distinct but small herd 120 miles northwest of Fairbanks, has been studied through a partnership with the ADF&G, the USFWS, and the BLM. The BLM has identified habitat use patterns, distribution, and movements during the five-year study. Fire history of the caribou range was compiled, with caribou locations to determine the use of burned areas.

Beaver Creek Fish Weir and Nome Creek Studies

In the Beaver Creek National Wild River management plan, the BLM proposed to conduct an inventory of fish, wildlife, and habitat within the river corridor and to continue to monitor the effects of river management actions, population trends, and habitat use. Toward this goal, the BLM in FY 98 and 99 continued a five-year study designed to:

- Enumerate the anadromous fisheries using the middle to upper reaches of Beaver Creek;
- Determine the timing and strength of the summer and fall salmon runs;
- Monitor the hydrological conditions at a weir site; and
- Collect and preserve scales and caudal fin tissue for genetic stock analysis if run size permits.

This study started in 1996 when the BLM installed a resistance board weir on Beaver Creek.

Accurate salmon escapement data are critical

for evaluating and providing stock status information on salmon populations and harvest management strategies, particularly in mixed-stock fisheries. The weir study should also provide useful information on whether recent recreational development of nearby Nome Creek is increasing harvest pressure by sport fisherman and negatively impacting the subsistence fisheries of the villages of Beaver and Steven's Village.

The Nome Creek watershed, approximately 60 miles northeast of Fairbanks in the White Moun-

tains National Recreation Area, is the subject of additional studies by the BLM fisheries biologists. Of particular interest is Nome Creek's resident fish populations, including an Arctic grayling "catch and release" sport fishery. Population characterization and life history information has been collected on the stock since the mid-1980s. In FY 98 and 99 the sport fishery was monitored in late spring during the spawning migration. Approximately 1200 fish were sampled for age and growth.

Geological Survey

Biological Research

The U.S. Geological Survey (USGS) conducts biological research in the Arctic to generate information that will help Department of the Interior agencies and other partners in Alaska meet their resource management responsibilities. These responsibilities include conservation of migratory birds, certain marine mammals, endangered species, anadromous fishes, and all biota inhabiting National Wildlife Refuges and National Parks and Preserves. Research is designed to address the effects of development, disturbance, hunter harvest, and natural environmental cycles on fish and wildlife populations. Other research will help develop improved census and survey methods that will better detect trends in populations. All research has the ultimate goal of providing information that will lead to better management decisions and actions to promote conservation of living resources in the vast ecosystems of the Arctic. Fish and wildlife populations in the U.S. Arctic are extensively shared with Canada and Russia, and a portion of the research effort is directed toward treaty and other international requirements to jointly manage shared resources.

Most of the biological research is conducted in the Arctic by USGS scientists from the USGS Alaska Biological Science Center (USGS-ABSC) in Anchorage, the USGS Forest and Rangeland Ecosystem Science Center (USGS-FRESC) in Corvallis, Oregon, and the Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks. Some additional research is performed by others of the 15 USGS research centers or the more than 50 Cooperative Research Units, each of which has special capabilities that may be applicable to problems in Arctic research.

Ecological research in Arctic ecosystems is

	Funding (thousands)	
	FY 98	FY 99
Energy and Minerals	3,500	3,500
Natural Hazards	3,500	3,500
Global Change	1,000	1,000
Marine and Coastal Geology	250	250
Geomagnetism	250	250
Ice and Climate	250	250
Hydrology	130	130
Mapping	750	750
Marine Mammals	1,660	1,660
Migratory Birds	2,390	2,390
Fisheries Research	360	360
Cooperative Research	330	330
Terrestrial Ecology	1,130	1,130
Park Research	1,140	1,140
Basic Marine Res./ N. Pacific Ocean	0	6,600
Total	16,640	23,240

difficult, given the harsh conditions, frequently inaccessible habitats, and often wide-ranging movements of Arctic biota. It is also very costly. Since it has often been necessary to develop new methods of obtaining information, some of the most advanced technologies have been developed for, or first applied to, research in the Arctic. Satellite-linked biotelemetry and heavy metal tracers are but two of many new techniques that have been successfully applied to the problems of fish and wildlife conservation in the Arctic.

Wildlife Ecology

Long-term ecological research on the population dynamics and wolf-prey relationships of gray wolves and their primary ungulate prey, caribou and moose, continued in 1998-1999 at Denali National Park and Preserve. Begun in 1986, this research program is directed by staff of the USGS-ABSC in close cooperation with National Park Service (NPS) staff at Denali. To date, these studies have provided new information on the population dynamics, predation behavior, social structure, and genetic relationships of wolves; the population dynamics, reproductive performance, and calf sur-

vival patterns for caribou; and the influences of weather and landscape use patterns on wolf–caribou relationships. Research findings to date have been summarized in a 1998 book titled *The Wolves of Denali*. In 1998, studies of moose population dynamics were added to the ongoing wolf and caribou projects.

During these studies, winter severity has greatly affected the vital rates of wolves and caribou and wolf–prey relationships observed. A six-year period of above-average winter snowfalls resulted in more than doubling of the wolf population to 7.8 wolves/1000 km² via increased pup recruitment and decreased dispersal of young wolves. The caribou population declined from 3200 animals to about 2000 as a result of poor recruitment of young and higher adult mortality. Caribou mortality, for both calves and adults, was primarily the result of predation by wolves and grizzly bears, but nutritional condition was implicated to play a major role in determining the vulnerability for all caribou age classes. Although moose were not intensively studied during this period, their numbers appeared to be stable based on periodic surveys. Since 1995, winter severity has been near the long-term average, and the wolf population has declined to 4.8 wolves/1000 km² while the caribou herd has stabilized at 2000.

In addition to continuing to monitor population size and vital rates for wolves, caribou, and moose, ongoing studies are investigating the role of salmon in the diets of wolves and influences on wolf–prey relationships, fine-scale movements and activities of wolves during the denning season, comparisons of influences of summer and winter weather on growth rates of caribou calves, and interactions of nutritional condition, calf mortality, and productivity of moose.

Development of a long-term ecological monitoring program at Denali National Park and Preserve began in 1992. The program originally took a “watershed” approach, involving collocation of intensive study efforts for a variety of biological and physical parameters in a single watershed. The park, working closely with the USGS-ABSC, is moving now to expand the spatial scale of the monitoring program to include the entire park and to develop stronger linkages with management information needs. Monitoring program development at Denali is providing excellent information on implementing monitoring in the sub-Arctic, where landscapes are huge and costs can be prohibitive. Now that the program has been underway for several years, monitoring data are also becoming

available and are helping demonstrate the program’s value. For example, air quality monitoring has revealed the frequency of occurrence of Arctic haze and Asian dust events in the Denali region and has demonstrated the existence of contamination pathways to this pristine environment.

For the 12th and 13th consecutive years, the NPS, in cooperation with the USGS-FRESC, monitored reproductive characteristics of golden eagles in Denali National Park and Preserve in 1998 and 1999. Biologists monitored 70–76 golden eagle nesting areas in the northeastern portion of the park using two aerial surveys each year in 1998 and 1999. Each year the first survey was conducted during incubation to monitor nesting area occupancy and laying rate, and the second survey was conducted late in the nesting period to count fledglings and determine success rate. Twenty-one successful pairs raised 31 fledglings in 1998, and 55 successful pairs raised 71 fledglings in 1999. Since 1988 the overall annual reproductive output of golden eagles in the park was influenced most strongly by the proportion of pairs that laid eggs. Laying rates for golden eagles were highly correlated with the numbers of snowshoe hare and willow ptarmigan observed in the study area. High productivity in 1989 and 1999 occurred during peaks in snowshoe hare abundance in the study area. The golden eagle study is the only long-term population study of this long-lived aerial predator in sub-Arctic and Arctic regions of North America.

Beginning in 1997, USGS-FRESC and NPS have been supporting research through the Department of Fisheries and Wildlife at Oregon State University to examine factors that influence the reproductive success of golden eagles in Denali National Park and Preserve. Using remote sensing and field sampling, biologists are exploring the relation between nesting area occupancy and reproductive success of golden eagles in relation to landscape composition and configuration at multiple scales. Work in 1998 and 1999 included mapping vegetation communities in 50 golden eagle nesting areas (using color infrared photography and field sampling) and completing 2640 point counts to characterize prey habitat. Completion of this project is anticipated by May 2001.

Concurrent with reproductive and habitat studies, USGS-FRESC and NPS biologists continued to examine behavior, movements, and survival of juvenile golden eagles from natal areas in the park using satellite radiotelemetry. From 1997 to 1999 biologists deployed 48 satellite radiotransmitters on nearly fledged golden eagles (more than 60

days of age). The USGS-ABSC is assisting with data collection. Preliminary results indicate that:

- Juvenile golden eagles from Denali National Park and Preserve overwinter in the inter-Rocky Mountain areas of southern Canada and the U.S. but some juveniles (and adults) may overwinter in interior Alaska and Canada when snowshoe hares are abundant;
- Survival rates during the first year of life are approximately 40%; and
- The North Slope of Alaska is an important “nursery” area for subadult golden eagles from Denali.

Starvation appears to be the main cause of mortality for juvenile golden eagles. Carcasses of dead radiotagged golden eagles were retrieved with the help of many biologists in Canada and Alaska, and postmortem examinations were conducted by Alberta Agriculture, Food and Rural Development, Animal Health Laboratories, Edmonton, Alberta, Canada. Completion of this study is anticipated by May 2001.

A coastal brown bear study in Katmai National Park and Preserve was completed after seven years of fieldwork in the fall of 1996. Since then, data analysis of nearly 3400 brown bear relocations has been ongoing. The products of this work will address bear–habitat relationships, bear home ranges, and seasonal bear movements. Work is ongoing to map vegetation communities, as well as salmon resource availability and other nutritional resources, within the park so that managers can better understand bear–habitat relationships.

In 1998 a USGS scientist identified a significant safety hazard in the misuse of red pepper spray bear deterrents. Typically these sprays are to be dispensed into the face of an oncoming aggressive bear. However, some people hoped that the noxious chemicals would have a repellent effect and were spraying it around tents and other items they wished to keep from curious bears. Research determined that misuse of these sprays resulted in bear attraction, rather than repulsion, a potentially hazardous situation. Publication of the research results attracted national and international attention and has resulted in a safer environment for both people and bears.

A cooperative study between the USGS, the University of Alaska Fairbanks, the NPS, and the Canon Corporation was completed in the fall of 1999 after two years of fieldwork. The focus of this work was bear–human interactions along areas of coastal Katmai National Park, where visitation for bear viewing is rapidly increasing. Deter-

mining patterns of bear activity in the presence, and absence, of people enables a quantitative assessment of human impacts in those areas. Preliminary data analyses show that bears extract significant nutrition (up to 20 kg of animal matter per low tide) from tidal flats by feeding on shellfish, marine invertebrates, and fish stranded by receding waters. Bears appear largely unaffected by current levels of human activity in these areas, though detailed data analyses slated for 1999–2000 will produce more definitive information.

Seasonal dynamics of the Arctic landscape are being monitored with satellite imagery from the advanced very-high-resolution radiometer (AVHRR) onboard National Oceanic and Atmospheric Administration (NOAA) polar-orbiting weather satellites. Because AVHRR data are inexpensive and broad-scale and are acquired daily, the imagery is ideal for studying annual and seasonal variations of environmental processes in the Arctic, such as snow ablation, vegetation phenology, sea surface temperature, and fire. Since 1996, USGS-ABSC has processed and archived daily AVHRR imagery for numerous study areas throughout Alaska and adjacent areas. The data are being used to investigate how wildlife populations respond to variations in the temporal availability and quality of their habitats.

In collaboration with the Alaska Cooperative Fish and Wildlife Research Unit, AVHRR data were used to study a 12-year record (1985–1996) of annual variations in the timing of snowmelt and vegetation growth on the Alaska North Slope with respect to the annual calving behavior of the Porcupine caribou herd. The AVHRR data were used to derive chronological maps of photosynthetically active biomass (termed NDVI, or vegetation greenness). Preliminary analyses of NDVI and caribou calf survival revealed a marked relationship (85%) between the onset and rate of spring vegetation growth and neonatal caribou calf mortality. These findings have fostered an expansion of this research to include other Arctic caribou herds in Alaska and Canada. USGS-ABSC is also collaborating with scientists from San Diego State University who are investigating gross primary production and vegetation carbon assimilation on the Alaska North Slope, the Seward Peninsula, and eastern Siberia. This research is a component of the Arctic System Science Land–Atmosphere–Ice Interaction (LAI) study. USGS-ABSC is producing comprehensive AVHRR and NDVI databases for the 1998–2002 growing seasons, which are being used as a basis for interpreting and extrapo-

lating local-scale ground and aircraft observations of plant growth and carbon dioxide flux.

Fisheries Research

USGS-ABSC fisheries biologists are conducting a detailed study of the ecology and survival of chum salmon in Yukon River tributaries in Alaska. Although Alaska is often thought of as a pristine wilderness, recent developments have demonstrated that salmon stocks in Alaska may be in trouble. Weak returns of western Alaskan salmon stocks during the 1990s have resulted in both restrictions and closures on commercial and subsistence fisheries. Compared to more southerly stocks of chum salmon, little is known about the ecology, behavior, and productive capacity of Yukon River chum salmon. It is generally understood that there are two major runs: "summer" chum tend to spawn in lower Yukon tributaries primarily during July and August, while "fall" chum are found more frequently in upper Yukon tributaries during September, October, and November. Escapement indices, and in a few cases, weir- or sonar-derived population estimates, are available for some significant spawning populations. However, little else is known about the extent or magnitude of production or the factors limiting production of Yukon River chum salmon.

Initiated in 1996 this study is focused on the freshwater portion of the chum salmon's life cycle. The goal of the study is to estimate production in terms of numbers of smolts per spawner. Nested within the approach are estimates of egg deposition per spawner, survival from egg deposition to the alevin stage (pre-emergent sac-bearing fry), and survival from the alevin stage to emergence and emigration from the incubation area. Factors contributing to survival at each of these life stages will be informative and, when evaluated in light of the overall smolt production per spawner, should reveal production bottlenecks. An important facet of the research is to determine the environmental mechanisms (such as intra-gravel flow patterns, temperatures, and dissolved oxygen) driving spawning site selection and reproductive success, and the effects of environmental conditions on survival at critical life stages. Specific, detailed mapping of spawning locations has allowed examination of interannual patterns of spawning and helped to determine the degree of redd superimposition. The development of study site maps also sets the stage for spatial analysis of habitat selection and preference. After five years of data are collected on critical chum salmon life stages, models relating

spawner abundance and critical environmental conditions will be used to reveal controlling factors. These data will ultimately become useful in refining models assessing the effects of management, conservation, and rehabilitation strategies for Yukon River chum salmon.

USGS-ABSC scientists evaluated molecular DNA and other genetics approaches to study Yukon River salmon populations. Resource management agencies require methods to differentiate among populations in the lower river fisheries so that improved management decisions can be made. The results of this collaborative work with the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game are helping to refine genetic stock analyses for Yukon River chinook and chum salmon.

A new study was initiated in 1999 to determine the population structure, migratory patterns, and spawning locations of sockeye salmon in Lake Clark National Park. The NPS has raised concerns about whether these fish, subjects of a gauntlet of commercial and subsistence fisheries, are having sufficient escapement to the spawning grounds on NPS lands. Radiotelemetry and genetic population analyses will initially help to reveal some of the populations' attributes and provide information for refining the studies in the future.

Migratory Birds

The at-sea molting and wintering areas of spectacled eiders, a threatened species, have been a mystery since the discovery of the species over 120 years ago. One speculation was that they wintered somewhere in the Bering Sea near the ice edge or in polynyas off the Chukotka Peninsula of Russia. The need for precise information about the breeding and post-nesting periods of the spectacled eider became critical when the U.S. Fish and Wildlife Service (FWS) documented a 96% decline in breeding pairs on the Yukon-Kuskokwim Delta (YKD) in western Alaska. Little quantitative data existed for the status of the other nesting populations on the North Slope of Alaska and in Arctic Russia, but anecdotal information suggested declines in these breeding areas as well. Consequently the FWS listed, under authority of the Endangered Species Act, all breeding populations as threatened in 1993. There was little evidence that habitats had changed in the three primary nesting areas. However, there was concern about environmental degradation in marine molting and wintering grounds.

In 1993 the USGS-ABSC and the FWS initi-

ated a six-year study to determine the distribution of spectacled eiders during the migration, staging, molting, and wintering periods derived from locations of birds that were implanted with satellite transmitters in each of the three major breeding areas, and to estimate the abundance of birds at sea based on aerial surveys. Satellite transmitters were surgically implanted in 88 adult breeding spectacled eiders between 1993 and 1996 from each of the three major nesting areas in Arctic Russia, the North Slope of Alaska, and the YKD. Transmitters were programmed to transmit for 6 hours every 72 or 120 hours and were designed to last 6–8 months. Data from 82 of the 88 transmitters were received through the Argos Data Collection and Location System, which yielded nearly 4000 locations. Approximately 1200 of these locations were accepted for analysis as independent and biologically plausible. At-sea aerial surveys were designed based on satellite transmitter locations for specific geographic areas in the Bering, Chukchi, and Beaufort Seas. Surveys were centered on specific satellite signal locations and then expanded in all directions in an attempt to find other flocks. Observers in aircraft recorded species, flock size, and sex ratio of flocks, and these data were integrated with position coordinates to provide location information for each flock.

Two principal molting and staging areas were identified off coastal Alaska (Ledyard Bay and eastern Norton Sound) and two off coastal Russia (Mechigomenskiy Bay on the eastern Chukotka Peninsula and the area between the Indigirka and Kolyma deltas in the Russian Republic of Sakha). Aerial surveys resulted in an estimate of more than 10,000 birds molting and staging in monospecific flocks at Mechigomenskiy and Ledyard Bays and several thousand in eastern Norton Sound. Eastern Norton Sound was identified as the principal molting and staging area for females nesting on the YKD, and Ledyard and Mechigomenskiy Bays as the primary molting and staging areas for females nesting on the North Slope of Alaska. Males marked at all three breeding grounds molt and stage in Mechigomenskiy Bay, Ledyard Bay, and the Indigirka–Kolyma delta region. Males from the YKD molt and stage mainly at Mechigomenskiy Bay. Postbreeding migration corridors were offshore in the Bering, Chukchi, and Beaufort Seas. All marked eiders wintered south and southwest of St. Lawrence Island in the Bering Sea. Late-winter surveys indicated that about 333,000 spectacled eiders winter in single-species flocks in the pack ice in the Bering Sea. Now that the at-sea distribu-

tion of spectacled eiders has been documented, biologists are examining key physical and biotic components (bathymetry, sea ice distribution, sea surface temperatures, benthic invertebrate distributions and densities) of marine ecosystems known to support post-nesting spectacled eiders. These studies, initiated in 1997, may provide clues about factors limiting the recovery of spectacled eiders.

Steller's eiders are also considered threatened under authority of the Endangered Species Act. Little is known about the life history and biology of this sea duck. Steller's eiders nest in Arctic Russia and in very low densities on the YKD and North Slope of Alaska. Their numbers have declined significantly on the YKD and also on the North Slope, making nesting studies in Alaska difficult because of limitations in sample size. The causes for their decline are unknown. Populations of Steller's eiders from all nesting populations molt and winter along the Alaska Peninsula, and surveys of these birds have indicated declines since the 1960s. To begin to understand factors that may be limiting Steller's eiders, USGS biologists, in cooperation with the FWS, initiated a study of their annual survival. Survival estimates based on data from the 1990s were compared to estimates based on data collected in the late 1970s. Additionally, fidelity to molting areas and patterns of movement within and among lagoons were examined. Steller's eiders were captured during wing molt at Izembek and Nelson lagoons, Alaska, from late August through early October. Birds were marked with an FWS metal band, and band numbers of previously marked birds were recorded. Mark-recapture analysis techniques were employed to estimate annual survival and movement probabilities within and among lagoons for male and female eiders. Over 63,000 Steller's eiders were captured across all years of the study. Estimates of annual survival were 0.899 for females and 0.765 for males. Both sexes showed high rates of fidelity to specific molting locations (95%) within lagoons. However, there was no evidence that annual survival probability differed among groups molting in different locations, either within or among lagoons. There was evidence that annual survival decreased between the periods 1975–1981 and 1991–1997. The lower survival of males compared to females is atypical for waterfowl and may be linked to a female-biased sex ratio. The decrease in adult survival may have initiated the long-term population decline documented on breeding and post-nesting molting and wintering

areas. A shortage of males may be limiting reproductive potential. Research should now focus on determining the factors influencing adult male survival and understanding the linkage between breeding and molting distributions.

Scientists at the USGS-ABSC are conducting research on over 25 species of loons, waterfowl, shorebirds, seabirds, and passerines. One of these study species, the Aleutian Canada goose, is of special interest to the FWS; state management agencies in Alaska, Washington, Oregon, and California; and conservation organizations in Russia and Japan. Aleutian Canada geese were extirpated from most of their historical range after the introduction of non-native foxes between the 1830s and 1930s. As a result of restricted breeding distribution and numbers, the FWS listed the species as endangered in 1967. More recently the discovery of two previously unknown breeding populations on Chagulak and Kiliktagik Islands and an increase from approximately 800 birds in the mid-1970s to 32,000 birds in 1999 prompted the FWS to propose delisting Aleutian Canada geese to threatened status.

Despite the lack of genetic evidence of distinctions, banding data suggest there are at least two demographically distinct subpopulations of Aleutian Canada geese: Buldir Island birds from the western portion of their breeding range and Semidi Islands geese in the eastern Aleutian Islands. An examination of the genetic relationships between these two populations of geese employed recently developed bi-parentally inherited microsatellite loci and DNA sequence analysis of 143 base pairs of the control region of maternally inherited mitochondrial DNA to study these two populations. The primary objectives of this research were to use molecular genetic markers to assess the extent of gene flow among populations, the potential genetic effects of population bottlenecks, and genetic relationships of Aleutian Canada geese from Buldir Island and the Semidi Islands. Another small-bodied subspecies, the cackling Canada goose that nests exclusively on the YKD, was used for comparison. The widely separated island-nesting Aleutian Canada geese were genetically more closely related to each other than to mainland-nesting cackling Canada geese. The populations of Aleutian Canada geese from Buldir Island and the Semidi Islands were genetically differentiated from one another in terms of mitochondrial DNA haplotype and microsatellite allele frequencies, suggesting limited contemporary gene flow and/or major shifts in gene frequency through genetic

drift. These findings suggest that Aleutian Canada goose populations could be considered separate management units. Although the populations on Buldir Island and the Semidi Islands have experienced different rates of population growth since being listed as endangered, there is no statistically significant genetic evidence that either has gone through a recent population bottleneck. Additional genetic sampling of the western and eastern nesting populations, as well as an unsampled population from the central Aleutian Islands (Chagulak Island), would increase our understanding of the relationships of these remnant breeding populations.

USGS-FRESC scientists are helping the FWS design a large-scale survey of shorebirds on the North Slope of Alaska. The project, identified as the top priority of the Alaska Shorebird Working Group in 1997, will provide statistically rigorous maps of abundance and estimates of total shorebird population size in the National Petroleum Reserve-Alaska (NPPRA). New statistical and GIS methods have been developed and surveys carried out during each of the past two years. Estimates of shorebird abundance and population size have been completed for the eastern portion of the NPPRA. The project is expected to continue for 3–4 more years. The results will be used by the FWS in commenting on oil exploration activities and in contributing to the emerging National Shorebird Conservation Plan.

USGS biologists are conducting a six-year study of the habitat preferences, nesting and brood-rearing success, and parental feeding behavior of three species of loons that breed on the North Slope of Alaska. The study, designed in conjunction with the FWS, addresses issues and species of management concern. Of particular concern is the yellow-billed loon, which has a small breeding population and is concentrated in a small number of sites on the North Slope. The red-throated loon and Pacific loon are of concern because of population declines reported in some parts of Alaska. Most data are collected on the Colville River Delta, although aerial surveys for yellow-billed loons are flown throughout the NPPRA. Both are areas of management concern due to impending development by the oil industry. FY 00 will be the last year of data collection. Results show a clear difference among species in habitat use, and those differences can be related to differences in parental feeding behavior and other aspects of the species' natural history. Data on nesting and brood-rearing success indicate large

annual variation; preliminary analyses suggest that the variation can be explained, in part, by the timing of spring snowmelt. Analyses of yellow-billed loon habitat use throughout the NPRA will incorporate lake depth (interpreted from satellite imagery), landcover type (interpreted from a landcover map prepared by Ducks Unlimited), and various geographic metrics such as distance from the coast and nearest river channel.

Marine Mammals

The Department of the Interior has trust responsibility for managing three species of marine mammals: polar bears, Pacific walrus, and sea otters. Polar bears and Pacific walrus are apical carnivores in Arctic regions. The USGS has responsibility for conducting research to satisfy FWS information needs for these two species. The U.S. shares both species with Russia, and polar bears are also shared with Canada. The international nature of the populations requires the U.S. to coordinate research programs with both Russia and Canada. The focus of current research relates to international actions necessary to conserve shared populations. Both species are subject to legal harvests by Alaska Natives, and research seeks to develop methods for defining and monitoring populations to establish sustainable population goals. Resource development in the Arctic habitats and their potential impacts on populations of polar bears and Pacific walrus are also topics of research interest.

The USGS-ABSC research program on the Pacific walrus is focused on movement patterns, feeding behavior, and more recently, estimates of walrus abundance. Efforts over the last five years have focused on adult male populations summering in Bristol Bay. It is anticipated that research efforts will be extended to the female segment of the population in ice habitats in the near future.

Walrus in Bristol Bay have been counted daily during the summer months at Round Island and Cape Pierce by FWS and the Alaska Department of Fish and Game since the early 1980s. Initial efforts at modeling these data to determine an appropriate estimator were completed recently. Simulations suggest that an index derived from mean annual counts indicates trends better than a simple parametric-model-based index or the currently used index based on maximum annual counts. A more detailed analysis of abundance trends and recommendations for future monitoring designs are forthcoming. Although these data are useful for monitoring male walrus occupation in

Bristol Bay during summer, it is unknown whether the trends in Bristol Bay reflect trends in the overall population, because little is known about the interannual movement patterns of male walrus between haulouts in Russia and the U.S. and about the relationships between the status of male summering populations and the status of the overall population. It is unlikely that these patterns and relationships will be known in the near future, so current monitoring efforts should be viewed as a means of detecting interannual changes in the occupation of the main haulouts in the Bristol Bay region only.

Over the past five years, transmitters of various designs (both satellite and VHF) have been deployed on more than 50 male walrus in Bristol Bay. In addition, time-depth recorders (TDRs) were deployed and recovered from five animals in 1997. These efforts were aimed at investigating movement patterns, site fidelity, and diving behavior of walrus in the Bristol Bay area with the anticipation that telemetry studies will be extended to female walrus occupying ice habitats. Telemetry will be a necessary component of population surveys and disturbance studies. During this work, animals were tracked for periods of usually several months. Transmitter failures precluded tracking for longer periods. However, beginning in 1998, two animals were tracked for over a year. TDR data have been used to estimate the proportion of time spent in the water for several male walrus. Although TDR data have provided valuable information on the dive behavior of male walrus in Bristol Bay, the ability to recover similar devices from female walrus in ice habitats will be much more challenging.

Chemical immobilization of walrus is necessary to deploy telemetry devices and collect biological samples from live animals. Past methods of immobilizing walrus have not been entirely successful and continue to be a significant impediment to effective research on this species. Efforts will be continued to improve these methods, but progress is slow because of a lack of understanding of marine mammal pharmacology, particularly in walrus.

USGS-ABSC scientists continued to analyze movement data derived from satellite telemetry of adult female polar bears. During the past fiscal year, a manuscript describing the general movement patterns of polar bears in the northern Alaska Beaufort Sea region was submitted for publication in the *Canadian Journal of Zoology*. Analyses focused on the bears of northwestern Alaska and

adjacent Russia will begin in the coming year. Also this year USGS biologists and private sector collaborators developed a new approach to using satellite telemetry technology for describing movement patterns of adult female polar bears.

Using clustering algorithms to make objective decisions about groupings of telemetry observations has shown that there are actually four relatively discrete populations of polar bears adjacent to Alaska. Further, using two-dimensional kernel estimators, which were derived from the actual distributions of telemetry observations, this analysis has allowed researchers to determine the probabilities, on a monthly basis, of polar bears occurring at any point in the Chukchi and Beaufort Seas. The kernel analyses can also be used to calculate relative probabilities that any bear encountered derived from each of the four populations. This analysis formed the basis of a report prepared at the request of and presented to the Joint Commissioners of the International Users Agreement between Native people of northwestern Canada (Inuvialuit) and those of northern Alaska (Inupiat). In addition to the report to the Inuvialuit and Inupiat, a manuscript describing this procedure has been submitted for publication in the journal *Arctic*. Two additional manuscripts emphasizing different aspects of the method are also in preparation.

The ability to determine probabilistic densities of polar bears at all locations also made it possible to model the effects of hypothetical oil spills in the Arctic Ocean. USGS biologists worked with oil spill experts from BP Exploration Alaska, Inc., and other private sector experts to perform the first analysis of the possible effects of hypothetical oil spill scenarios in the Beaufort Sea. This analysis, which consumed nearly half of the fiscal year, culminated in a draft report submitted to the FWS. That report became the foundation for incidental take regulations covering the period beginning in January 2000. This modeling effort is in its infancy, and USGS biologists and their private sector partners are continuing to refine the assessments of the oil–bear interface.

A pilot study to determine if subcutaneously implanted satellite transmitters could be used to monitor the movements of adult male polar bears was initiated in the spring of 1996. Detailed movement data were collected for seven adult males during the spring and summer months. Preliminary data analyses indicated that adult males tended to be more sedentary than adult females during the period. Technical difficulties, apparently

antenna failure, caused premature failure of the satellite transmitters before animals could be recaptured the following spring. Detailed analyses of movements of these implanted males will be completed this year. Because of the invasive nature of this procedure and the inability to solve the antenna breakage problem, however, future efforts will seek other solutions to the problems in radio-tracking male polar bears.

USGS-ABSC research continues to study the occurrence patterns of maternal denning in Alaska. Ongoing research seeks to characterize denning habitats and test whether state-of-the-art thermal detection devices can allow dens to be located before human activities occur. A workshop is scheduled for 2001 to assemble potential users of infrared scanning as a management tool. If the conclusion of the workshop is that dens can predictably be located with infrared scans, then these scans will likely become an integral part of all land-use plans in regions where polar bear denning occurs.

A final report describing a research effort to map preferred denning habitats along Alaska's North Slope is being drafted. This report will allow the habitat types that account for over 70% of maternal dens found in the past two decades to be identified. Once identified and mapped, locations of these habitats will be incorporated into all future land management plans for polar bear habitats.

Polar bears continue to concentrate on land in the central Beaufort Sea region in late summer and autumn. In 1997, 1998, and 1999, 50 or more polar bears remained on the beach each year when the sea ice suddenly retreated north in August. The central Beaufort Sea is the home of the most productive oilfields in North America, and several stranded bears ended up hanging around oilfield facilities, where they posed a constant threat to the safety of oilfield workers. As oil exploration and development and other human activities expand to the east and west of the present development centers, biologists expect conflicts between polar bears and humans to be more frequent. Similarly 20–30 of those trapped bears spent the late summer and fall near the coastal village of Kaktovik, where they became accustomed to feeding on the scraps left by subsistence whaling activities, and they learned that humans need not be feared.

To properly manage human–bear interactions, we must have better knowledge of polar bear foraging strategies and the ecological importance of near-shore habitats. In response to that need,

USGS biologists plan to initiate research to answer questions such as:

- When and why can polar bears be expected to concentrate in near-shore areas where their opportunity to conflict with humans is greatest?
- What limiting factors at sea may be encouraging larger numbers of bears to remain on land for longer periods than in the past?
- What is the importance of land-based foods such as beach-cast marine mammals and human waste relative to ringed seals, which are thought to be the main component of their diet?

Answers to those and other questions will help assure that humans and polar bears can continue to co-exist in Alaska's Arctic. Consultations with the FWS and user groups superseded investigations of bears on land in the past year.

Biometrics

Ongoing biometric research by USGS-ABSC was continued in order to develop and assess statistical techniques for increasing the accuracy, precision, and scope of inferences and the cost-effectiveness of studies of Arctic wildlife. A maximum likelihood technique for estimating survival rates from age structure data was developed and used to estimate survival rates of sea otters based on carcasses recovered in Prince William Sound, Alaska. The new technique allowed detection of age-related patterns in survival rates and relaxed the previously required assumption of a stable population structure. Nonlinear regression and Bayesian techniques were used to develop models for counts of walrus at haul-out sites in Bristol

Bay and brown bears at salmon streams on Kodiak Island, Alaska. These models are being used to evaluate potential monitoring designs and to provide a basis for developing more efficient estimators of population trends.

Energy Studies in Alaska

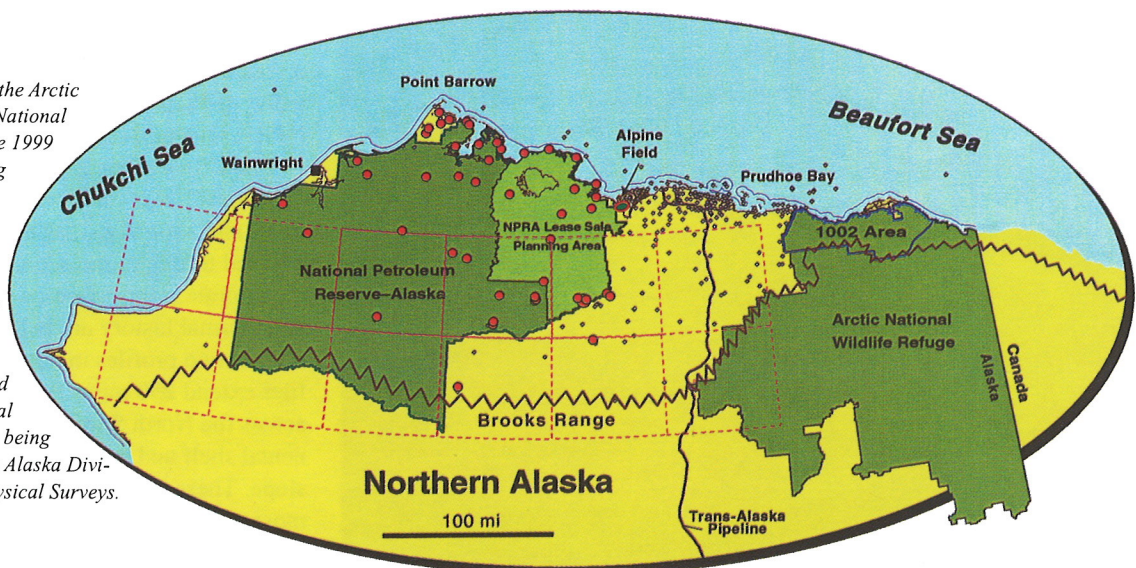
The USGS Energy Resources Program conducts geologic studies in Alaska to improve estimates of undiscovered energy resources. The energy resources of this region are important to the Nation's energy supply, as well as to remote Alaskan communities, and are a major consideration in land management decisions regarding Federal lands in Alaska.

Arctic National Wildlife Refuge Resource Assessment

The USGS released estimates of the volume of undiscovered oil and gas resources of the northern part (1002 Area) of the Arctic National Wildlife Refuge (ANWR) in 1998; supporting geologic analyses were released in April 1999 on CD-ROM as USGS Open-File Report 98-34: *Oil and Gas Resource Potential of the Arctic National Wildlife Refuge 1002 Area, Alaska*. This two-CD set includes results and complete documentation of the assessment, with 33 reports, 10 play descriptions, 7 data appendices, and an image gallery. The assessment reports significantly greater oil resource potential for this area than most previous assessments and is the most comprehensive USGS assessment of the area to date.

The report contains detailed analyses of petroleum systems, sequence stratigraphic interpreta-

Locations of the 1002 Area of the Arctic National Wildlife Refuge, the National Petroleum Reserve-Alaska, the 1999 oil and gas lease-sale planning area, the recently discovered Alpine oilfield, the Prudhoe Bay oilfield complex, and the Trans-Alaska Pipeline System. The red dots indicate the locations of cores displayed at the USGS Core Workshop (March 1999), and the rectangular grid marks the area for which digital geologic quadrangle maps are being compiled by the USGS and the Alaska Division of Geological and Geophysical Surveys.



tions, balanced structural cross sections, aeromagnetic and gravity surveys, and fluid-flow modeling. All available seismic data in the area, as well as from the adjacent offshore, were reprocessed and re-analyzed. The enhanced view of structure and stratigraphy provided by the reprocessed seismic data was critical to this assessment and identified previously unrecognized potential stratigraphic and structural traps for petroleum under the refuge. Additionally, the assessment reports economically recoverable resources using updated deposit simulation methods coupled with economic analyses.

National Petroleum Reserve-Alaska

The USGS is conducting a comprehensive study of the energy resource framework and an assessment of undiscovered oil and gas resources of the NPRA region. The 1999 ANWR assessment provides a baseline for this study, which will have two parts. The first part is a multidisciplinary basin analysis, which includes sequence stratigraphy; fluid-flow modeling; and petroleum system, geochemical, structural, and geophysical analyses. These studies will provide the scientific basis for the resource assessment. The second part of the study is the compilation and rescue of existing geologic and geophysical data generated during previous government studies of this region.

Basin Analysis. The North Slope of Alaska provides a unique opportunity for field examination of rock units, which, in the subsurface, contain the largest petroleum accumulations in the nation and

have significant potential for undiscovered oil and gas. Using seismic images to show where specific rock strata come to the surface, USGS scientists have examined the rocks in the field to test their interpretations of the seismic data and verify their geologic models for hydrocarbon generation sources, migration pathways, trapping mechanisms, reservoir quality, and timing.

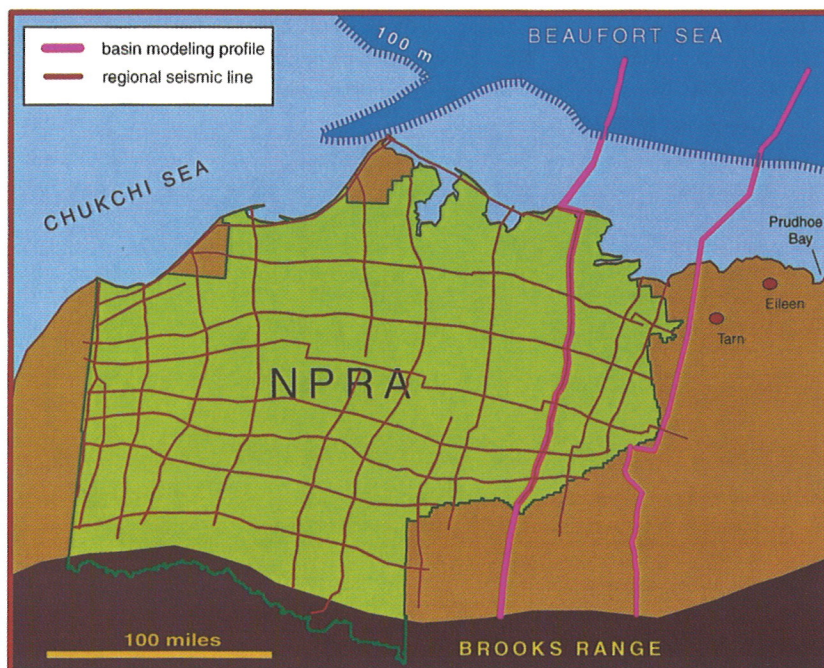
Current field studies in the eastern NPRA focus on analyses of sequence stratigraphy, structural style, aeromagnetic anomalies, and hydrocarbon geochemistry of potential petroleum systems. Especially exciting is the discovery and study of oil-bearing sandstones, now exposed at the surface, that have been interpreted as an exhumed oil accumulation, perhaps originally holding more than one billion barrels of oil. This sandstone reservoir is interpreted as a Cretaceous low-stand turbidite fan deposit. The discovery of this surface outcrop is truly significant for our understanding of the petroleum potential of the NPRA because it confirms the occurrence of good reservoir quality in turbidite sandstones and indicates oil accumulation in a stratigraphic trap, perhaps as large as 12 miles across, containing oil from a Triassic shale source rock.

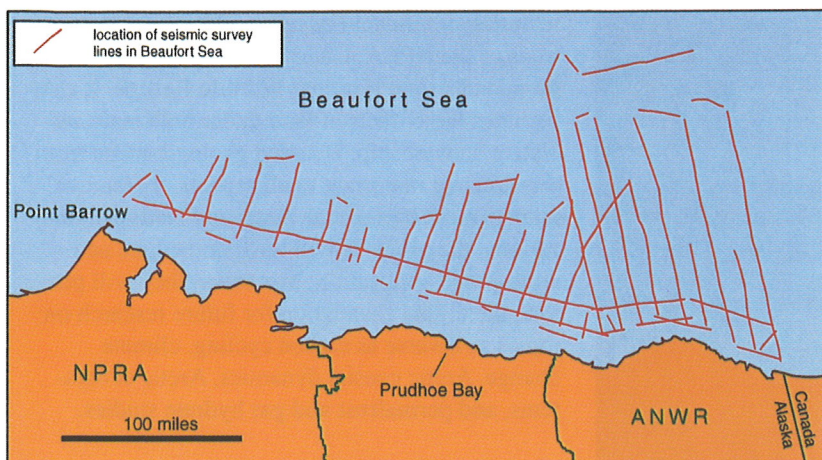
Sequence stratigraphic interpretations based on seismic imaging, wire-line logs, and core analyses have documented trap and reservoir characteristics in the Alpine oilfield (429 million barrels of oil recoverable), the discovery of which led to the recent NPRA oil and gas lease sale by the Department of the Interior. The Alpine Field oil is trapped by the northward truncation of incised valley-fill sands in the Jurassic Kingak Shale that occurs beneath the regional Lower Cretaceous unconformity. The northern truncation limit of the reservoir interval has been mapped westward across northeastern NPRA, and several potential valley-fill sequences have been identified on NPRA seismic data.

Fluid-flow modeling attempts to trace the flow of various fluids (meteoric and pore water, as well as oil and natural gas) as the sedimentary basin evolved through time. Computer models that incorporate information on rock properties, ages, and thermal history are being used to analyze fluid flow in two profiles in northern Alaska. These profiles extend 250 miles from the Brooks Range across the North Slope to the Beaufort Sea continental shelf and partway down the continental slope. These profiles are constrained throughout most of their extent by seismic data.

USGS scientists are currently conducting petro-

Locations of the network of USGS reprocessed seismic lines in the NPRA that are being prepared for open-file release later this year, the two regional profiles being used in basin modeling studies, and the Eileen and Tarn gas hydrate accumulations that are the focus of USGS and DOE research activity on hydrate occurrence and production.





Locations of USGS seismic survey lines in the Beaufort Sea. Data from these lines have been reprocessed and will be published as an open-file report later this year.

leum geochemical analyses of samples collected in the field and from drill cores and comparing the compositions with published data, commercial geochemical databases, and previous USGS analyses to define the petroleum systems in and adjacent to the NPRA. Defining petroleum systems requires understanding the source of the petroleum and the structural and stratigraphic framework within which it migrated and accumulated. Geochemical studies of oils, gases, seeps, stained reservoir rocks, and source beds provide the key links relating the fundamental elements of source rock, migration pathway, and trap of the petroleum system to the resource analysis. These analyses also will be used to characterize background levels of organic compounds in surface occurrences of petroleum to define naturally occurring levels of potentially hazardous compounds in the Alaskan Arctic ecosystem. Within the last year the USGS released two Alaska-wide geochemical data sets in CD-ROM format. One is a compilation of more than 10,000 analyses of thermal maturity measurements from wells and surface samples, *Thermal Maturity of Sedimentary Rocks in Alaska: Digital Resources*, USGS Digital Data Series DDS-54. The other release includes the entire USGS geochemical data set for Alaska, *Organic Geochemistry Data of Alaska*, USGS Digital Data Series DDS-59.

The USGS is developing a digital three-dimensional framework for the entire sedimentary basin to better understand the structural and stratigraphic framework of the NPRA region. A series of structure contour maps of several primary stratigraphic horizons are being generated for the relatively undeformed foreland part of the basin. In the fold and thrust belt, the research objective is to document structural styles, structural geometry, and timing of deformation. Balanced structural

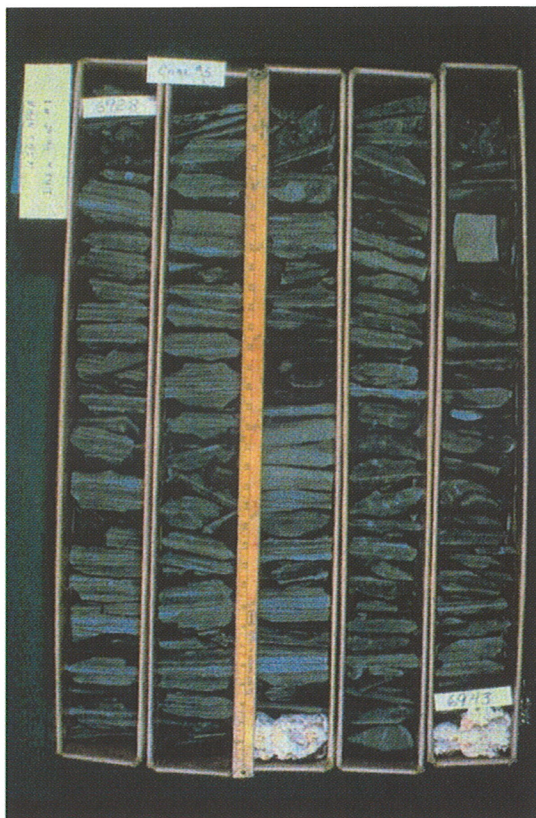
cross sections are planned using seismic data and field studies, and the timing of structural development is being calibrated using new and existing apatite fission-track analyses.

The USGS has reprocessed 84 seismic line segments from the NPRA and the Beaufort Sea using migration and depth conversion techniques and has combined them into a regional network consisting of 24 lines, totaling nearly 3500 line-miles. These reprocessed seismic data sets are being prepared for open-file release in CD-ROM format later this year. Additionally, the USGS has generated synthetic seismograms for most of the NPRA wells to facilitate matching seismic reflectors with stratigraphic boundaries, age determinations, occurrences of oil and gas, measurements of porosity and permeability, and identification of source rocks derived from the drilling. These synthetic seismograms provide critical ground truth for the seismic records.

The USGS research effort in northern Alaska has been enhanced by the acquisition of supplemental seismic data from the petroleum industry. BP-Amoco, Chevron, Shell, and Texaco have generously provided seismic data collected in areas adjacent to the NPRA that facilitate direct correlation between onshore and offshore areas and provide regional context. The Arctic Slope Regional Corporation facilitated access to industry data from the Brooks Range foothills southeast of the NPRA that provide new views of subsurface structure and stratigraphy in the area of recent USGS fieldwork.

Data Access and Data Rescue. The USGS held a Core Workshop at the USGS Core Research Center in Denver, Colorado, in March 1999, attracting more than 45 participants from industry and state and Federal agencies. Cores from over 40 NPRA wells were on display and available for examination and sampling. This workshop was co-sponsored by the Petroleum Technology Transfer Council and was held in support of the Department of the Interior's NPRA Oil and Gas Lease Sale No. 991, held in May 1999. A single CD-ROM (OFR 99-015), produced as a part of the workshop, includes data and core photographs of 11 of the NPRA wells. A second CD-ROM with similar information for 14 additional wells is in production and will be released later this year.

The USGS is cataloging and archiving more than 14,000 line-miles of seismic data, well log data, and well core holdings from the NPRA to preserve those data and make them readily avail-



Core from the NPRA
Drew Point Test Well No.
1, interval 6928 to 6943.

able to USGS scientists and the public. These seismic data were recorded on nine-track magnetic tapes that are currently deteriorating, the well log data were recorded on Mylar that is now deteriorating, and the well cores are in aging core storage boxes. Millions of dollars were spent acquiring these data and samples; this effort will ensure that seismic and well log data will be preserved on CD-ROM media using industry-standard formats and will be stable under standard office conditions. Further, data in digital format can be served over the Internet from a properly configured web server, allowing simultaneous access to multiple users. The well cores will be incorporated into the Core Research Center, located at the Denver Federal Center, where they will be inventoried, slabbled, boxed, photographed, and made available for viewing.

The USGS and the Alaska Division of Geological and Geophysical Surveys (DGGs) are digitizing existing geologic maps of the northern part of the Brooks Range and foothills, extending from the coast of the Chukchi Sea eastward to the Canadian border. This collaborative effort will result in a seamless digital synthesis of geologic map data collected independently over several decades by scientists of the USGS and DGGs. The map area

includes significant Federal lands, including portions of the NPRA, Gates of the Arctic National Park, and Arctic National Wildlife Refuge. It also includes large tracts of land under both state and Native stewardship. Detailed geologic maps from this area are important to all aspects of resource management by Federal, state, and Native organizations; the products will have immediate and widespread application. Moreover, they will provide the digital foundation for future research on topics as diverse as carbon cycling, climate change, Arctic coastal dynamics, Arctic ecosystems, and permafrost and gas hydrate studies.

Other Regions of Alaska

Assessment of Coalbed Methane for Rural Alaska. A cooperative project between the USGS and the State of Alaska is assessing coalbed methane as a potential energy resource for three remote Alaskan communities: Wainwright, Chignik, and Fort Yukon. Access to this relatively inexpensive and clean energy source could reduce Native villages' current dependence on diesel generators for electricity and foster local industrial development in these communities. Gas resource assessment requires computation of net coal tonnage, measurement of gas content by canister-desorption of coal core, measurement of coal permeability and gas producibility prospects by well pump testing, and evaluation of the environmental impact of disposing of water produced with the coal bed gas. The USGS and the DGGs plan to drill two holes at each site to sample the methane-generating coals and to measure the in-place gas they contain.

Drilling and scientific results will determine the course and speed of development of Alaskan coalbed gas exploration efforts for the near future. The existence of large coalbed gas resources would undoubtedly influence the economic viability and routing of new gas pipelines proposed for Alaska. Additionally, the results from this project will strongly influence Native corporation planning by determining the feasibility of replacing diesel generators with coalbed gas fuel supplies, either for direct home use or for electricity generation. Finally, land management decisions must take into account the presence of potentially exploitable coalbed gas or coal resources.

Natural Gas Hydrates. The USGS and the Department of Energy, in cooperation with private industry, are assessing the occurrence, recoverability, production characteristics, and resource potential of permafrost-associated natural gas hydrates and associated free-gas accumulations in the Prud-

hoe Bay–Kuparuk River area on the North Slope. Two known gas-hydrate/free-gas accumulations, Eileen and Tarn, are being evaluated. The initial phase will identify and map the gas hydrate distribution of the Eileen and Tarn accumulations, characterize their reservoir properties, and model their production characteristics. In the second phase the USGS will propose drilling a production well to evaluate production characteristics of the gas hydrate in one of the areas.

Petroleum Resources of Central Alaska. Much new subsurface data from central Alaska has become available since the energy resources of Alaska were last assessed by the USGS in 1995. The USGS is now collecting and evaluating this new information in preparation for an assessment of central Alaska, tentatively scheduled for the fall of 2002.

Central Alaska is a remote and sparsely populated region that includes mountainous areas underlain by rocks of Precambrian to Mesozoic age and lowlands underlain by nonmarine deposits of Cenozoic age. The region occupies an area of about 300,000 square miles and is bounded on the north by the Brooks Range, on the south by the Alaska Range, on the east by the Canadian border, and on the west by the Bering Sea. Major landowners in this region include the Federal government, the State of Alaska, and Native corporations and villages. Currently there is no petroleum production in central Alaska, and only about a dozen exploratory wells have been drilled. Nevertheless, there are some intriguing possibilities for petroleum discoveries that may provide energy for remote Alaskan communities that must import their energy needs at considerable expense. The 1995 USGS assessment concluded that the most attractive petroleum exploration objectives are hypothetical accumulations of natural gas in mildly deformed, coal-bearing strata of Cenozoic age. The Cenozoic basins are almost entirely unexplored, despite some important geologic similarities to the petroleum-rich Cook Inlet basin. In addition, unmetamorphosed Paleozoic and Mesozoic rocks in some areas may also have potential for oil and gas. Additional studies are underway to identify those areas with the greatest energy resource potential.

Volcano Studies

Eruption Response in Alaska

On April 17, 1999, following more than three months of precursory seismic and thermal activity,

Shishaldin volcano in the eastern Aleutian Islands began a brief but vigorous episode of explosive eruptions that sent volcanic ash plumes to over 50,000 feet above sea level intermittently for about one month. This explosive activity from one of Alaska's most active volcanoes (28 eruptions since 1774) was successfully monitored by the Alaska Volcano Observatory (AVO) using a newly installed real-time seismic network and improved techniques for rapidly examining meteorological satellite imagery. Volcanic ash from Shishaldin posed a threat to jet aircraft in the heavily traveled North Pacific air routes, but because of information provided by the USGS to the National Weather Service and the Federal Aviation Administration, aircraft were rerouted around potentially hazardous ash clouds. Volcanic ash erupted into the high atmosphere is highly hazardous to modern high-performance jet aircraft because it erodes compressor blades, melts onto critical engine parts, and causes loss of engine power. Hazardous concentrations of volcanic ash can drift at air traffic altitudes for hundreds to thousands of miles downwind following a volcanic eruption. Worldwide, approximately 100 jet aircraft in the last 18 years have accidentally entered volcanic ash clouds, putting many thousands of passengers at risk.

Monitoring Improvements

AVO established a real-time seismic network at Great Sitkin and Kanaga volcanoes on Adak Island, proving that it is possible to work in the remote western Aleutians and paving the way for eventual monitoring of all of Alaska's potentially active volcanoes. Concurrent geologic field studies established that volcanoes on Adak have produced larger, more explosive eruptions than previously realized.

International Cooperation

AVO also continued its participation in the Kamchatka Volcanic Event Response Team. KVERT was set up in 1993 so that information about Russian volcanic activity that might affect U.S.-controlled airspace could be quickly reported by volcanologists in Kamchatka to AVO for dissemination to the aviation community through the much more reliable communications pathways of AVO. KVERT typically reports on three eruptions per year, giving warnings of restless volcanoes prior to eruption so that satellite images can be scrutinized efficiently.

Department of Defense

The Department of Defense continues to operate and maintain facilities in the Arctic. To support these operations, the DoD conducts a broad-based Arctic research program. The Arctic program is conducted by all three services and extends from the ocean floor to the magnetosphere.

Although overall funding for Arctic research within the Department of Defense (DoD) has decreased since the end of the Cold War, the Department still has active interest in the Arctic. Specific DoD objectives for Arctic research include (but are not limited to):

- Understanding the interaction of the Arctic environment with military systems, including environmental remediation;
- Understanding energy exchange and atmosphere-ocean interaction dynamics, and the impact of the energy exchange process on global circulation;
- Understanding the structure and physics of the middle and upper atmosphere; and
- Understanding the biology and biophysics for sustaining health and optimized human performance in cold environments.

Although the DoD program is reviewed as a whole during the biennial Technology Area Review and Assessment (TARA), the three military services actually conduct research to meet their specific objectives. Consequently each service's major accomplishments will be reported separately.

Air Force

The Air Force conducts research in upper atmospheric and ionospheric physics, primarily by the Air Force Research Laboratory, Space Vehicles Directorate, Battlespace Environment Division, and the Air Force Office of Scientific Research (AFOSR). These offices coordinate their effort to understand the effects of space weather. This research is primarily conducted in the Arctic "polar cap." The goal of the research is to understand the basic physical and chemical processes and dynamics of the polar ionosphere, with the main objectives to specify, predict, and mitigate disruptions to DoD communications, navigation,

	Funding (thousands)	
	FY 98	FY 99
Arctic Engineering	2,515	1,819
Permafrost/Frozen Ground	523	316
Snow and Ice Hydrology	2,056	1,513
Oceanography	3,836	3,439
Lower Atmosphere	110	81
High-Freq Active Auroral Program	5,000	12,500
Medical and Human Engineering	1,210	993
Total	15,250	20,661

and surveillance systems. To actively pursue and maintain a well-rounded program, the research effort combines experimental measurements to determine specific physical processes, first-principles numerical modeling efforts, and a strong connection to ongoing theoretical research.

The Air Force maintains a wide range of ground-based radio, radar, and optical diagnostics to perform the needed measurements. These are conducted from Nord, Qaanaaq, Thule, Sondrestrom, and Narssarssuaq, Greenland (in cooperation with the Danish Meteorological Institute); Ny Alesund, Longyearbyen (Spitsbergen), and Tromso, Norway (in cooperation with the University of Oslo, Norway); and Goose Bay, Labrador (Canada). The ground-based measurements are often complemented by measurements from instruments on sounding rockets and polar-orbiting satellites. From this understanding, numerical models to specify and ultimately predict the behavior of this complex region are being developed. This research and model development are needed for real-time support to DoD communications, navigation, and surveillance systems.

Polar Cap Patch Studies in Greenland

Major experimental campaigns were conducted at Sondrestrom, Qaanaaq, and Thule, Greenland, in January and September 1999 to investigate the formation and evolution of polar cap patches and to

quantify the effects of these traveling plasma density enhancements on DoD systems. By operating sites near the auroral zone (Sondrestrom) and in the central polar cap (Qaanaaq and Thule), we are able to observe both the initial formation of these structures near the dayside auroral zone and their subsequent motion and evolution inside the polar cap. Both campaigns included optical, radar, radio frequency, and GPS (global positioning system) measurements. The January campaign was conducted in cooperation with NSF, while the September observations were coordinated with the global space weather campaign called Scientific Committee for Solar-Terrestrial Physics (SCOSTEP), Solar-Terrestrial Physics—Results, Applications, and Modeling Phase (S-RAMP).

High-Frequency Active Auroral Research Program

Under the High-Frequency Active Auroral Research Program (HAARP), jointly managed by the Air Force Research Laboratory and the Office of Naval Research, the new Ionospheric Research Observatory is under construction in Gakona, Alaska. The facility includes a high-power, high-frequency (HF) transmitting system and a suite of radio and optical diagnostic instruments. The present HF transmitting system includes a phased-array antenna, consisting of 48 elements, with crossed-dipole antennas driven individually by 10-kW transmitters, resulting in a maximum radiated power of 960 kW. Plans call for the system to evolve to 180 antenna elements and a radiated power of 3.6 MW. The system has especially flexible operating characteristics, including a wide frequency band (from 2.8 to 10 MHz); simultaneous operation of the array at two different frequencies; rapid (10 microseconds) scanning over a 30° cone around the zenith; arbitrary linear or circular wave polarization; and flexible beam, waveform, and radiation pattern control.

The suite of radio and optical diagnostic instruments available to the facility is extensive and diverse and plays an important role in monitoring the local geophysical and electromagnetic background. These instruments are essential during active experiments employing the HF transmitter, providing knowledge of conditions in the ionosphere and in space prior to, during, and after its operation. Data collected from the instruments are processed and displayed at the site and can be provided in real time to other researchers via the Internet. Many of the instruments are important diagnostic tools in their own right, having the

capability to observe solar-related disturbances in space and in the ionosphere, as well as their subsequent effects on radiowave propagation. The facility has been available for ionosphere and radio-science experimental research programs, at the 960-kW power level, since March 1999. Earlier experiments included transmissions to the NASA's Wind and Cassini satellites to study radiowave refractive properties of the ionosphere over great distances in space.

Army

The U.S. Army Research Office (ARO), located in Research Triangle Park, North Carolina, has a mission to support basic research that leads to an increase in fundamental knowledge that may have short- or long-range impacts on Army capabilities. ARO is involved in Arctic research and development largely through the sponsorship of extramural basic research directed toward the topics of environmental quality and the properties and processes of snow, ice, and frozen ground.

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), with offices in Hanover, New Hampshire, and Fairbanks and Anchorage, Alaska, is the center of engineering expertise for cold regions and winter conditions for the Corps of Engineers, the Army, and the DoD. CRREL is the only Federal laboratory with a primary focus on Arctic and cold regions problems and is internationally recognized as a center of excellence in Arctic research. While the CRREL research program is designed to be responsive to the needs of the military, a majority of the research and engineering results also benefit the civilian sector. Hence, a significant effort is made to assure that the transfer of technological innovations is broad-based. In the same vein, CRREL research projects are often done in collaboration with other Federal agencies, academic institutions, and private companies.

The U.S. Army Research Institute of Environmental Medicine (USARIEM), located in Natick, Massachusetts, conducts basic and applied biological and biophysical research to elucidate novel approaches for sustaining health and optimizing performance of humans exposed to cold environments. USARIEM research findings provide the biomedical basis for Army doctrine to minimize adverse effects of cold on individual military personnel, crews, and troop populations deployed in cold climates, including Arctic regions. USARIEM employs multidisciplinary

teams of scientists using human, animal, tissue, cellular, and mathematical models to delineate pathophysiological mechanisms of cold injury, identify biomedical risk factors influencing susceptibility to cold injury, and provide physiological data for developing and validating mathematical models predicting human cold tolerance. Additionally USARIEM formulates and validates exposure guidelines and safety limits to prevent cold injury during military training, develops strategies to safely extend cold tolerance and work capabilities in cold climates, and provides biomedical support for cold-stress health hazard assessment and MANPRINT efforts of Army materiel and clothing developers. USARIEM research capabilities include state-of-the-art technology for collecting human thermoregulatory data in the laboratory and non-intrusive, ambulatory, real-time monitoring of warfighter physiological status during military operations in cold conditions.

Medical and Human Engineering

USARIEM maintains an active research program in the area of human physiological responses to cold. A current emphasis concerns the extent to which the normal shivering and circulatory responses to cold exposure become fatigued when these responses are sustained for long periods of cold exposure. One USARIEM study demonstrated that when human volunteers were exposed to cold and then rewarmed to normal body temperature several times over a single day, shivering declined and body temperature fell more during the second and third cold exposure of the day than during the first.

Another series of physiological studies at USARIEM documented that fatigue associated with prolonged physical exertion sustained for many days or weeks impairs the normal shivering and/or circulatory adjustments to cold exposure, perhaps by modulating the response to cold by the sympathetic branch of the autonomic nervous system. In contrast, a single, one-hour bout of aerobic exercise does not appear to degrade shivering during subsequent cold exposure, although the exercise-induced elevation in muscle blood flow that persists following exercise may accelerate body heat loss during cold exposure. USARIEM experiments also demonstrated that when women were exposed to cold during the luteal phase of their menstrual cycle, shivering and circulatory responses to cold were slower to develop and skin heat loss was greater than during the follicular phase.

USARIEM research has also addressed issues

related to the rewarming of hypothermia victims. One area of study concerns the blood coagulation disturbances, vascular collapse, and shock that occasionally develop when hypothermia victims are rewarmed. As a model for simulating responses during rewarming of accidental hypothermia victims, USARIEM studied the responses of patients at Stanford University Medical Center who were rendered hypothermic to 31–33°C for brain surgery and then rewarmed. The blood of 7 of 11 of these showed a rise in the bacterial poison lipopolysaccharide (LPS), which derives from the intestines and is known to cause many of the same symptoms as seen in rewarming from hypothermia. It appears that the processes of hypothermia and rewarming damage the gut wall, permitting LPS to leak out of the gut and enter the blood, where it exerts its toxic effects. It would be appropriate in hypothermia patients to consider means of preventing entry of the LPS into the blood, neutralizing it, and protecting the body from its effects. USARIEM researchers using an animal model also demonstrated that a new method for rapid rewarming in which warmed, oxygenated perfluorocarbon liquid was breathed, enabling approximately four times faster rewarming from deep hypothermia than breathing warmed air or oxygen, due in part to the greater thermal capacity of the liquid.

USARIEM research also supports development of new cold-weather protective clothing. Recent biophysical evaluations of prototype garment materials designed to improve cold protection of the U.S. Air Force S-1034 PPA flight suit worn during U2 high-altitude reconnaissance flights indicated that some of these new materials can improve thermal comfort of the flight suit. Prototype boot systems constructed using an exothermic phase-change material, which purportedly releases heat into the boot upon exposure to extreme cold, had previously been found to release inadequate heat for preventing non-freezing cold injury at very low temperatures. However, follow-on human studies, in which volunteers sat or walked in cold conditions (–12.3°C) wearing boots with the phase-change materials embedded, showed that the amount of heat released did contribute to higher toe skin temperatures, which may increase comfort, protection, and tolerance.

Environmental Site Characterization and Remediation

The CRREL research and engineering program reflects worldwide interest and concern over envi-

ronmental issues. There has been a significant increase in activities related to assessing the presence and extent of contaminants at sites currently and formerly held by the military and in developing techniques to remediate existing conditions and prevent future problems. Pervasive in all of these activities, and those described in the other program areas, is a component that considers the impact of climate variability.

During FY 98 and 99 a broad array of remediation technologies have been developed, responding to the need to carefully consider the specific physical characteristics of a site and the properties of the contaminant. Common to all of these efforts is the objective of developing technologies that are economically sound, are highly effective, and have a low environmental impact. For instance, CRREL has demonstrated that phytoremediation can be used to treat petroleum-contaminated soils in cold regions. Phytoremediation capitalizes on the interaction between natural plants and indigenous microbial communities. Secretions from the plant's root system stimulate the microbial communities to more rapidly degrade contaminants in the soil. This innovative technique is applicable to locations that lack significant infrastructure, and it has minimal equipment and energy requirements.

In another instance, remnant particles of white phosphorus have been shown to exist in munitions impact areas in wetlands. When ingested, the white phosphorus is lethal to waterfowl. If the area is drained using pumps and ditches, the contaminant is exposed to the air and volatilizes. Tests have consistently shown that an 85% decrease in contamination concentrations can be attained in four months using this technique.

A final example of recent accomplishments in the development of remediation techniques is the application of natural freezing methods to encapsulate wastes associated with landfills where there is a threat of contaminant migration from the site.

Closely related to establishing and testing new remediation techniques is the need to develop methods to detect the extent and characteristics of a contaminated region. CRREL has developed and applied a host of tools to address this issue, including ground-penetrating radar, DC resistivity soundings and profiling, groundwater flow probes, drilling and well logs, sonar subbottom profiling, and bedrock and sedimentary mapping. Results from this work have recently been used to establish hydrological contaminant pathways for either placement of monitoring wells or remediation pumping.

Arctic Engineering, Permafrost, and Frozen Ground

Rehabilitation and more efficient operation of the military infrastructure continues to be a central theme in the DoD. In FY 98 and 99 CRREL has applied its considerable experience and innovative technologies to assist in analyzing the heat and moisture exchange at exterior walls, windows, and doors of existing buildings. Thermal models of the building envelope are applied to locate areas of high heat loss and to determine economical and effective methods to alleviate identified problems. Results from infrared thermal analyses are being used to determine in-place condensation resistance factors for windows. The experiences gained in the study of existing buildings are being applied in the design of new structures.

Modified usage requirements and the concerns over the impact of a warming climate have motivated studies on the effects of thawing soils on the load-bearing capacity of roads and runways. Sub-surface measurement of soil temperature and moisture content and measurements of environmental conditions are coupled with soil strength tests to develop and improve models of changing soil conditions. These results can be applied to immediate design issues and can be used for establishing construction techniques for mitigating the effects of permafrost degradation.

CRREL continues to play an active role in the development of oil and gas reserves along Alaska's North Slope. Acknowledging the need to consider alternate energy sources, CRREL researchers are involved in DOE's effort to assess the feasibility of using methane hydrates as a form of energy. It appears there are vast reserves of methane, trapped underground in ice-like hydrate deposits. The capability has now been established at CRREL to form this material in the laboratory, providing a source of numerous test specimens for use in studying the mechanical properties of methane hydrates and methane-hydrate-rich soils. Understanding the mechanical properties of this substance is necessary for establishing safe and economical recovery methods.

CRREL also conducted fundamental studies in FY 98 and 99 on the cause and effect of permafrost degradation. A research site has been established in the Tanana Flats, 100 miles south of the Arctic Circle, in an area that is obviously experiencing extensive natural degradation. Ongoing investigations include the relationship of the degradation to ground and air thermal conditions, the physical characteristics of the ice component



CRREL permafrost degradation research site in the Tanana Flats, Alaska, where the impact of natural degradation on the ecosystem is pronounced.

in the permafrost, climate change, and soil and vegetation change.

Snow and Ice Hydrology

The ability to simulate the evolution of a snow cover is important for a wide variety of investigations. CRREL has been at the center of research on the processes that affect the distribution of Arctic snow covers on land and sea ice. Work is aimed at understanding how climate change effects on vegetation and snowfall could alter the Arctic tundra snow cover. For instance, changes in vegetation properties may impact the amount of blowing snow trapped in shrubs. Studies also consider associated ecosystem processes and conditions, including permafrost, hydrology, and winter

CRREL researchers sampling shrub vegetation at Ivotuk, 200 miles south of Barrow on the Alaska North Slope.



decomposition of soil organic material and associated release of greenhouse gases. Results from this work are also applicable to issues of winter trafficability and route selection. The development of tools for efficiently measuring snow depth distribution over wide areas has been a byproduct of this effort.

Oceanography

Navigation in ice-covered waters is a significant challenge to both surface and submarine vessels. During FY 98 and 99 CRREL was involved in a number of research programs aimed at improving the ability to predict ice conditions, including ice thickness and concentration. These include the development and validation of a new version of the Navy's Polar Ice Prediction System model using direct observations from field experiments and remote sensing tools. A new GIS (geographic information system) ice atlas is being developed for Cook Inlet, Alaska; it will include meteorological and ice conditions for the area over the past 20–25 years. CRREL is also involved in the ice trials of the U.S. Coast Guard's newest icebreaker, the USCGC *Healy*, scheduled for the spring of 2000. CRREL researchers will characterize the icebreaking capability of the ship, quantifying her performance in terms of transiting speeds through various thicknesses of level ice, backing and performance in thick ice and pressure ridges, and maneuvering capabilities in a range of ice conditions. Ice conditions will be characterized by measuring ice properties such as concentration, type, thickness, temperature, salinity, and density.

The distribution of the ice cover depends on energy exchange processes between the air, ice, and ocean. The NSF- and ONR-sponsored program SHEBA (Surface Heat Budget of the Arctic Ocean) was initiated to develop a better understanding of this complex interaction. This large, interdisciplinary research program had two primary goals: to determine the ice–ocean–atmosphere processes that control the ice–albedo and the cloud radiation feedback mechanisms, and to improve the treatment of the Arctic in general circulation models, used in studies of climate variability. CRREL researchers have played key roles in the SHEBA program. During the recently completed, year-long field program, CRREL led efforts that are critical to addressing both of the SHEBA goals. Detailed observations of ice albedo, ice mass balance, snow properties, and conditions in the atmospheric boundary layer were made throughout the field program. Early results

*The Canadian icebreaker
Des Groseilliers and the
research camp during the
SHEBA experiment, October
1997.*



indicate that there was a net thinning of the ice during the experiment, that there are five distinct phases in the seasonal evolution of the albedo, and that summertime clouds contribute to a net heating of the surface temperatures. These and other results will be used to develop a quantitative understanding of the processes that collectively make up the feedback mechanisms, including their spatial and temporal variability.

The issues of the role of the Arctic in climate variability and of improved navigability in ice-covered waters are closely related. Both depend on models of sea ice motion. Typically models of sea ice motion represent the ice cover as a continuum with variable thickness. CRREL has established a granular model of the Arctic ice pack that considers the interaction of individual ice floes. This model provides a much more detailed representation of the distribution of the ice cover. Recent model results show that the motion of the model pack produces leads that replicate those that appear in satellite imagery.

Navy

The Office of Naval Research's High Latitude Program investigates processes (physical, biological, chemical, and geological) active in all polar oceanic areas, with special emphasis given to

high-latitude marginal seas. The goals of the program are to improve the Navy's understanding of air-sea-ice exchange processes, mechanisms of cross-shelf transport, and the process of deep ocean convection, and to incorporate the improved dynamical understanding of these processes into new environmental models that can better support fleet activities in the next decade and beyond. These program goals are being addressed partially through participation in the SHEBA experiment and the ongoing ONR- and NSF-sponsored Science Submarine Cruise (SCICEX) program.

All ONR Ocean, Atmosphere and Space Department-funded programs receive an annual summary report from each principal investigator. These summaries document each task's objectives, accomplishments, and publications during the past year. In 1998, ONR began providing these annual summary reports as a CD-ROM with selected reports on the World Wide Web. These collections have provided an easy-to-use compendium of accomplishments. In the interim a few significant highlights are summarized below.

The Navy continues to fund substantial research into the dynamics of sea ice surfaces. Sea ice provides a superb platform for studying the upper ocean without the complicating effect of surface waves. The long-term goals are to understand the turbulent transfer of momentum, heat, and salt and



USS Hawkbill at the SCICEX ice camp.

other contaminants in naturally occurring boundary layers of the ocean and to apply this knowledge to understanding air-ice-ocean interaction in polar regions and the impact of this transfer on the large-scale coupled atmosphere-ocean dynamic system. This work also has direct application for modeling pollutant dispersal over the Arctic.

A major accomplishment came during the summer 1998 and 1999 SCICEX cruises. The SCICEX 1999 experiment aboard USS *Hawkbill* was an experiment with several firsts. Dr. Margo Edwards, from the University of Hawaii, the first woman scientist embarked on a SCICEX cruise, led the scientific party. The experiment involved an ice camp in the Arctic (roughly 170 nautical miles north of Barrow, Alaska), with its own scientific parties. It was the first SCICEX cruise to be visited by a distinguished group of VIPs, including the Secretary of the Navy, the Chief of Naval Operations, the head of the National Science Foundation, and a U.S. Senator (Robb, D-VA).

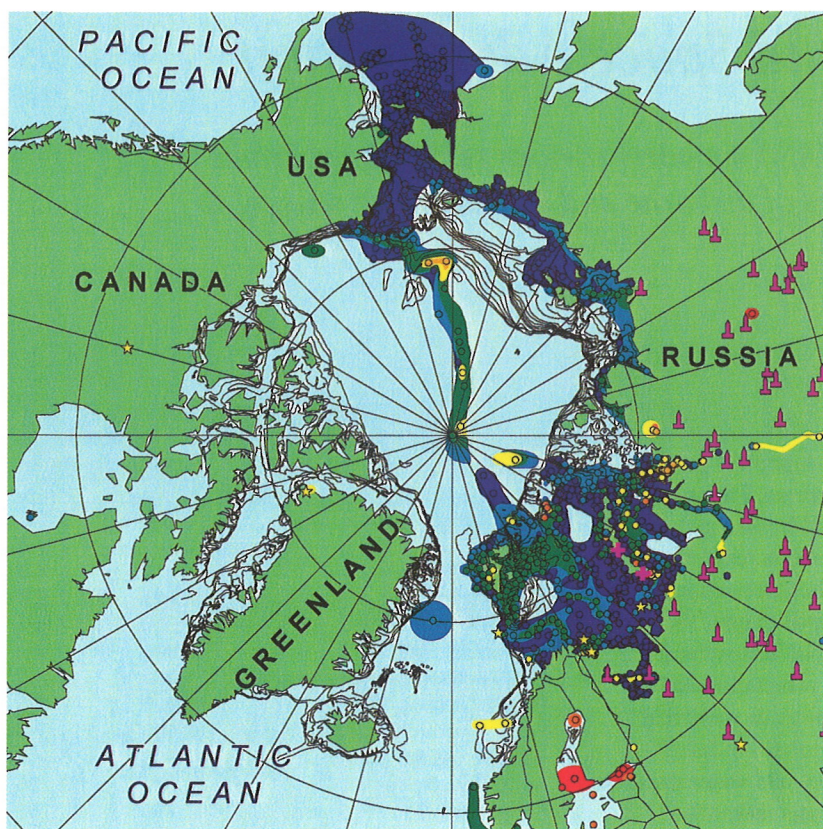
Although results are still in an early stage of analysis, the cruise surveyed the Chukchi Sea borderlands in unprecedented detail and found that some key topographic features of the Lomonosov Ridge were in significant error on existing charts. The high-resolution swath bathymetry was generated using the hull-mounted SCAMP (seafloor characterization and mapping pods) consisting of a SeaMARC-type sidescan sonar, a chirp subbottom profiler, and a data acquisition system.

The primary goal of this research was to improve the understanding of those processes in the upper Arctic Ocean that influence the heat balance and sustain the ice cover. This goal encompasses the upper halocline and includes mesoscale features, including their origins, prevalence, dynamics, and influence on heat transport. A secondary role of this program is to participate

in assessing the potential utility of submarines as research platforms. To meet these goals the Navy sponsored research into continuously measuring the vertical distribution of horizontal currents, temperature, and salinity in the upper Arctic Ocean from a submarine. These measurements were taken under the ice pack in some instances and provided a first-time characterization of the upper-ocean mesoscale (small-scale) features.

The Arctic Environmental Atlas

In September of 1999, the *Arctic Environmental Atlas*, supported by funding from the Office of Naval Research, the Naval Research Laboratory, and Hunter College, CUNY, was released to the public. This atlas of environmental information and the accompanying CD are intended to display graphically and make available to a wide audience the data and references to data compiled as a result of the Arctic Nuclear Waste Assessment Program (ANWAP). ANWAP was established in 1993 by the Office of Naval Research (ONR) to determine the level, transport, and fate of radioactivity in the Arctic derived from the practices of the former Soviet Union and to estimate the potential of the radioactivity to contaminate Alaska. Eighty-five principal investigators conducted a broad spectrum of projects, ranging from measurement and experimental programs investigating biogeochemical processes in the Arctic Ocean to computer-modeling studies examining the movement of water and ice. A data repository for work performed under ANWAP was established at the Naval Research Laboratory (NRL) as a geographic information system (GIS). The GIS was designed initially to address the radionuclide-contamination issue and to create a database of information collected from ANWAP expeditions in 1993, 1994, and 1995. Early in the GIS program the authors linked the U.S. data-gathering work and the Arctic Monitoring and Assessment Program (AMAP), headquartered in Oslo, Norway. NRL expanded its efforts to document the extent of additional contaminants, such as organochlorines and heavy metals. These data are included in this atlas and CD. The GIS organizes all data by latitude and longitude and enables the data to be analyzed and displayed accordingly. The atlas and CD contain more than 100 maps of the physical, chemical, or biological conditions in the Arctic and related regions generated from the GIS database; a general narrative on Arctic environmental conditions and contaminants; and an array of photographs taken largely by the authors. The CD also contains the actual data used to generate the maps.



^{137}Cs , Bq/kg, dw

0 to 5
5 to 10
10 to 20
20 to 50

50 to 100
100 to 1,000
1,000 to 10,000
10,000 to 825,000

Nuclear Explosions

and Accidents

+ Military Explosion
▲ Non-Military Explosion
★ Nuclear Accident

Sample map from the Arctic Environmental Atlas, showing cesium-137 in surface sediments, 1990–1997.

The Arctic Environmental Atlas, authored by Kathleen Crane and Jennifer Lee Gallasso, may be obtained from Liane Young, ONR-00PA, 800 N. Quincy St, Arlington, VA 22217-5660.

Significant data compilations also came from Russian researchers and institutions supported by collaborative U.S.–Russian scientific agreements. Nearly 7,000 core sites located around the Arctic were added to the sediment-property database. Of these, close to 3,000 were from Russian sources, while Norwegian (Norsk Polarinstitutt), German, Canadian, and U.S. data comprise the remainder of the database. Over 100,000 km of single-channel seismic data were digitized from already published and unclassified documents, providing the raw materials for new bathymetric maps of the Barents and Kara Seas.

This atlas represents more than 18,300 data points (exclusive of the bathymetry and large digitized data sets) from the NRL Arctic GIS, which was developed under ANWAP. The atlas includes the following data:

- Stations and ship tracks from expeditions funded by ANWAP from 1993 to 1995 in the Arctic seas;
- Atmospheric, riverine, and marine transport pathways to and within the Arctic;
- Digitized distribution and migration paths of important fish stocks, marine mammals, and birds;
- Distribution and concentration of radionuclides, strontium-90, and plutonium-239,240 in marine, lacustrine, and riverine surface-water sediments and in some biota in the Arctic and its neighboring regions;
- Distribution of known nuclear events that have occurred around the Arctic, and the locations and characteristics of known radionuclide dump sites in the Arctic, Atlantic, and Pacific Oceans;
- Distribution of known nuclear power plants, weapons factories, laboratory sites of plutonium and uranium production and enrichment, nuclear test sites, chemical weapon production and waste sites, and military sites in and around the Arctic;
- Digitized bathymetry of the Arctic Ocean and its neighboring seas;
- Compilations of surface-sediment grain size, clay mineralogy, and total organic carbon along most of the continental shelves of the Arctic;
- Atmospheric measurements of ozone and sulfate, nitrate, and nitrogen deposition in the Arctic;
- Temperature variations and permafrost distributions in the Arctic;
- Hydrocarbon distribution in the Arctic;
- Levels of certain organochlorine contaminants; and
- Levels of mercury, lead, cadmium, and arsenic.

National Aeronautics and Space Administration

As part of its Office of Earth Science, NASA supports various research programs in the Arctic that emphasize applications of airborne and space remote sensing to studies of the earth and space sciences.

NASA's Arctic research program is part of NASA's Earth Science Enterprise. The science questions that this program addresses include:

- How will stratospheric ozone respond to a reduction in the atmospheric abundances of ozone-destroying industrial chemicals?
- How does the chemistry of atmospheric constituents respond to and affect climate?
- Will polar ice sheets change in ways that would seriously affect global sea level?
- Can weather, precipitation, and water resources be related to global climate anomalies?
- Is climate currently varying in ways we can understand and predict?

The following activities form part of NASA's current Arctic research program:

- The Program for Arctic Regional Climate Assessment (PARCA), which was focused on Greenland during 1998-99 and has made considerable strides in obtaining the raw material for re-evaluating the mass balance of the Greenland ice sheet;
- Research in Alaska, with studies of glaciers reported here;
- The Arctic Ocean and adjacent seas, with developments in both observational and modeling techniques; and
- Arctic tropospheric and stratospheric chemistry.

Program for Arctic Regional Climate Assessment

The Program for Arctic Regional Climate Assessment (PARCA) is a NASA project that was formally initiated in 1995 by combining into one coordinated program various efforts, started in 1991, to assess whether airborne laser altimetry could be applied to measure ice sheet thickness changes. PARCA has the prime goal of measuring and understanding the mass balance of the Greenland ice sheet, with a view to assessing its present

	Funding (thousands)	
	FY 98	FY 99
Polar Ice Interactions	5,100	5,500
Ecology	2,100	2,225
Solid Earth Science	480	480
Arctic Ozone	2,900	5,600
Clouds and Radiation	2,000	1,500
Sub-orbital Science	2,800	2,300
Iono/Thermo/Mesospheric SR&T	1,000	780
Magnetospheric SR&T	400	400
FAST Auroral Snapshot	2,600	1,000
Solar Terrestrial Theory	400	400
Arctic Data Systems	11,800	11,225
Research Balloon Program	750	750
Sounding Rocket Program	1,413	1,700
Total	33,743	33,860

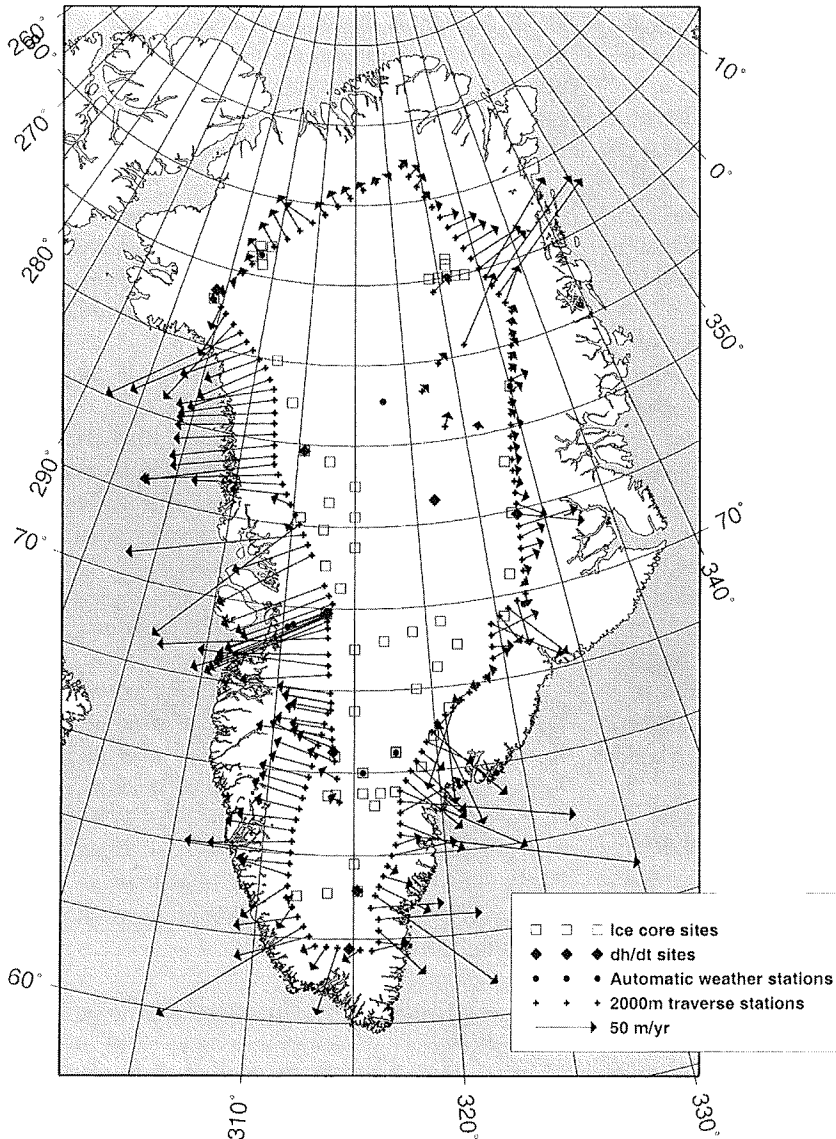
and possible future impact on sea level. Toward that end, the main components of the program are as follows:

- Airborne laser-altimetry surveys along precise repeat tracks across all major ice drainage basins in order to measure changes in ice surface elevation;
- Ice thickness measurements along the same flight lines;
- Shallow ice coring at many locations to infer snow accumulation rates and their spatial and interannual variability, recent climate history, and atmospheric chemistry;
- Estimates of snow accumulation rates from atmospheric model diagnosis of precipitation rates from winds and moisture amounts given by European Centre for Medium-Range Weather Forecasts (ECMWF) operational analyses;
- Surface-based measurements of ice motion at approximately 30-km intervals along the 2000-m contour completely around the ice sheet in order to calculate the total ice discharge for comparison with total snow accumulation and thus to infer the mass balance of most of the ice sheet;

- Local measurements of ice thickness changes in shallow drill holes;
- Investigations of individual glaciers and ice streams responsible for much of the outflow from the ice sheet;
- Monitoring of surface characteristics of the ice sheet using satellite radar altimetry, synthetic aperture radar (SAR), passive-microwave, scatterometer, and visible and infrared data;
- Investigations of surface energy balance and factors affecting snow accumulation and surface ablation; and
- Continuous monitoring of crustal motion using global positioning system (GPS) receivers at coastal sites.

The years 1998 and 1999 represent a milestone

Greenland, showing the locations of PARCA activities since 1993.



period for PARCA, with the airborne laser-altimeter and radar-sounding resurvey of the ice sheet, and completion of many complementary field activities, with an emphasis on ice coring. The emphasis now becomes analysis of the data, with new measurements focused on addressing important problems revealed by the analysis. Here, we present summaries of the 1998-1999 field, modeling, and data analysis activities.

The laser-altimeter resurvey of the northern part of the ice sheet shows a pattern of significant change—predominantly thinning—near the coast but very little elevation change over most of the interior ice sheet. The laser surveys provide estimates of elevation change over the five years from 1993-94 to 1998-99, and these will be extended by NASA's Geoscience Laser Altimeter System (GLAS) to be launched on NASA's Icesat satellite in 2001. The PARCA measurements will also provide baseline data sets for comparison with GLAS data to yield a total time series of elevation change from 1993-94 through the GLAS lifetime. Together with the earlier coverage by satellite radar altimeters, these data sets will yield a time series of elevation change over southern Greenland covering almost 30 years. The laser data have also been used, in a collaborative project with European scientists, to produce an improved digital elevation model for the ice sheet.

Analysis of ice core data indicates that interannual variability of snow accumulation rates can explain at least some of the patterns of thickening and thinning observed in the south of the ice sheet. Moreover, we have used the core data to help bridge the time gap between 1978-1988 radar altimeter surveys and the 1993-1998 laser surveys of the southern half of the ice sheet. The cores show that, over the southern part, there was a trend towards lower accumulation rates in the latter period. This coincided with a reduction in measured thickening rates between the times of the radar and laser surveys. The magnitude of this reduction matches well with estimates based on core data, lending confidence to results obtained by merging the radar and laser measurements with future Icesat data to compile a 30-year time series of thickening and thinning rates for this part of the ice sheet.

Comparisons between core results and model estimates of snow accumulation show strong links between the North Atlantic Oscillation and accumulation rates and offer the possibility of monitoring future spatial and temporal accumulation variability by model data assimilation of a few core data from key locations. This information is

extremely important in interpreting time series of satellite altimetry data, and NASA plans to compile maps of the magnitude of surface elevation trends that could be caused by accumulation variability for various time intervals to help identify regions where observed changes exceed these values.

The network of automatic weather stations on the ice sheet is now almost complete and is routinely providing measurements of meteorological conditions, including accumulation rate, in near real time to many scientists studying a broad spectrum of research problems. These data will also be important for interpreting GLAS data.

Ice thickness has been successfully measured along all the aircraft flight lines, with results available within a few months of acquisition to any interested investigator. They are important to most PARCA investigations but are also extensively used by non-PARCA scientists. Over the coming year the entire data set will be used, together with the laser topography measurements, to produce an improved map of the bedrock beneath the ice sheet. Radar sounding is also used to map internal layers in the ice sheet, indicative of past dynamics and basal conditions, and high-resolution radars have been used to map near-surface layers to infer snow accumulation rates. Further development of this approach is directed towards an airborne shallow-depth sounder capable of tracking the depths of volcanic layers between ice core sites and thus inferring spatial and temporal variability of snow accumulation rates over large regions.

Observations of vertical crustal motion at two coastal sites show submergence rather than the anticipated uplift. For this signal to be an elastic response to recent loading, the values of ice thickening would have to be very high—far higher than observed—suggesting that the submergence is a delayed response to Holocene changes of the ice sheet significantly different from those in current models. However, the available time series is short, and at least another five years of observations will be required to address these issues rigorously.

Significant progress is being made towards understanding the microwave signatures of the ice sheet. These are strongly affected by conditions beneath the surface, and they contain information on depth hoar and ice layer intensity, snow temperatures and wetness, and accumulation rate. The PARCA investigations have produced a better physical understanding of how these processes affect the microwave signatures, with the prospect of more reliable techniques for extracting information from them.

The main result from the mass balance investigations is that most of the coastal regions of the ice sheet are changing quite rapidly—predominantly thinning—but the reason isn't clear. Farther inland, patterns of thickening and thinning can to some extent be explained by interannual variability of snow accumulation. However, both the laser results and those from comparison of inland snow accumulation with ice discharge across the 2000-m traverse show the ice sheet, taken as a whole, to be almost exactly in balance. Near-coastal changes are expected to be sensitive to temporal variability in surface ablation rates. Although coastal summer temperatures have increased recently, particularly along the east coast, the increase cannot explain observed thinning rates of several meters per year. This suggests that discharge velocities must also have increased. Based on these observations the PARCA scientists have recommended a focused study of the coastal regions, emphasizing surface ablation and its sensitivity to summer warming and possible albedo feedbacks, and also the dynamics of those glaciers that are observed to be changing rapidly.

In FY 00 the major PARCA objectives are:

- Interpretation of the existing observations;
- Increased emphasis on modeling studies;
- Focused investigation of those major outlet glaciers known to be thinning;
- Continuation of studies using satellite data (microwave time series, SAR, etc);
- Maintenance of the automatic weather station (AWS) network and installation of one or two new stations in ablation areas, with shallow “ice cores of opportunity” at some visited AWS locations to fill data gaps; and
- Continuation of the global positioning system (GPS) measurements of crustal motion at Kangerlussuaq and Kulusuk.

The outlet glacier studies would include aircraft laser-altimeter and radar-sounding surveys along lines previously surveyed, with a few additional lines to obtain key ice thickness profiles. Resurvey of Canadian ice caps, first surveyed in 1995, is also planned to detect changes in a region that is likely to be highly sensitive to climate change. The aircraft flights would also provide an opportunity to test the shallow-depth radar.

Elevation Change of the Greenland Ice Sheet, 1993–1999

A key objective of PARCA was to refine the combination of airborne GPS positioning and laser ranging technology to an accuracy better than 10

cm, with the longer-term objective of applying this capability to measurement of the mass balance of the Greenland ice sheet. This was achieved through the development of the Airborne Topographic Mapper, or ATM-1. In the process of achieving this, baseline measurements of the ice sheet were acquired that will contribute significantly to validation and analysis of data from NASA's Icesat. All major ice drainage basins were surveyed in 1993-94 with both a scanning laser altimeter (giving surface elevations to 10-cm accuracy) and a depth sounding radar (giving thicknesses to 10-m accuracy) and in 1998-99 were resurveyed. The results in the south indicated areas of thickening and thinning above elevations of 2000 m but an overall mass balance for the area. The results in the south also revealed unexpectedly high rates of thinning at lower elevations, particularly along east coast outlet glaciers. These results appeared in the March 5, 1999, edition of *Science*, accompanied by a significant amount of national and international press coverage.

The northern half of the ice sheet was resurveyed in May 1999 using the NASA P-3. During this deployment, 14 data collection flights were

accomplished in 17 days, providing a ribbon of data 40,000 km long. The primary purpose of this field mission was to resurvey flight lines that were first surveyed during the 1994 field season. The data from 1994-1999 repeating tracks are currently undergoing analysis similar to the information from the south of Greenland, and a comprehensive map of five-year changes in Greenland will be submitted as a follow-on *Science* paper. Preliminary results indicate additional areas of significant near-coastal thinning in the north of Greenland. Additional flight tracks were surveyed for various PARCA investigators and for the Icesat project. Furthermore, the capability to extract glacier velocity from repeat flight lines of the ATM-1 over rapidly flowing glaciers has been developed. Cross-correlation analysis is conducted on the two data sets, and high-fidelity, unambiguous velocity vectors are determined over crevassed surfaces.

A new, lighter version of the Airborne Topographic Mapper (ATM-2) has been developed. The new version is adaptable to a small aircraft platform and uses a smaller scan mirror spinning at 20 Hz and 15 degrees off-nadir, as compared to 10 Hz and 10 degrees off-nadir for ATM-1. Both instruments operate at 5 kHz at an aircraft ground clearance of 400-700 m to provide data swaths 140-350 m wide.

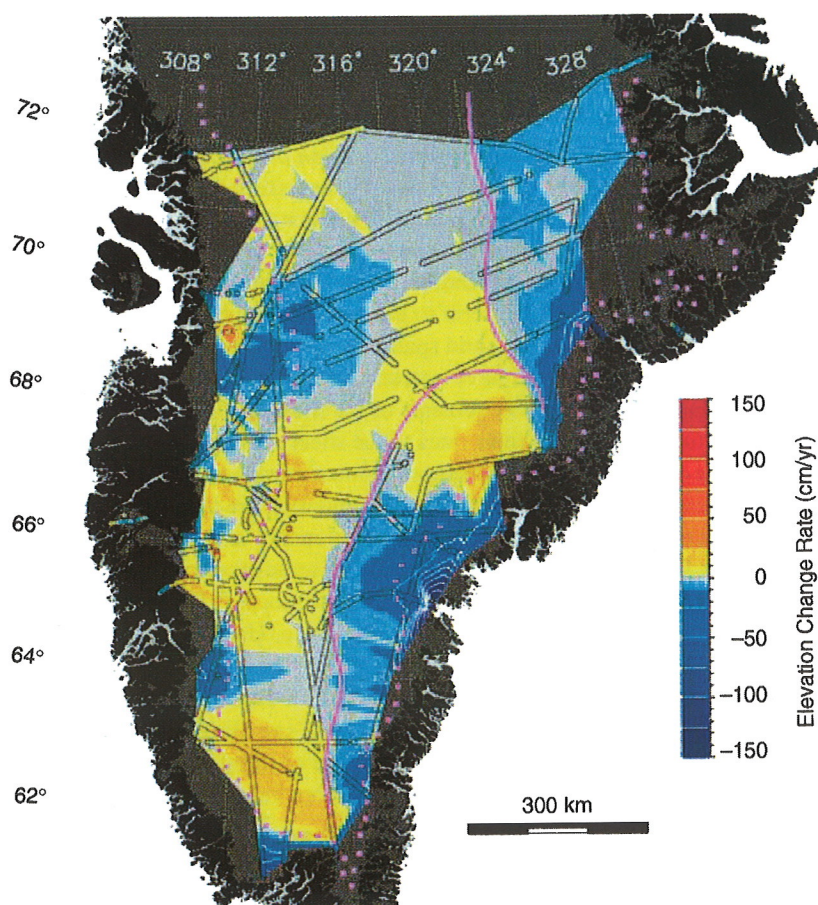
Elevation Change of the Southern Greenland Ice Sheet, 1978-1988

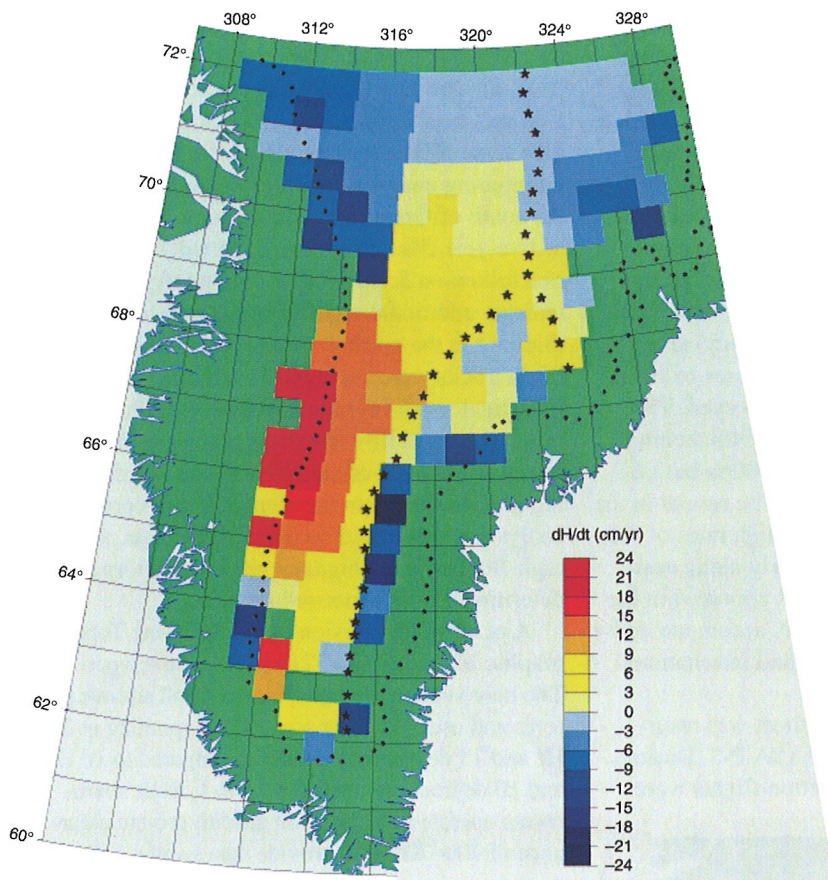
The ATM-1 is able to measure surface elevation change along resurveyed flight lines and over the period covered by the two surveys, 1993-94 to 1998-99. Satellite radar altimetry provides broader coverage and a longer and earlier time interval, from 1978 to 1988, but is not able to survey areas of the ice sheet where the surface slopes are large (as this introduces ambiguities in terms of locating the measurements). The two techniques are therefore complementary in some respects.

As well as using satellite altimeter data to document long-term elevation change of the Greenland ice sheet, the data are being used to investigate seasonal and interannual variations in the ice sheet elevations to place the long-term measurements in context. Major objectives of this research are:

- To develop new techniques to significantly improve the accuracy of elevation change estimates derived from satellite altimetry;
- To measure the elevation change of the Greenland ice sheet over a 10-year period using Seasat (1978) and Geosat (1985-1988) altimeter data; and

Greenland airborne laser and GPS tracks for 1998 and 1999, together with estimated surface elevation changes for 1993-1998 in the southern half of the ice sheet.





Spatial distribution of the rate of surface elevation change (dH/dt) from 1978 to 1988 from an analysis of Seasat and Geosat satellite radar altimeter data. The dH/dt values are shown in 50×50 -km cells. The approximate locations of the ice divide (stars) and 2000-m surface elevation contour (dots) are also shown. Spatial variations in dH/dt from +24 to -24 cm/yr are evident over distances of less than 300 km, but a spatial average of the data yield an average rate of change not significantly different from zero.

- To understand and interpret the spatial pattern and temporal variability of observed radar altimeter elevation change results using in-situ data in collaboration with other PARCA investigators.

A complete re-examination of elevation change over the southern Greenland ice sheet from 1978 to 1988 using Seasat and Geosat satellite radar altimeter datasets is now complete. This research incorporated technical advances in ice sheet retracking, orbit computation, orbit error reduction, and intersatellite bias estimation, which have significantly improved the accuracy of the elevation change measurements. A spatial average of the elevation change results for the southern ice sheet yields a rate of elevation change of 1.3 ± 1.5 cm/yr (unadjusted for isostatic uplift), which is not significantly different from zero. Approximately 90% of the area above the 2000-m contour is represented. About 75% of the area between the 1700-m and 2000-m contours west of the ice divide is also included. The average elevation change result is significantly smaller than previously published growth rates, which exceeded 20 cm/yr for all latitudes (south of 72°N) and all elevation bands.

However, the zero growth rate is in quantitative agreement with airborne laser altimeter results from 1993–1998 for the southern Greenland ice sheet above 2000 m.

While the average rate of elevation change is not significantly different from zero, the results show large regional variations in the elevation change estimates from -24 to +24 cm/yr. The spatial pattern of elevation change is also in qualitative agreement with airborne laser results.

Quantitative analysis of the radar and laser data, in conjunction with ice core accumulation data spanning the period from 1978 to 1998, indicates that a decrease in average accumulation between 1978–1988 and 1993–1998 caused significant differences between the radar and laser results in the area west of the ice divide near the 2000-m contour from 64 to 67°N. Preliminary analysis by other PARCA investigators indicates that much of the large spatial variations in the radar results for southern Greenland can be explained by short-term temporal variability in snow accumulation.

The close agreement between the satellite radar altimeter surface elevation change results from 1978–1988 and the airborne laser altimeter surface elevation change results from 1993–1998 indicates that the southern Greenland ice sheet above 2000 m has been approximately in balance for two decades (1978–1998).

Net Snow Accumulation over Greenland

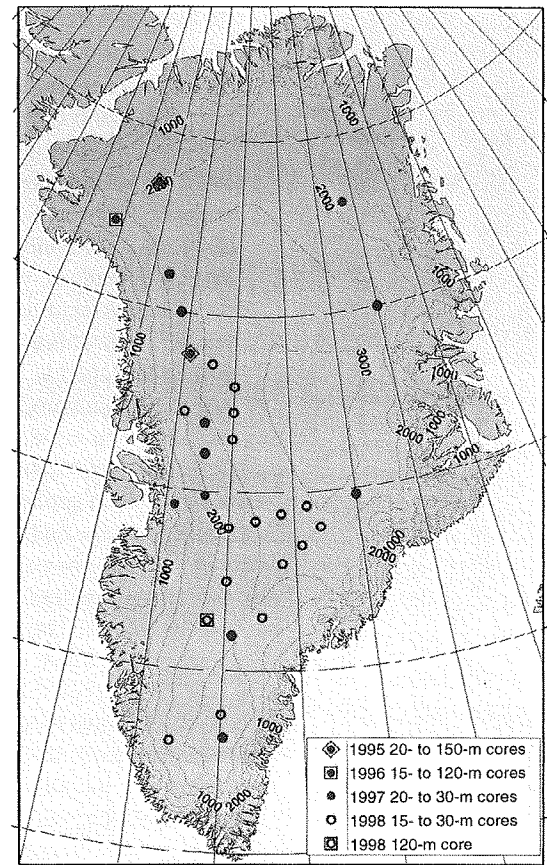
A key element to assessing the mass balance of the ice sheet is an understanding of the spatial and temporal variability of net snow accumulation over Greenland. Net snow accumulation is the primary input term to the overall mass balance of the ice sheet, and spatial variations in net accumulation will have a strong influence on repeat altimetry measurements of ice sheet elevation that are used to infer rates of ice sheet thickening and thinning. Widely spaced, contemporaneous measurements of annual net accumulation are also required to validate precipitation model results and to understand the influence of atmospheric circulation phenomena such as the North Atlantic Oscillation on ice sheet mass balance. Understanding recent temporal variability in particular is required for validating various remote sensing techniques aimed at improving the spatial sampling of accumulation measurements because of implicit averaging over time scales ranging from years to decades in such methods.

PARCA ice core accumulation studies are focusing on high-resolution (annual) accumulation histo-

ries for the last 200 years at a limited number of sites and for the last 40 years at a greater number of sites. Thirty-three shallow ice cores (20 m) and one deeper (120 m) ice core were collected at 27 widely distributed locations around the ice sheet during the 1997 and 1998 field seasons. Multiple cores were collected at a number of locations to better understand short-scale spatial variability in snow accumulation. A light-weight electro-mechanical drill was developed specifically for the shallow coring operations to minimize ground time and to allow the use of ski-equipped Twin Otter aircraft for deployment to the core sites. The deeper core was collected using the Ohio State electromechanical drill system. Density measurements were made during collection using conventional techniques.

Establishing annual accumulation rates requires exact dating of each annual layer in the firn and/or ice cores. Six seasonally varying parameters are measured continuously along the length of each core. A continuous-flow analytical system measures hydrogen peroxide, nitrate, ammonia, and calcium, while stable oxygen isotopic ratios are measured by mass spectrometry, and insoluble dust is measured by the Coulter technique for discrete samples. The result of the multiparameter approach is a depth–age scale with minimal uncertainty.

Accumulation rates can also be estimated in perennially dry snow zones on the ice sheet using observations of microwave emission at a 4.5-cm wavelength. The physical snow property linking the accumulation rate with 4.5-cm emission is random snow density stratification on millimeter to centimeter scales. The variance, and perhaps the depth-scale length, of such layering varies with accumulation rate—regions with low accumulation rates display stronger layering than do regions with high accumulation rates. While the physics underlying this covariance remains somewhat indeterminate at this time, the observed covariance is strong. From an electrodynamic standpoint, the fine-scale density layering corresponds to similarly fine-scale stratification in the dielectric constant. Thus, variations in layering correspond to variations in reflection and emission properties and in particular to variations in the polarization dependence of emission. The latter variations are observed using, for example, the scanning multi-channel microwave radiometer. Observations are interpreted (via electrodynamic modeling) in terms of layering parameters and thus accumulation rate. The resulting map of accumulation rates



Shallow and deep ice core locations.

over the dry snow zone in Greenland, originally tuned using historical accumulation rate data, compares very favorably with recent ground-based accumulation rate estimates at roughly 10–20 locations acquired by the PARCA field program.

The Greenland Climate Network

Climatological observations and surface energy balance studies are key to understanding the surface processes linked with ice sheet mass balance. Long-term climate records at different sites on the ice sheet are needed to assess the snow pack energy and mass balance of the accumulation zone and to gain more complete information on the spatial variation of climate over the ice sheet. The Greenland Climate Network (GC-Net) was established in the spring of 1994 with the emphasis on monitoring climatological and glaciological parameters at various locations on the ice sheet over a period of at least 5–10 years. The objectives of the GC-Net automatic weather station (AWS) network are:

- To assess daily, annual, and interannual variability in accumulation rate, surface climatology, and surface energy balance at selected



A Greenland automatic weather station, forming part of the Greenland Climate Network (GC-Net).

locations on the ice sheet where high sensitivity of the ice sheet mass balance to climate anomalies is predicted from modeling results;

- To calibrate applications of satellite-derived parameters and algorithms;
- To assess accurate surface elevation, location, and near-surface density at the AWS location with the option to revisit the locations to get temporal information for dynamic ice sheet modeling; and
- To collect ground-based validation data during the forthcoming Icesat mission, which will be launched in 2001.

Currently 18 stations, each measuring 32 parameters, have been installed on the ice sheet at various elevations and locations. Quality control procedures have been applied to all GC-Net data from 1995 through to the end of 1999, with archived data now covering in excess of 50 station-years. The overall success rate of data acquisition for all the stations is 94%. The AWS data are transmitted hourly via satellite link, and data retrieval has been automated, providing updated information each hour. The most recent six days of hourly surface meteorological ASCII data and plots are updated hourly on the Internet (http://cires.colorado.edu/steffen/aws/current_GC-Net_plots.html).

There are over 40 registered GC-Net users, with applications including:

- High-resolution atmospheric circulation model validation;
- AVHRR Polar Pathfinder surface albedo and temperature comparison;
- Surface height variations, accumulation characteristics, and timing of melt;
- Annual average temperature comparison with isotope data from ice cores;
- Verification of katabatic wind models; and
- Surface climatology and energy balance.

Ice Flow in the Greenland Northeast Ice Stream

Only recently discovered through analysis of SAR imagery, the northeast Greenland ice stream is the dominant contributor to the overall mass balance and stability of a large part of northeast Greenland. It appears as a nearly straight feature about 700 km long, with identifiable margins for most of its length and a topographically undulating interior resulting from rapid ice flow over the bed topography. Since it penetrates inland to within 100 km of the ice divide, it has the potential to rapidly draw down the interior of the ice sheet should it ever exhibit unstable flow behavior. With its unique geometry and dynamics as well as its

potential impact on mass balance, the northeast Greenland ice stream is an important area for glaciological study.

Data remotely sensed from satellite and airborne platforms have greatly expanded our knowledge of this ice stream. In particular, it has been possible to measure ice flow over nearly the entire ice stream using SAR interferometry from data recorded by the European Space Agency ERS-1 and ERS-2 satellites. A large volume of data was required to accommodate the vast scale of the ice stream, and these data had to be collected during many satellite passes. Nevertheless, this large volume of data can be processed with relative ease with modern computers, and the map provides greater coverage and detail than could ever be accomplished with traditional field survey methods.

The velocity map confirms that the ice stream begins as a narrow, 10- to 15-km band of flow that is enhanced from the surrounding ice sheet. Although the flow is not exceptionally fast at this point—only 15–30 m/yr—its speed is well above that of the surrounding ice, with well-defined shear margins. Farther downstream a tributary of enhanced flow merges with the ice stream. This tributary is much broader and, in contrast to the first tributary, lacks well-defined shear margins. Roughly 100 km downstream the ice stream broadens to a width of nearly 50 km, with speeds of 50–75 m/yr. From here the speed increases gradually downstream over the next 200 km until the ice undergoes an abrupt change in speed from roughly 100 to 300–400 m/yr over a distance of approximately 20 km. This increase in speed is coincident with a peak and then rapid decline in the driving stress, which is similar in character to that observed for ice stream onsets in western Antarctica. The flow then divides to contribute ice to three major outlet glaciers: Nioghalvfjærdsbrae, Zachariae, and Storstrømmen. The data also show that Nioghalvfjærdsbrae derives a large part of its ice from an independent tributary.

These data are being analyzed in conjunction with ice thickness data collected by the University of Kansas ice penetrating radar. They will be used to measure ice flux through several “gates” where the thickness is known. The measured fluxes will then be compared with estimated fluxes derived from accumulation data. Differences between measured and estimated fluxes indicate a mass imbalance and consequent thickening or thinning of the ice sheet. The data are also being analyzed using sophisticated ice sheet models with the goal

of improving our understanding of how such ice streams form and what factors control their overall stability.

Ice Thickness Measurements over the Greenland Ice Sheet

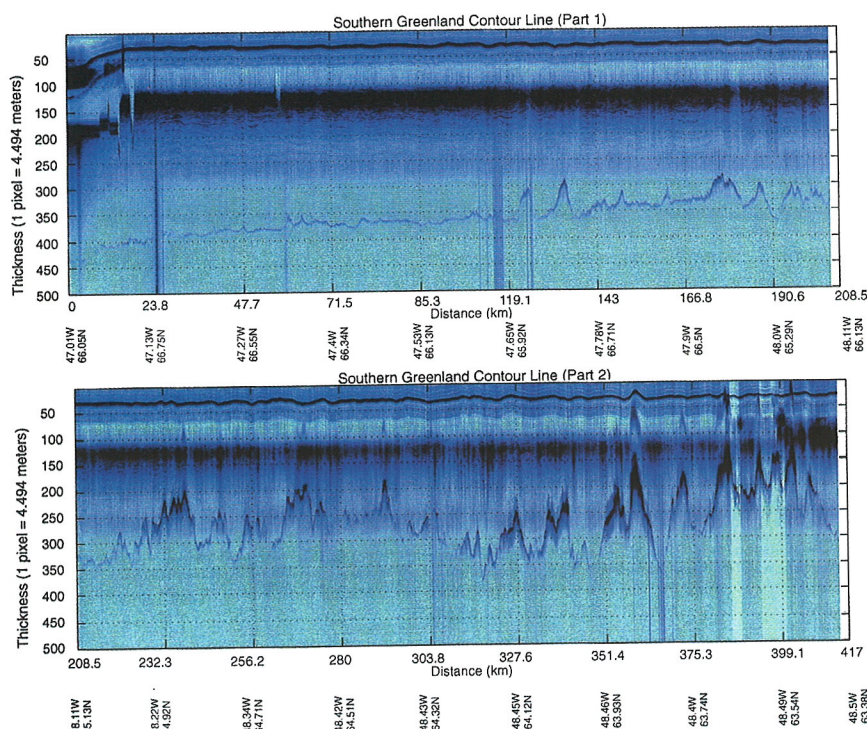
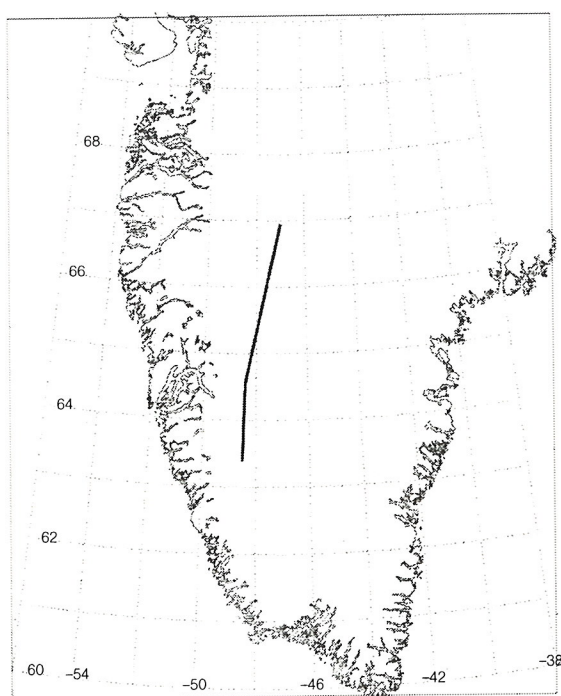
Ice thickness observations are an important component of any study of large ice masses, including Greenland. The PARCA program has provided the framework for the development of technology that has improved capabilities in this area.

Two coherent radar depth sounders have been developed within the PARCA program, one with connectorized components and the other with RF integrated circuits. Together, these sounders have collected a large volume of ice thickness data since 1993. These depth sounders operate at the center frequency of 150 MHz. Their transmitters generate a pulse of 1.6- μ s duration along with 200 W of peak power (the actual transmit power is about 70 W because of cable losses), which is frequency-modulated over a bandwidth of 17 MHz. These systems use two antennas that are mounted under the left and right wings of the aircraft, one for transmission and the other for reception. Each antenna is a four-element dipole array with two-way beam widths of 18 and 66 degrees in planes perpendicular and parallel to the flight path, respectively. The receiver for the coherent depth

sounders amplifies and compresses the received signals in a weighted surface acoustic wave compressor to an effective pulse of about 60 ns. This results in a depth resolution of about 5 m in ice. The compressed signal is coherently detected and integrated by summing consecutive pulses. The coherent integration serves as a low-pass filter and reduces the along-track antenna beam width from about 66 to 17 degrees. First-order processing of all data collected since 1993 has been completed. These data are available to the user community through the World Wide Web (<http://tornado.rsl.ukans.edu/Greenlanddata.htm>).

Recent advances in hardware and processing techniques are producing radio-echograms that reveal more detailed information about the internal layering structure of the ice sheet than ever before. When traced over large distances, these layers, presumably isochrones, provide insight into the past shapes and states of the ice sheet and can be used to constrain ice sheet flow models for a more accurate representation of their present and past characteristics. Efforts are underway to identify significant layers at various depths in the ice and trace each layer horizontally as far as possible (hundreds of kilometers). Moreover, because these layers pass through deep ice core sites (GISP2, GRIP, and NGRIP) where age-depth relationships are known, the age of each layer can be determined.

Radio-echogram for a transect in southern Greenland. The map shows the location, and the radio-echogram is in two parts, from north (top right) to south (bottom right). The units on the vertical axis of the echogram are pixels of 4.494 m. These data were collected on July 18, 1998, during the period of heavy melt. Ice thickness decreased from about 1700 m at the beginning of the flight line to about 700 m at a distance of 350 km, with peak-to-peak deviations of more than 800 m.



The layer tracing is accomplished through a combination of image enhancement and correlation analysis techniques. An interactive tool has been developed that allows a user to visually select a point on a layer. The tool then automatically analyzes the correlations between the radar returns within a vertical window centered on that point and those in a similar window within an adjacent trace. By finding the best pattern match, the position of that layer in the adjacent trace is identified. The process is repeated automatically, one trace at a time, until the flight line ends or suitable correlations cannot be found. In this way the layer depth is determined for the full flight line. When all of the flight lines are analyzed, intersecting points can be compared and a three-dimensional representation can be achieved. With the successful acquisition of data over much of Greenland, there is now a comprehensive set of radio-echograms for most of the ice sheet, and ultimately, digital elevation models of each retrievable layer will be produced.

Ice Mass Loading and Glacial Rebound in Greenland

GPS and absolute gravity measurements are being made on bedrock along the edge of the Greenland ice sheet to detect vertical motion of the earth's crust. The study has two main objectives. One is to put constraints on the ongoing change in ice mass averaged over a few hundred kilometers from the observation point. Any such change in ice load would cause vertical crustal motion. The other objective is to confirm predictions of post-glacial rebound models that indicate that the margins of Greenland should be rising at about 3–4 mm/yr because of the earth's continuing viscous adjustment to Holocene deglaciation. By combining GPS and absolute gravity measurements, it should eventually be possible to separate these two contributions to vertical uplift.

To make these observations, continuously recording GPS receivers were installed at Kangerlussuaq in the summer of 1995 and at Kulusuk in the summer of 1996. These two sites are at about the same latitude but directly across the ice cap from one another. The sites have been visited with an absolute gravimeter for about 1–2 weeks every summer since 1995 for Kangerlussuaq and since 1996 for Kulusuk. The GPS solutions show a significant secular subsidence rate of 4.7 ± 2.1 mm/yr at Kangerlussuaq but no significant subsidence

(1.5 ± 2.4 mm/yr) at Kulusuk. Because the gravity measurements are made only once per year, the trends in gravity are less well determined and cannot yet be combined with the GPS trends to separate the post-glacial rebound signal from the effects of ongoing changes in ice.

The GPS subsidence at Kangerlussuaq is surprising. Models predict that the viscous effects should be causing Kangerlussuaq to uplift rather than subside, with an uplift rate of about 3.5 ± 2 mm/yr. After this predicted uplift is removed from the GPS secular subsidence value, the residual subsidence is 8.2 ± 3 mm/yr. This residual subsidence is presumably due to a combination of:

- Ongoing changes in ice;
- Errors in the Greenland component of the model for the melting prior to 4000 years ago;
- The earth's viscous response to any changes in ice that might have occurred during the past 4000 years; and
- Systematic errors in the GPS measurements.

This large a subsidence is unlikely to be primarily caused by ongoing changes in ice. A subsidence of 8 mm/yr at the edge of the ice sheet would require the ice to be thickening at a rate of about 30–50 cm/yr averaged over a few hundred kilometers from Kangerlussuaq. This rate of thickening is substantially larger than that indicated by altimeter observations of ice sheet surface elevations in the region. Even the lower bound of $8.2 - 3 \approx 5$ mm/yr would require the ice to be thickening at a rate of about 10–20 cm/yr. Instead, it is more likely that there is something wrong or incomplete about the assumptions for past changes in ice. For example, suppose that the total mass of melting Greenland ice prior to 4000 years ago is represented correctly in the model but that this melting ice was concentrated in the far northeastern portion of the ice sheet rather than in the center (as assumed in the model). In that case, visco-elastic models predict that the present-day motion of Kangerlussuaq would total about 2 mm/yr of subsidence, instead of the 3.5 mm/yr of uplift predicted using the exact model. If there really were 2 mm/yr of viscous subsidence caused by the Pleistocene deglaciation, then the GPS estimate, after removing this viscous component, would be 3 ± 5 mm/yr, which is not significantly different from zero. The accumulation of more gravity data will eventually permit the separation of the viscous part of the signal from the effects of ongoing changes in ice mass and so presumably help to resolve this question.

Alaska Glacier Research

Vertical Ice Motion Signals on Alaskan Glaciers and Lakes

One of the key interests of glaciologists is in understanding the nature of, and reasons for, glacier surging, whereby some glaciers periodically significantly increase their flux. Features noticed in SAR interferometry, called “bull’s eyes,” may provide important clues to the behavior of surging glaciers. Interferometric phase bull’s eyes from ERS SAR data were identified on East Bagley Icefield in midwinter during the 1993–1995 surge of Bagley Icefield and Bering Glacier, in the Chugach-St. Elias Mountains of south-central Alaska. These bull’s eye signals in the data imply unexpected surface motion events on a scale of a few centimeters of motion per day across roughly circular regions extending a kilometer or more across. Geophysical reasoning is used to resolve an essential ambiguity in the direction of implied surface motion—horizontal versus vertical—intrinsic to these data. The phase bull’s eyes appear as concentric rings of phase typically 0.5–4 km in diameter. It is expected that they indicate uplift or dropping of the glacier surface by a few centimeters over the course of 1–3 days, driven by moving pockets of water beneath the glacier.

These bull’s eyes are strongly associated with the surge of Bagley Icefield and Bering Glacier, and they are also commonly found on other non-surging glaciers. In particular, phase bull’s eyes have been identified on the Black Rapids Glacier in the Alaska Range of central Alaska, the Harding Icefield in south-central Alaska, and several other non-surging glaciers in the vicinity of Bering Glacier. Furthermore, phase bull’s eyes persisted on the stagnant ice of the piedmont lobe of Bering Glacier near the terminus after cessation of the 1993–1995 surge. There the phase bull’s eyes consistently indicated localized surface-drop events that we associate with drainage of discrete pockets of subglacial water.

Similar phase bull’s eye signals have also been observed on winter fast ice along the shores of Tustumena and Skilak Lakes on the Kenai Peninsula, south-central Alaska. In this case, vertical motion of the lake ice may be associated with the changing snow load and/or freezing. Related phase signals are commonly observed on smaller lakes as well. For both lake ice bull’s eyes and the bull’s eyes on the stagnant ice of the Bering piedmont lobe, the possibility of horizontal motion contributing to the signal is ruled out, which sup-

ports the vertical motion hypothesis. The observation of these subtle events, made possible by space-borne SAR data, may become a useful contribution to our understanding of subglacial hydrological processes.

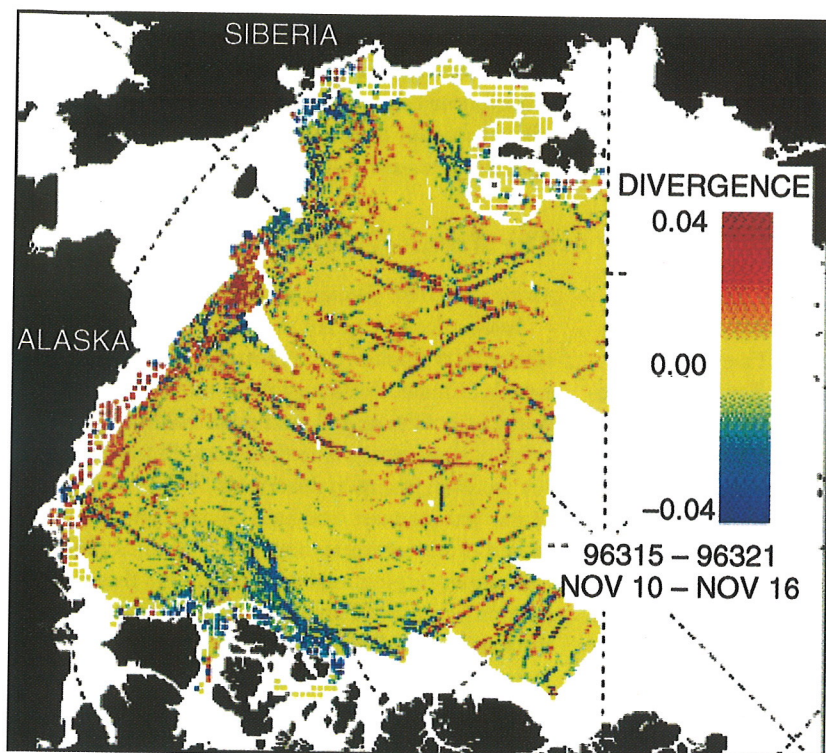
The Arctic Ocean

Arctic Ice Drift, Deformation, and Thickness

Interactions between sea ice, ocean, and atmosphere in the polar region strongly affect the earth’s climate. Sea ice growth, movement, and decay affect the energy and mass balance of the polar ocean system. The thickness distribution of sea ice is an essential descriptor of the Arctic Ocean sea ice mass and heat balance and is a record of the interplay between dynamics (lead formation, ridging, and advection) and thermodynamics (ice growth and melt). Our knowledge of the Arctic ice thickness distribution is derived largely from analyses of sonar data from submarine cruises. Moored upward-looking sonars have also been used to sample the thickness distribution at fixed locations. However, these observations do not provide a complete spatial picture or allow continual monitoring of the thickness distribution.

Space-borne SAR imagery provides large spatial coverage and an amazingly detailed look at sea ice, but the level of detail is so great that it is not at first apparent how to use the data for improving sea ice data sets and models. NASA’s Radarsat Geophysical Processor System (RGPS) offers a solution. It uses over 100 wide-swath radar images of the Arctic Ocean every three days and produces estimates of ice motion, ice deformation, and thin ice thickness distribution (0–2 m). The thin end of the thickness distributions is important because this is the crucial range that produces the most ice growth, the most turbulent heat flux to the atmosphere, and the most salt flux to the ocean.

The novel approach of estimating ice thickness depends on repeated observations of material elements or cells of sea ice in sequential SAR imagery. Line segments connecting the four vertices of a cell define its boundaries. The drift and deformation of a cell over time are obtained by tracking the displacement of its vertices in the SAR imagery. Ice thicknesses during the winter are produced from estimates of ice age. The age histogram of the ice in a cell is computed from the temporal record of area changes. Ice age is converted to ice thickness using an empirical air-temperature-dependent ice growth formula, with the temperature taken from fields derived from surface meas-



Ice divergence in the western Arctic Ocean over the period November 10–16, 1996, as estimated using the Radarsat Geophysical Processor System. The divergence refers to the fraction of open area.

Except for the regions near the ice margin, all deformation is localized along leads, while the rest of the ice cover remains unaffected. The length and alignment of some of the leads are quite remarkable. Several leads can be seen to span a large fraction of the Arctic Ocean.

urements. The evolution of the seasonal ice thickness distribution and the sea ice volume production due to deformation can hence be estimated (the growth of multiyear ice is excluded). The volume production is computed directly from the thickness histograms. Between early November 1996 and late March 1997, more than 1000 km³ of sea ice was produced, with an approximately equal volume stored in ridges and undeformed ice.

These algorithms are implemented in the RGPS, which is dedicated to the analysis of SAR data of sea ice collected by the Canadian Radarsat satellite. Radarsat was launched in November 1995 into a 24-day repeat cycle. This orbit configuration and the wide-swath (460 km) ScanSAR mode allow the repeat coverage of the Arctic Ocean every 3–7 days. The 24-day repeat cycle of the satellite produces close to eight observations of the western Arctic Ocean within the Alaska SAR Facility (ASF) reception mask in Fairbanks, Alaska.

The RGPS deformation measurements offer an unprecedented level of spatial and temporal coverage and detail for all seasons of the year. For the first time, there are extensive measurements of ice motion that can be used in concert with a variety of ice models for verification studies, for driving the models as forcing fields, and in data assimilation procedures. The ice production rates esti-

mated with RGPS can be compared to those computed by models driven by the geostrophic wind and a force balance approach. The ice motion measured with RGPS can be used directly as a forcing field for an ice model, and the uncertainty in the ice motion can thus be reduced. Finally, the RGPS ice displacement measurements can be assimilated directly into an ice–ocean model so that ice trajectories in the model can be made to match the observed trajectories. The value of these uses for the RGPS products will increase as the observational record becomes longer and a greater variety of seasons is recorded. Preliminary results for two winter seasons, 1996 and 1997, show that the two years have evolved in markedly different manners. Ultimately, a long record of the ice deformation and ice production rates can be developed that will contribute to the assessment of the evolution of the Arctic Ocean.

Arctic Sea Ice Modeling

The development of a clear understanding of the Arctic pack ice and the way in which it deforms into leads and supports new ice growth, as outlined in the previous section, depends on the development of models that can reliably reproduce its behavior. A new approach to modeling the Arctic ice pack has been developed in which the ice pack is composed of a granular aggregate of ice parcels. This contrasts with typical ice–ocean models of the Arctic ice pack, which are large-scale continuum models that use a plastic yield surface to characterize the constitutive behavior of the pack. In the granular model each floe is a continuum having its own ice thickness distribution. Floe-scale behavior such as thermodynamic ice growth and melt, wind and water drag, and pressure ridging are incorporated via parameterizations derived from field observations and computer simulations. The boundaries of the model pack are kinematically driven by RGPS ice motion data derived from SAR imagery. Simulations performed with the granular model successfully reproduce the general deformation patterns visible in SAR images captured during the recently completed SHEBA field experiment. The model simulates the evolution of the ice thickness distribution over the SHEBA year. Point stresses calculated within the model are compared with modeled global average stresses and point stress measurements made during SHEBA. A demonstration of the model is available on the World Wide Web (<http://www.crrel.usace.army.mil/ierd>).

Arctic Sea Ice Anomalies

Recent analyses of observations have identified interesting variations in the North Atlantic and so-called Arctic Oscillations, the North Atlantic thermohaline regime, the sea ice distribution, precipitation, permafrost distribution, and many other climate variables. It remains to be determined whether these variations are consistent with, or indicators of, the type of polar amplification predicted by global climate model experiments. The existence of quasistationary regimes has been found explicitly in models and analyses of the atmospheric global circulation. What relevance do these have to climate change? To answer this question, it is necessary to understand the nature of natural variability, in the form of quasistationary regimes, and to consider that anthropogenic forcing would be manifested by a projection onto these patterns of natural internal variability.

The existence of hemispheric-scale regimes such as the Arctic Oscillation is somewhat controversial. Doubts have been raised as to the physical coherence of hemispheric regimes. It is possible that conflicting evidence for the existence of hemispheric regimes can be reconciled if Pacific and Atlantic sector variability, although predominantly quasi-independent, can become partially synchronized from time to time. The notion of atmospheric chaotic synchronization has been discussed in the context of interhemispheric synchronization and may therefore also apply to intersector synchronization. Thus, if a change in global climate is felt in the Arctic as an amplification of a particular mode of the Arctic Oscillation, it is

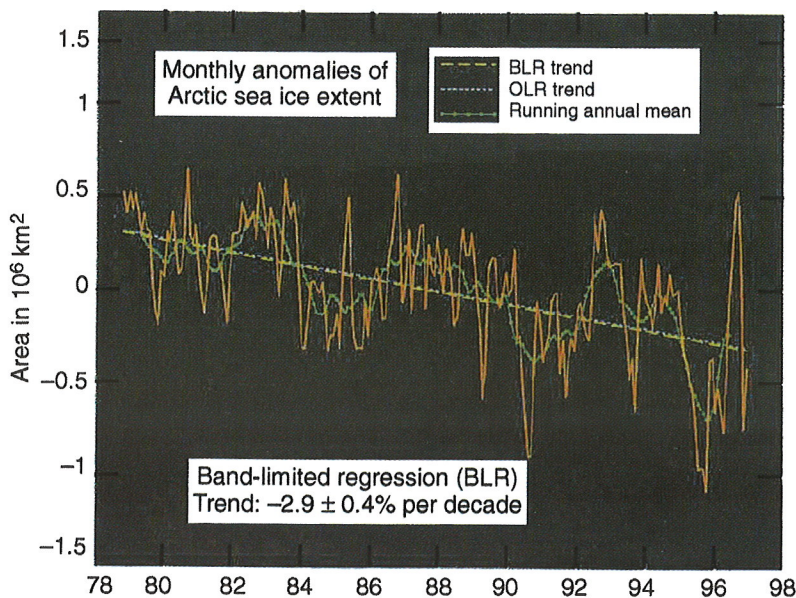
important that studies of other Arctic climate trends, such as the frequency and severity of sea ice anomalies, be conducted in this context.

The Arctic Oscillation is postulated to be strongly associated with stratospheric circulation over the pole and also with lower-latitude momentum and energy transports. Recent efforts in Arctic regional climate system modeling have focused on these aspects of Arctic climate. Specifically it has been found that the use of ensemble predictions of regional climate is important for establishing significance and for investigating basic model behavior. Several tests have been undertaken to assess the model response to lateral and upper boundary forcing. When a nonspecific local lateral boundary condition is used, a broader forcing zone enhances the skill of the results somewhat, but the effect is not as dramatic as that of introducing improvements to the upper boundary condition and simulation of the stratosphere.

These results show that a nonspecific local upper boundary condition that absorbs, rather than reflects, vertically propagating planetary and gravity wave energy is an important contributor to skillful simulations within the Arctic Basin. With this boundary condition in place, a parameterization of gravity wave drag is appropriate for a regional climate model at lower resolutions. Finally, a domain that extends well into the mid-stratosphere, combined with an appropriate upper boundary condition and gravity wave drag parameterization, produces optimal results.

Since the late 1980s, during the period of persistence and intensification of the positive mode of the pattern now associated with the Arctic Oscillation, Arctic sea ice extent continued its net decrease in coverage seen since the late 1970s. However, larger interannual variability in ice extent and larger regional reductions in ice cover accompanied this net decrease. For example, during the summer of 1998, record reductions in ice cover occurred in the Beaufort and Chukchi Seas. Open water formed earlier than in prior years, and the September ice extent in this region was 25% less than the previous minimum for 1953–1997. Seven percent of the Arctic Basin that had been perennially ice covered was ice-free in 1998. This reduction in western Arctic ice extent can be attributed in part to preconditioning by light ice cover in autumn 1997 and to atmospheric circulation patterns during the following winter through autumn that favored southerly and easterly winds. Such decreases in northerly winds, and the associated weakening or displacement of the Beaufort

Reduction in sea ice cover in the Arctic, from passive microwave data, between 1978 and 1998. The 1990s have provided four record-breaking years for minimum sea ice extent.



Gyre, are typical of winters that precede years with below-normal ice extent in the western Arctic. Further analyses of conditions during the summer of 1999 indicate continued below-normal ice extent in late summer, with a relatively large expanse of the ice pack consisting of reduced concentrations compared to other years. While these ice conditions favored another light ice year comparable to 1998, the southerly winds that developed in the summer of 1998 and that appear to have contributed to the record 1998 reduction did not repeat in 1999. The results suggest that synoptic-scale and even local processes exert a considerable influence on the strength of regional variations in ice cover.

To understand how such local, regional, and hemispheric conditions interact to effect the observed regional changes in ice cover requires a combination of observational studies and model diagnostic analyses. In the summer of 1990, a record reduction in regional ice cover similar to that seen in 1998 occurred in the Siberian Arctic. For this case, observations and Arctic regional climate system model results were used to gain insight into the mechanisms driving the observed reduction in ice extent. Analyses of observations, coupled model experiments, and stand-alone ice model output suggested a positive feedback between ice dynamics and ice melt that contributed to the ice extent anomaly. The Arctic regional climate system model was able to reproduce the general patterns seen in comparison sea level pressure fields in most months, but the discrepancies significantly affected the model's ability to simulate details of sea ice transport and warm air advection linked to the unusual ice conditions. The use of a prescribed sea ice fraction in the coupled model yields relatively small changes in the surface energy balance compared to the coupled model with a dynamic ice cover, but it significantly affects atmospheric circulation in spring and late summer. The results highlight the importance of regional atmospheric circulation in driving interannual variations in Arctic ice extent and illustrate the level of model performance needed to simulate such variations.

Such detailed observational analyses and modeling require improved data sets that span as long a time period as possible. The AVHRR Polar Pathfinder effort, part of the NOAA/NASA Pathfinder project, was established to support such work. The goal of the AVHRR Polar Pathfinder was to locate, acquire, and process advanced very high resolution radiometer (AVHRR) imagery into

geolocated and calibrated radiances, cloud masks, surface clear-sky broadband albedo, clear-sky skin temperatures, satellite viewing times, and viewing and solar geometry for the high-latitude portions of the Northern and Southern Hemispheres (all area north of 48°N and south of 53°S). AVHRR global area coverage data for August 1981 to July 1998 have been acquired and processed into twice-daily 5-km grids, with some products also provided at 25-km resolution. AVHRR finer-resolution data for 3.5 years of coverage in the Northern Hemisphere and 2.75 years of coverage in the Southern Hemisphere were processed into 1.25-km grids for the same suite of products. The resulting data sets are being transferred to the National Snow and Ice Data Center (NSIDC) for archiving and distribution. Using these data, researchers now have at their disposal an extensive AVHRR data set for investigations of high-latitude processes. In addition, the data lend themselves to development and testing of algorithms. The products are particularly relevant for climate research and algorithm development as applied to relatively long time periods and large areas.

Arctic Sea Ice Extent

In addition to AVHRR-derived data sets, NASA researchers have continued to analyze passive microwave data sets, and in 1999 they completed the analysis of an 18.2-year record of the Arctic ice, covering the period from November 1978 to December 1996. This analysis used data from the Nimbus 7 scanning multichannel microwave radiometer (SMMR) and the Defense Meteorological Satellite Program (DMSP) special sensor microwave imager (SSM/I) for the entire Arctic region. The result showed an overall decreasing trend in Arctic sea ice extents of $34,000 \pm 3,700 \text{ km}^2/\text{yr}$ ($-2.8\%/decade$). Each season also registered overall decreases, with the strongest trend occurring for spring and the weakest trend occurring for autumn. These results contribute to the growing evidence for overall Arctic sea ice decreases, found through research studies done by several groups around the world.

The results were also analyzed for each of nine regions constituting the Arctic sea ice cover. There were marked regional contrasts in the results, as well as strong interannual variability. The regions registering the largest decreases, on a yearly average basis, were the Kara and Barents Seas, at $15,200 \pm 4,400 \text{ km}^2/\text{yr}$ ($-10.5\%/decade$), and the Seas of Okhotsk and Japan, at $9,700 \pm 2,300 \text{ km}^2/\text{yr}$ ($-20.1\%/decade$). Three regions, however,

showed increases, although only one of those, the Gulf of St. Lawrence, had increases that were statistically significant at 95% or above. The increases in the Gulf of St. Lawrence and the decreases in the Kara and Barents Seas, the Seas of Okhotsk and Japan, and the Northern Hemisphere total were all statistically significant at a 99% level. Interannual variability is such that these results should not be used to predict further decreases. Some regions show suggestions of cyclical behavior, and the pattern of ice decreases east of Greenland and ice increases west of Greenland is likely related to phasing of the North Atlantic Oscillation; both of these relationships leave open the possibility that a lengthened record could show some reversals of the results obtained so far.

Two other variables calculated from the 18.2-year sea ice data set are the sea ice area and ice-free area within the ice pack. Ice area is the cumulative area of sea ice cover, calculated by summing, over all ocean pixels with ice concentrations of at least 15%, the product of ice concentration multiplied by pixel area. The ice-free area is the area of ocean not covered by sea ice within the ice pack and is calculated as the difference between ice extent and ice area. The year-to-year variability of sea ice area is similar to that of ice extent, except that the sea ice area is always lower than the ice extent, because of the presence of leads and polynyas within the ice pack. The hemispheric decrease in ice area over the 18.2-year period is $29,500 \pm 3,800 \text{ km}^2/\text{yr}$. The strongest ice area decreases are in the same regions as the strongest ice extent decreases; in each region the ice area trend has the same sign as the ice extent trend.

The hemispheric ice-free area within the ice pack exhibits a statistically significant overall decrease of $4,800 \pm 1,600 \text{ km}^2/\text{yr}$. Four of the nine Arctic regions exhibit positive trends—the Gulf of St. Lawrence, the Canadian Archipelago, Baffin Bay/Labrador Sea, and the Bering Sea—but only the Gulf of St. Lawrence and the Canadian Archipelago increases are statistically significant at 95% or above. The remaining five regions—the Greenland Sea, the Kara and Barents Seas, the Arctic Ocean, Hudson Bay, and the Seas of Okhotsk and Japan—all show negative trends, but only the Greenland Sea and Hudson Bay decreases are statistically significant. Interestingly, neither the decreases in sea ice extent or ice area are statistically significant for these latter two very different regions. Hudson Bay is influenced by continental climate, whereas the Greenland Sea is more influenced by a maritime climate. As noted above, a

longer time series is much desired for improving the understanding of the changes occurring in these and each of the other regions.

Arctic Clouds and Radiation

The foundation for substantial progress in Arctic radiation fluxes, in terms of their understanding, modeling, and evaluation from satellite data, has been laid during this period by the Surface Heat Budget of the Arctic Ocean (SHEBA) and the FIRE Arctic Clouds experiments. NASA's contribution to the SHEBA experiment consisted primarily of aircraft over-flights of the ice camp to obtain remote and in-situ measurements of the properties of clouds and the sea ice and ocean surface. The NASA ER-2 flew at an altitude of 20 km with a suite of remote sensors that can be used to infer the characteristics of the surface and clouds below. Other aircraft, instrumented with in-situ and remote sensing instruments, were used to measure radiation fluxes and the physical, optical, and chemical properties of the clouds. Observations collected during the field phase of the project are being used to evaluate and improve climate model parameterizations of Arctic cloud and radiation processes, satellite remote sensing of cloud and surface characteristics, and understanding of cloud-radiation feedbacks in the Arctic.

One of the most striking findings of the experiment is the persistence of mixed-phase clouds and thin multiple cloud layers during all seasons, observed by surface-based cloud radar and lidar and also by aircraft. These aspects of the Arctic clouds present considerable difficulty both to their modeling and sensing from satellites. Preliminary modeling studies indicate that accurate treatment of the Arctic mixed-phase clouds requires additional prognostic equations in climate models, specifically cloud particle concentration and supersaturation, to be used with a specified or interactive field of atmospheric aerosol.

The combination of active (radar and lidar) and passive (visible, infrared, microwave, and millimeter-wave) sensors has shown substantially improved success in the remote sensing of these complex cloud types. This suite of remote sensing instruments, not yet available in space, is providing valuable information as the community prepares for the unique opportunity during the period 2003–2004, when lidar (Icesat, PICASSO-CENA) and radar (Cloudsat) will be space-borne.

The SHEBA experiment has provided an ideal data set for evaluating satellite estimates of surface temperature, albedo, and radiation fluxes.

Using AVHRR data along with simple models, new techniques are being developed to determine all-sky (rather than only clear-sky) values of surface temperature and albedo. Because of the influence of clouds on both the surface temperature and albedo, clear-sky values (which are typically retrieved by satellite) can be significantly different from the all-sky values. The surface albedo observations obtained during SHEBA have been used to evaluate eight sea ice albedo parameterizations. The results show that these parameterizations yield very different representations of the seasonal cycle of sea ice albedo. Two sea ice albedo parameterizations (one simple, one complex, but showing the same annually averaged albedo during SHEBA) were incorporated into a single-cell ice thickness distribution model. The surface albedo parameterization with more complex dependence on surface features gave a degraded simulation of surface albedo because the simulation of certain surface features was deficient. The albedo parameterization with the more complex dependence on surface features showed a significantly larger ice albedo feedback for a warming perturbation than did the simple albedo parameterization.

Central to the remote sensing of clouds and determination of the surface radiation flux is accurate observation of sea ice surface features. Aircraft imaging (visible and microwave) during SHEBA and FIRE allowed high-resolution interpretation of the complex sea ice features (such as melt ponds and leads) that are too small to be seen individually from satellite. It is anticipated that these observations will particularly help with the ambiguities in summer ice concentration observations that are currently determined from satellite.

Arctic Ocean Surface Properties and Fluxes

The surface of the Arctic Ocean is a critical pathway within the Arctic climate system. If we understand the quantities of heat and moisture exchanged at the surface, we have a useful handle on the climate roles of the ocean and atmosphere, individually and jointly. This is one motivation for the emphasis of NASA's Polar Exchange at the Sea Surface (POLES) project on Arctic surface properties and fluxes. Another is the extremely rich, but poorly mined, veins of data that can be extracted from the in-situ and satellite data sets of the last 20 years. POLES is a NASA interdisciplinary project that has focused on key questions related to processes that occur at the atmosphere-ice-ocean interface.

What is happening in the Arctic has excited the

interest of the climatology community. Atlantic Water (approximately 300 m deep) within the Arctic Ocean is warmer than ever observed and is penetrating farther into the basin. Sea ice is declining in extent and probably in thickness. The Arctic atmosphere has had a weakened anticyclone in the 1990s, leading to a much changed sea ice circulation, mass field, and export. Global temperatures in 1998 were the warmest in a 150-year record.

The heat and moisture supply to the Arctic is by advection from lower latitudes. Until recently these processes could be quantified only by sparse rawinsondes or weather model re-analyses flawed by poor moisture and boundary layer processes. Using TOVS PathP temperature and moisture retrievals, the POLES team has computed a new 18-year climatology of moisture flux into the Arctic, as well as precipitation, evaporation, and net precipitation. Improvements to the surface winds from the National Center for Environmental Prediction (NCEP) re-analysis have been computed.

In the polar regions the surface heat balance and vertical heat fluxes are dominated by radiation. A crucial question that cannot be answered yet is whether clouds and the Arctic radiation balance are changing, as are other components of Arctic climate. To compute radiation correctly one must have the correct cloud amounts and properties. The POLES team has produced a new cloud data set from TOVS and has provided the algorithms for another to be computed from AVHRR. Both are substantial improvements over alternative cloud data sets from ISCCP or weather model re-analyses.

POLES has been contributing to the investigation of climate change in the Arctic using the POLES ice-ocean model. By forcing the model with 40-year NCEP atmospheric data and with a better, but shorter, POLES forcing data set, the POLES team has analyzed variability in the model output. In 1998 the POLES project reported an increase in the inflow of warm Atlantic Water. In 1999 the POLES team found a 20% decrease in modeled sea ice mass in the last decade, forced by changes in atmospheric circulation that have considerably altered patterns of ice advection, growth, and melt in the whole Arctic. The team is exploring whether submarine data substantiate this drop in ice mass. The model predicts that ice extent will decrease as seen in satellite observation. The POLES team is studying the space and time variations in ice growth and melt and will provide this model output as an ocean buoyancy flux data set.

Arctic research has always been data-limited.

POLES has set out to ameliorate this predicament by creating new data sets and has focused in particular on the two-decade record that can be constructed from Nimbus and NOAA and newer satellites and from the Arctic buoys. Both data sources date from 1979. These data sets can make a valuable contribution to our understanding of the Arctic seasonal cycle and interannual variability and a small contribution to interdecadal studies, for which longer data sets such as the weather model re-analyses are better. The 20-year record up to the present is also the perfect preparation for proper utilization of the new EOS sensors. Beyond the realm of satellites, POLES has provided the community with the Arctic hydrographic climatology, the 2-m air temperature, and the ice-ocean model forcing data set.

The Arctic and Climate

Results from the Goddard Institute for Space Studies (GISS) Global Climate Model experiments show that for both the recent past and future projections, climate change is a strong function of sea ice change in the Arctic. Globally, when sea ice is not allowed to change, surface air temperature sensitivity to doubled CO_2 is reduced by 37%. The contribution of Arctic sea ice variation to CO_2 -temperature sensitivity is a strong function of sea ice thickness; with greater sea ice thickness, the sea ice is more difficult to remove in a doubled CO_2 warming experiment, and therefore the global warming is less. For the last 50 years, changes in surface air temperature in the Northern Hemisphere are a strong function of changes in sea ice coverage that have occurred. The results emphasize the importance of providing good observa-

tions of both sea ice coverage and sea ice thickness, both mean values and observed variations, to modelers. The GISS model will continue to be used to investigate the role of the Arctic in climate change, providing an important service in establishing the role of the polar oceans in the climate system.

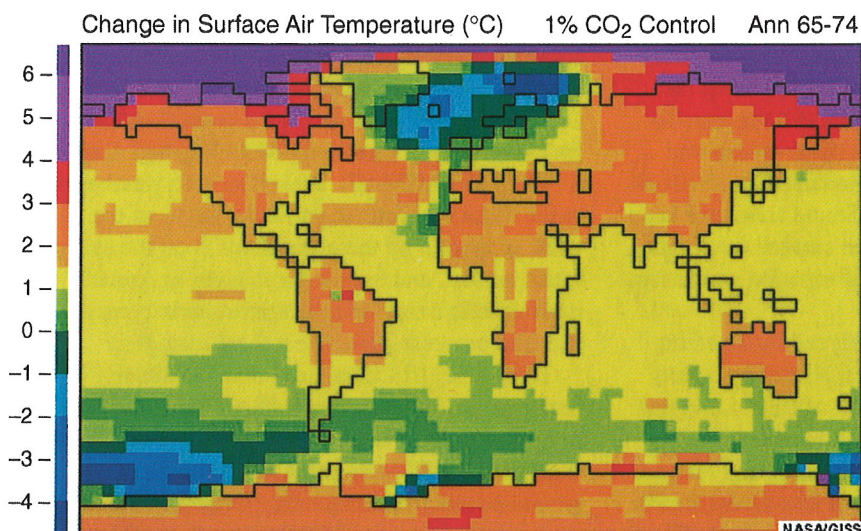
Ice Processes in the Polynyas of the Northern Hemisphere Marginal Seas

The importance of the marginal Arctic and sub-Arctic polynyas (areas of persistent open water within ice-covered regions) relates to their role in ice formation and ocean-atmosphere heat transport, their high biological productivity, and their control on the production of water masses that influence conditions across the rest of the oceans. NASA research during 1998-99 has focused on polynyas in the Sea of Okhotsk, the Bering Sea, and the Baffin Bay region of the Labrador Sea.

During winter in the Okhotsk Sea, the sea becomes 50–80% ice-covered, and the major ice-producing polynyas occur along the northwest coast, in Shelikhov Bay, and in the sea ice over the 200-m deep Kashevarov Bank. For each of these polynyas, a combination of passive microwave, SAR, and AVHRR have been used to determine the distribution of ice types and ice growth as a function of time. The coastal polynyas are driven by the strong, cold northerly winds that are generated by the interaction of the Siberian high and Aleutian low-pressure systems. The Kashevarov polynya is oceanographically maintained by a strong tidal resonance over the bank, where the turbulent mixing induced by the tides generates warm water upwelling, keeping the bank ice-free. The dense water generated in the northwest coastal polynyas flows to the east, then south along the east side of Sakhalin Island. South of Sakhalin, it mixes with other water masses, then enters the North Pacific through Bussol Strait, where it contributes to the North Pacific Intermediate Water (NPIW). The Shelikhov dense water directly enters the deep Okhotsk, and the fate of the water cooled by the Kashevarov upwelling is unknown.

The Sea of Okhotsk polynya work is being applied in two different ways. First, it is part of a three-year oceanographic and remote sensing study (1999–2001), which involves polynya monitoring by remote sensing, oceanographic conductivity-temperature-density (CTD) surveys within the Sea of Okhotsk, and oceanographic instrumentation of the shelves and of Bussol Strait, which is the major outflow passage between the Okhotsk

Predicted surface air temperatures in 2070, from the NASA Goddard Institute for Space Studies. The model predictions are based on a 1% increase in CO_2 per year, resulting in a doubling of atmospheric CO_2 by 2070. Predicted temperature rises are largest in the Arctic.



and Pacific Ocean. The project goals are to monitor the production of the polynya dense water and to determine the flux of this water into the North Pacific, to see if remote monitoring of the NPIW production is feasible. Second, using passive microwave and meteorological data for the period 1979–1998, a 20-year time series of the ice and dense water production of the shelf polynyas has been derived. Comparison of these time series with the Arctic Oscillation (AO) time series shows a large correlation between the two, with a major drop in the ice and brine production occurring at the time of the 1989 AO shift. Also, in a related winter 1999 Bering Sea experiment, a similar field and remote sensing study has just been completed that compares the remotely sensed properties of the St. Lawrence Island polynya with a detailed over-winter current meter and CTD deployment in the polynya region.

In Baffin Bay a combination of remote sensing and in-situ data have been used to drive a data assimilation model for the purpose of establishing the amount of energy lost through the North Water polynyas and quantifying the importance of the North Water polynyas to the overall thermodynamics of the bay. The model used is a two-dimensional dynamic–thermodynamic ice model coupled to a three-dimensional ocean model with turbulence closure. The simulations have been run at a temporal resolution of 30 seconds (ocean) and 2 minutes (ice) over the year of 1998. Atmospheric forcing is based on the NCEP re-analysis fields, with higher-resolution meteorological information obtained from eight fixed stations (including Carey Island in Smith Sound) and automated weather stations deployed as part of the Canadian North Open Water (NOW) project. The assimilation portion of the model incorporates remotely sensed ice cover measurements. Daily ice fractions over the entire bay have been estimated from SSM/I using the NASA Team Algorithm with local tie points. To incorporate higher-resolution observations and assimilate ice thickness, 37 Radarsat ScanSAR-B images of the critical Smith Sound area have been manually classified into seven surface cover categories. All of the ice cover information was resampled to the model domain.

The model output was analyzed by summing and averaging the various heat flux components over areas corresponding to all of Baffin Bay and the North Water. The results showed that Baffin Bay has a very dynamic evolution during the year. The average ocean surface heat loss across Baffin Bay in 1998 was calculated to be 75 W/m². The

heat loss was calculated from sensible and latent heat flux densities, the net radiation balance, and the energy used for ice formation.

During winter and spring, variability in ocean surface heat loss (100–200 W/m²) in Baffin Bay is dominated by changes in the North Water. In April the North Water accounts for 27% of the total Baffin Bay heat loss. During summer the heat loss of the entire bay drops to near zero, and there are a few short periods when the bay actually gains energy from the atmosphere. During autumn the North Water accounts for only 11–17% of the total Baffin Bay heat loss, and during winter the thin ice cover in the polynyas again dominates the surface energy balance, with values ranging between 150 and 200 W/m² for the polynya regions. On an annual basis the North Water (about 11% of the area) is responsible for about 22% of the heat loss of Baffin Bay and about 67% of the ice production. This study is being extended to cover the 1989–1998 period in order to derive the long-term means, trends, and interannual variability of heat transfer and ice production in Baffin Bay and the North Water.

Polynyas represent areas of strong interdisciplinary interest to NASA and will continue to be studied to shed light on key biological and physical processes that can help to address questions related to biological productivity and climate.

The Arctic Atmosphere

NASA supports a number of tasks related to measuring and understanding chemical and dynamic processes in the Arctic atmosphere from the upper troposphere through the stratosphere and lower mesosphere. Such studies include measurements and their subsequent analyses using space-, aircraft-, balloon-, and ground-based instruments. These activities are accomplished through NASA's Upper Atmosphere Research Program (UARP) and Atmospheric Chemistry Modeling and Analysis Program (ACMAP), as well as via a number of space flight missions. A particular focus of the work supported by these programs is on the seasonal, annual, and long-term changes in Arctic stratospheric ozone and the atmospheric constituents and processes that affect these changes.

The SAGE III Ozone Loss and Validation Experiment (SOLVE) is a NASA/UARP-led field campaign that utilized the NASA ER-2 and DC-8 research aircraft, high-altitude balloons, and ground-based and satellite instruments in the Arctic during the winter of 1999–2000. One of the

goals of the SOLVE campaign was to obtain important data for calibrating and validating the new version of the Stratospheric Aerosols and Gases Experiment (SAGE III) satellite instrument. SAGE III builds on the accomplishments and capabilities of the instrument lineage of the Stratospheric Aerosol Measurement (SAM), SAGE, and SAGE II. SAGE III is an important component of NASA's EOS program and has the role of providing global, long-term measurements of key components of the earth's atmosphere, including the vertical distribution of aerosols and ozone from the upper troposphere through the stratosphere. The first SAGE III instrument is planned to be launched on a Russian Meteor 3M weather satellite and because of its orbit will be focused on high-latitude observations. Unfortunately, because of delays imposed by the Russian Space Agency, which is responsible for the spacecraft and launch, SAGE III will not be in orbit until late in 2000. Real-time correlative measurements were made during SOLVE with other satellite instruments that measure ozone, aerosols, and other atmospheric constituents at high latitudes (such as POAM II on the SPOT 5 satellite).

Another primary purpose of the SOLVE campaign was to evaluate the potential of Antarctic-like ozone losses occurring in the Arctic. This objective is driven by recently observed Arctic ozone losses that have reached levels that are becoming comparable to early Antarctic losses. The large Arctic losses observed over the last decade cannot be explained adequately by current atmospheric models. This lack of understanding undercuts our ability to predict future ozone losses and ultimately to describe the features and time scale of expected ozone recovery in a future atmosphere with changing abundances of carbon dioxide, water vapor, methane, and sulfate aerosols and changing dynamics and temperature.

The 1997 Photochemistry of Ozone Loss in the Arctic Region in Summer (POLARIS) aircraft campaign was designed to understand the seasonal behavior of polar stratospheric ozone as it changes from very high concentrations in spring down to very low concentrations in autumn. Very recent analysis of POLARIS data has provided an improved understanding of the partitioning of the NO_y and Cl_y reservoirs. The enhanced and uninterrupted solar illumination at summer high latitudes increased the abundances of NO_x within the NO_y reservoir and the associated catalytic loss of ozone. Models using currently recommended rate coefficients and photochemical parameters

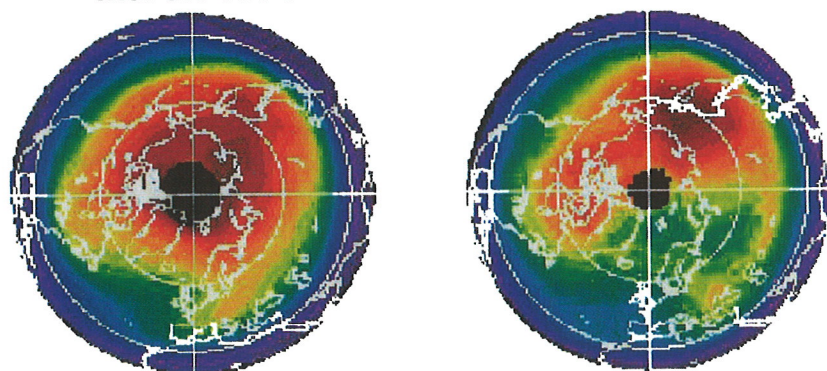
show unsatisfactory agreement with the NO_x to NO_y ratio measured during POLARIS. This has prompted new and improved laboratory studies of several reactions, the results from which greatly improve the model-observation agreement. New ER-2 instrumentation during POLARIS allowed for more complete measurements of the chemical species that make up the Cl_y reservoir. The evaluation of the partitioning within this reservoir observed during POLARIS demonstrates a good understanding of chlorine photochemistry throughout the lower stratosphere.

Measurements of the distribution of total ozone over the Arctic have continued with the total ozone mapping spectrometer (TOMS) series of instruments. Most recently TOMS instruments were launched aboard NASA's Earth Probe (EP) satellite in July 1996 and another aboard the Japanese ADEOS satellite in August 1996. The ADEOS-TOMS operated until the failure of the ADEOS satellite in June 1997. The TOMS-EP satellite instrument, while continuing to gather data well beyond its originally projected lifetime, has experienced mechanical problems over the past year that cast doubt on its ability to last much beyond 2000. The next generation of TOMS, the Ozone Mapping Instrument (OMI), is planned for launch on EOS/CHEM in December 2002. Because of the critical need to continue the acquisition of the total ozone data without interruption through the launch of EOS CHEM, NASA has contracted to launch a remaining TOMS instrument on a small, rapid-response satellite, Quik-TOMS.

The TOMS observations have proved very useful in showing the interannual variability of ozone loss over the Arctic. The lowest ozone column amounts seen over the Arctic in the winter of 1996-97 were as much as 40% below comparable amounts seen early in the TOMS record (1979-80), when the Nimbus 7 satellite provided TOMS data. These low values were caused largely by the presence of low temperatures throughout much of that winter and a lack of atmospheric wave activity that allowed for a stable polar vortex to last well into March. The region of ozone depletion was centered over the pole for most of its existence, which lasted until the breakdown of the polar vortex in April 1997. The following two winters, 1997-98 and 1998-99, were much more benign for ozone loss, with the absence of either prolonged low temperatures or a long-lived stable polar vortex. However, the winter of 1999-2000 had large regions of temperatures low enough to form the

March 1971

March 1998



Change in ozone distribution in the Arctic from March 1971 to March 1998, as revealed by the total ozone mapping spectrometer. The picture of stratospheric ozone reduction in the Arctic is less consistent than in the Antarctic but remains an important subject for continued monitoring.

240 310 380 450 520
Total DU

polar stratospheric clouds (PSCs) needed to transform the ozone-destroying chlorine into its active form. The evolution of the stratospheric meteorology through the spring of 2000 when sunlight returned permitted extreme levels of ozone depletion over large regions of the Arctic. Loss rates approached 2% per day in March 2000.

The lowest ozone column amount seen in the Arctic in the spring of 1997, 219 Dobson Units (DU, 1 DU = 1 milli atm cm, or corresponding to 2.67×10^{16} mole/cm²), is still much above the corresponding amounts seen over the Antarctic in September and October. The region of low ozone seen in the Arctic is also appreciably smaller (roughly threefold) than that seen in the Antarctic. Demonstration that this ozone depletion takes place in the lower stratosphere was provided by data from the Upper Atmosphere Research Satellite (UARS), as well as the POAM II satellite instrument, balloon-borne ozonesondes, and ground-based lidars. Measurements of trace chemical species in the Arctic stratosphere are made regularly by the UARS satellite. A particularly important set of measurements are those of the microwave limb sounder (MLS), which measures O₃ and ClO, the active form of atmospheric chlorine that catalytically destroys ozone. MLS measurements have been useful in pointing out the abundance of high levels of ClO in the Arctic.

The Halogen Occultation Experiment (HALOE) on UARS provides another important set of atmospheric chemical data for understanding the potential for future ozone loss in the Arctic. HALOE is able to measure profile concentrations of the atmospheric chlorine reservoir species HCl. These

measurements have recently shown that the abundance of HCl in the upper stratosphere has begun to decline, an expected result of declining amounts of chlorine source compounds in the troposphere. MLS, however, has measured record high ClO and low ozone values at high northern latitudes in the spring of 1997. Because of slightly higher temperatures and less persistent confinement, Arctic ozone losses have not been as severe as in the Antarctic. Interannual variability in the dynamical conditions of the Arctic vortex is in general greater than in the Antarctic, and ozone distributions in the winter and spring will therefore have much greater interannual variation than in the Antarctic. A slight cooling of the stratosphere due to increasing concentrations of radiatively active gases in the troposphere has the potential to exacerbate and increase the frequency of ozone depletion in the Arctic through the formation of increased amounts of polar stratospheric clouds. Even though the stratospheric abundances of chlorine are beginning to decline, trends in other trace species and temperature can delay and diminish any expected recovery of Arctic ozone.

Arctic atmospheric measurements with a suite of ground-based instruments and with small balloon ozonesondes are routinely made as part of the activities of the international Network for Detection of Stratospheric Change (NDSC). The sites for the Arctic component of these measurements are Eureka, Canada; Ny Ålesund, Spitsbergen; and Thule and Søndre Strømfjord, Greenland. Measurement activities at these sites include ozone, aerosol, and temperature lidars; Fourier transform spectrometer measurements of a large range of species such as HCl, HF, O₃, HNO₃, and N₂O; microwave measurements of ozone, water vapor, and ClO; UV/visible spectrometer measurements of NO₂, ozone, OCIO, and BrO; Dobson/Brewer measurements of total column ozone; and ozone profiles with ozonesondes. NDSC observations over the last two years show that conditions in the Arctic stratosphere were unfavorable for ozone loss, a corroboration of the satellite data.

NASA's UARP and ACPMAP continue to support measurements and multidimensional models for atmospheric chemistry and transport needed to study the global atmosphere. The mission results presented above underscore the necessity to include the full range of dynamical, radiative, and chemical processes in models that are used to predict future ozone losses given prescribed scenarios for emission of CFCs, their substitutes, and other chlorine- and bromine-containing compounds.

Department of Commerce

National Oceanic and Atmospheric Administration

NOAA performs research in the high-latitude regions of the planet in connection with its environmental assessment, monitoring, and prediction responsibilities. Research programs focus on scientific questions addressing the Arctic environment and its relation to the global environment.

National Marine Fisheries Service

National Marine Mammal Laboratory

NMFS's Protected Resources Management Division and the National Marine Mammal Laboratory are responsible for protection, management, and research on 22 species of marine mammals that commonly occur in Alaska, including five endangered species (bowhead, fin, humpback, northern right, and sperm whales), one threatened species (Steller sea lion), and one depleted species (northern fur seal). Protection involves implementing recovery plans for the Steller sea lion and the humpback whale, implementing the Northern Fur Seal Conservation Plan, developing and implementing a conservation plan for the harbor seal, and cooperating with the International Whaling Commission regarding subsistence takes of bowhead whales. In 1994, Congress amended the Marine Mammal Protection Act (MMPA), adding several new sections, including one pertaining to cooperative agreements in Alaska. The amended MMPA notes that "The Secretary may enter into cooperative agreements with Alaska Native organizations to conserve marine mammals and provide co-management of subsistence use by Alaska Natives." The amendments specifically provide NMFS with the authority to award grants to Alaska Native organizations to:

- Collect and analyze data on marine mammal populations;
- Monitor the harvest of marine mammals for subsistence use;
- Participate in marine mammal research; and
- Develop co-management structures with Federal and state agencies.

NMFS's Alaska Regional Office has developed a program to determine subsistence takes of

	Funding (thousands)	
	FY 98	FY 99
Atmos Trace Constituents	34	40
Fisheries Assessment/Management	5,984	7,374
Marine Mammal Assessment	2,300	3,050
Coastal Hazards	50	50
Ocean Assessment	95	160
Stratospheric Ozone	2	2
Satellites/Data Management	292	325
Remote Sensing	208	279
Aircraft/Vessels	1,515	1,515
Climate and Global Change	382	416
Arctic Ice	150	150
Weather Research	102	165
West. Arctic/Bering Sea Ecosystem	2,072	2,114
Barrow Observatory	250	300
Undersea Research	134	0
Arctic Research Initiative	1,500	1,650
Total	15,070	17,590

Steller sea lions, harbor seals, and beluga whales. Through contracts with the Alaska Department of Fish and Game, the Cook Inlet Marine Mammal Council, and the Alaska Native Marine Mammal Hunters Committee, comprehensive data on the number of animals taken for subsistence, or struck and lost, each year from 1992 through 1996 have been collected. These data are critical in determining whether these animals should be listed as "strategic" under MMPA. For several years the Alaska Regional Office has supported and partially funded the Alaska Native Harbor Seal Commission and is working to establish a Native commission for managing Steller sea lions. The office continues to work with the Indigenous People's Commission for Marine Mammals, the Pribilof Islands Joint Management Board, the Alaska Beluga Whale Committee, and several other groups to further conservation of marine mammals taken for subsistence. NMFS has continued the systematic

collection of tissue samples from Steller sea lions, harbor seals, and beluga whales in Alaska to determine whether contaminant levels in tissues intended for human consumption are at acceptable levels and also to aid in stock determination. NMFS has also been instrumental in spearheading efforts to overcome the negative impacts of development on the Pribilof Islands by working with the Coast Guard, EPA, the U.S. Army Corps of Engineers, Alaska state agencies, and the residents and governments on St. Paul and St. George Islands. Finally, NMFS has been working with Russian and American marine scientists to support additional research on local problems and on the health of the overall Bering Sea ecosystem.

Field research at the National Marine Mammal Laboratory on marine mammals off central and northern Alaska has concentrated on five species in recent years: Steller sea lions, harbor seals, northern fur seals, beluga whales, and gray whales. In FY 97, a survey was initiated to determine the abundance and distribution of small cetaceans within 200 miles of the coastline. Alaskan coastal waters from Dixon Entrance to Bristol Bay were divided into three regions, corresponding to stock boundaries for the harbor porpoise, and surveys were completed in one region each year from 1997 to 1999. The initial results of these surveys indicate that the abundance of harbor porpoises in the Gulf of Alaska is significantly higher than previous estimates, most likely due to a difference in the habitat surveyed. Conversely the estimate of harbor porpoise abundance in southeast Alaska was not significantly different from earlier estimates.

The breeding range of the Steller sea lion extends from the Kuril Islands and the Sea of Okhotsk, eastward through the Aleutian Islands and the Gulf of Alaska, and then south to central California. The number of sea lions throughout the range has declined by over 66%, from about 300,000 in the 1960s to 116,000 in 1989. The first range-wide survey in 1994 indicated a further decline. At present the area from southeastern Alaska through Oregon is the only region where the number of animals is not declining. Counts of animals in rookeries and haulout sites within most of Alaska showed a rapid decline between the 1970s and 1989 and a continued but slower decline from 1989 to 1996. The causes for this decline have not been identified.

In 1990, Steller sea lions were listed under the Endangered Species Act as threatened throughout their range. No evidence existed then to separate

the species by stock. Subsequently the National Marine Mammal Laboratory and university scientists conducted joint studies that have shown genetic differences supporting a separation in the Gulf of Alaska. These genetic data, along with supporting data on the size of pups, movement patterns, fidelity to birth sites, and population trends, were judged sufficient to warrant separation of the species into two management units, a western stock and an eastern stock. The population of the eastern stock has remained stable over the past 20 years, but the western stock continues to decline, culminating in its status changing to endangered in June 1997. The eastern stock remains listed as threatened.

Research on the Cook Inlet beluga whale population has been conducted annually over the last seven years. The primary focus of beluga whale surveys has been in the Cook Inlet region. Here, in cooperation with the Alaska Beluga Whale Committee, the Cook Inlet Marine Mammal Council, the Alaska Native Marine Mammal Native Hunters Committee, the Alaska Department of Fish and Game, and NMFS's Alaska Regional Office, scientists have attempted to determine the abundance of a relatively small and isolated population. Aerial surveys have indicated that the abundance of Cook Inlet beluga whales declined by nearly 50% between 1994 and 1998. The abundance estimated from the June 1998 aerial counts was 437 whales. Research has also been directed toward catching whales and outfitting them with radio and satellite tags to determine movement patterns and correction factors for aerial surveys. Efforts are underway to determine if the number of animals in Cook Inlet is sufficient to support recent subsistence harvests of approximately 70 animals per year.

The Marine Mammal Health and Stranding Response Program (MMHSRP) was established in 1992 to facilitate the collection and dissemination of data on the health of marine mammals and health trends in marine mammal populations in the wild; to correlate these trends with available data on physical, chemical, and biological environmental parameters; and to coordinate effective responses to unusual marine mammal mortalities. In 1987 the Minerals Management Service provided funds to NOAA to establish and conduct the Alaska Marine Mammal Tissue Archival Project (AMMTAP) for the collection and long-term storage of tissues from Alaskan marine mammals. AMMTAP continues now in conjunction with MMHSRP with funding provided from NMFS and DOI's Biological Resources Division of the U.S. Geological Survey.

The program involves the participation and cooperation of Federal agencies, state agencies, international organizations, universities, and Native American organizations. Samples continue to be collected to determine the levels of contaminants in Alaskan marine mammals, to determine the health of populations, and to examine correlations between health and contaminant levels. In addition, the data are being used by public health organizations to examine circumpolar patterns of chlorinated hydrocarbon concentrations and the potential risk to people who eat marine mammals as subsistence foods.

MMHSRP has involved the evaluation of health and contaminant issues through the analysis and banking of marine mammal tissues from subsistence hunting activities. NMFS's Environmental Conservation Division has led the analysis of these tissues for contaminants in collaboration with the National Institute of Standards and Technology (NIST) and other international research laboratories. These tissues were analyzed for a variety of purposes:

- Ongoing monitoring (Steller sea lions and beluga whales);
- Specimen banking (beluga whales, bowhead whales, and harbor seals); and
- Ongoing studies to determine the impact of contaminants on marine mammal health.

In FY 96 and 97, over 500 samples were acquired or analyzed for chlorinated hydrocarbons and essential and non-essential elements.

NIST serves as the repository for the archived tissues and sera from Arctic animals. Samples are cryogenically frozen and stored for future analyses as needed when new methods are developed or as new questions are asked. A quality assurance component, spearheaded by NIST, monitors the collection and analyses of these samples to ensure the consistency and accuracy of data. Two interlaboratory comparisons were performed in recent years, and tissues were collected and analyzed for a new beluga whale liver control material.

Finally, health issues in marine mammal populations are addressed through cooperation with the Armed Forces Institute of Pathology and the Department of Agriculture. Tissues from the animals are being analyzed for evidence of disease and will be stored for future analyses as needed. Sera from these animals have been banked for future studies of the presence of antibodies to specific diseases. In addition, analyses are being performed to monitor the presence of diseases of current concern.

All of the data collected are centralized into a database that can be accessed by researchers and managers. The information collected will help managers make risk assessment and impact decisions regarding marine mammal populations in the Arctic. In addition, these data will contribute to our knowledge about the presence and possible effects of anthropogenic contaminants present in the Arctic ecosystem.

Resource Assessment and Conservation Engineering Division

Marine Fisheries Assessment. NMFS continued its long-standing commitment to assessment studies of U.S. living marine resources in the Bering Sea, Aleutian Islands, and Gulf of Alaska during FY 98 and 99. This effort includes fishery-independent resource surveys, collection of data from commercial fisheries through fisheries observers, collection of recreational and commercial harvest statistics, and basic population biology and ecological research. The scientific information generated by these activities supports Federal fishery conservation and management responsibilities in the 200-mile U.S. Exclusive Economic Zone.

The Alaska Fisheries Science Center (AFSC) in Seattle continues to annually assess the stock condition for most species of marine finfish and shellfish having commercial, recreational, or ecological significance in western U.S. Arctic waters (the Bering Sea, Aleutian Islands, and Gulf of Alaska). These assessments provide measures of population abundance independent of those derived from analyses of catch and landing statistics, and they also address the status and health of the marine ecosystem as a whole. Information syntheses incorporate identification of stock units, short-term prediction of abundance trends, biological interaction of species and species groups, and general ecosystem response to environmental change. When combined with data from the commercial fleet (such as fishing effort, location, catch composition, and fish size and age) collected through the AFSC's Observer Program, AFSC stock assessments provide recommendations for managing the fisheries and conserving the supporting resource base.

Living marine resource populations are sampled at sea aboard NOAA ships, chartered fishing vessels, and cooperating foreign research vessels. Significant area-extensive survey efforts rotate every three years between the eastern Bering Sea, the Aleutian Islands and the Gulf of Alaska, and the west coast of the U.S. During intervening

years, standardized AFSC assessment surveys are conducted within each region. Annual estimates of stock abundance are completed for commercially important species, such as walleye pollock, Pacific cod, sablefish, yellowfin sole, and king and tanner crabs. Dedicated scientific cruises are also conducted to study biological and physical processes that affect stock assessments.

The principal survey methods include bottom trawls for demersal fish and crabs, hydroacoustic and midwater trawls for semipelagic fish, and special purpose nets for eggs, larvae, and juvenile fish and shellfish. Trawl and acoustic surveys are used to estimate biomass and define community structure; biological collections are taken to examine variability in growth, mortality, and stock recruitment.

Recruitment indices and processes that generate variations in abundance are studied to improve prediction through the Fisheries–Oceanography Coordinated Investigations (FOCI). FOCI is a cooperative program between AFSC and NOAA’s Pacific Marine Environmental Laboratory (PMEL) in Seattle. To increase the accuracy and precision of these assessments, AFSC scientists conduct biological research to define recruitment processes, develop computer models to simulate interactions and dynamics of population change, and conduct or collaborate in extramural studies to improve sampling methods and survey designs.

Pacific Salmon. The five species of Pacific salmon in the Alaska region are one of the Nation’s most valuable resources. The salmon in the vast marine areas off Alaska are managed via a complex mixture of domestic and international bodies, treaties, regulations, and agreements. Research objectives are to:

- Assess interception rates of U.S. stocks in boundary fisheries associated with the Pacific Salmon Treaty;
- Assess impacts on North American stocks from large releases of Asian hatchery stocks;
- Support the Ocean Carrying Capacity Program; and
- Determine the origin of salmon incidentally caught in domestic groundfish fisheries.

Ocean Carrying Capacity. Auke Bay Laboratory’s Ocean Carrying Capacity Program continues the NMFS role in the stewardship of living marine resources of the North Pacific. Early research efforts focused on measuring and assessing the effects of various high-seas fisheries such as the Japanese mothership salmon fishery and the high-seas driftnet squid fisheries. Much of the exper-

tise, biological methodology, and working relationships developed while addressing those issues are now directed toward understanding the effects of environmental and biological interactions on the productivity of the North Pacific. This research program bridges the gap between ongoing coastal ecosystems studies in Prince William Sound and the high-seas Carrying Capacity and Climate Change study developed by the North Pacific Marine Sciences Organization and North Pacific Anadromous Fish Commission scientists from Canada, Japan, Russia, and the U.S. For the past several years, research activities have included:

- Salmonid growth studies, using scale patterns as an indicator of freshwater and ocean growth patterns;
- Salmon energetics studies, linking basic physiology and behavior with habitat conditions to evaluate the effects of changes in temperature and predator/prey densities on growth, consumption, and ultimately trophic interactions;
- Field and laboratory studies of oceanographic conditions, phytoplankton and zooplankton abundance, and salmon abundance, distribution, and stock origins; and
- Stock identification studies, which are part of an international, multi-agency program to develop comprehensive genetic, scale pattern, parasite, and tag recovery databases for stock identification of North Pacific salmonids.

Survey efforts in support of these activities have ranged from the inside waters of southeastern Alaska to the Aleutian Islands.

National Ocean Service

NOAA’s National Ocean Service conducts environmental research and monitoring, performs information synthesis, and disseminates data and information products to support management decisions affecting coastal and marine resources and environments in the U.S. Arctic. These activities date back to 1974 as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), which was established under an inter-agency agreement between NOAA and the Bureau of Land Management. The program was designed to plan, conduct, and report on a suite of multidisciplinary studies responding to the specific needs, goals, and objectives of the Department of the Interior in its decisions on oil and gas leasing off the coast of Alaska. From 1974 to 1992, OCSEAP produced a mammoth record of research reports and other data products, culminating in a 74-vol-

ume series of OCSEAP final reports and a bibliography consisting of over 4000 entries. OCSEAP research and information products, such as oil spill trajectory and weathering models, seismic exposure analysis models, avian energetics models, and many innovative research protocols, are largely responsible for expanding our understanding of both the physical environment and biological resources of coastal and offshore Alaska. Interpretation and synthesis of OCSEAP still continue to identify and delineate a number of environmental and resource management issues, such as elevated levels of metals, notably cadmium, in sediment and biological tissues, particularly in reference to Pacific walrus.

Since 1984, NOAA's National Status and Trends (NS&T) program has sampled sediment and biota (mussels and demersal fish) at several sites in Alaska to determine the levels and temporal trends of contaminants, including toxic trace elements, a variety of pesticides, petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs), and a number of chlorinated industrial chemicals, such as polychlorinated biphenyls. The sampling sites are located in the Gulf of Alaska, Bering Sea, Chukchi Sea, and Beaufort Sea. Although sampling frequency is low, the results based on sampling efforts during 1984–1992 have recently been compiled in a report and are available on the Internet at <http://seaserver.nos.noaa.gov>. The program is also in the process of establishing a number of permanent sampling sites in the U.S. Arctic.

More recently, since 1993 the NS&T program has been engaged in describing the spatial distribution and scales of contamination from radionuclides in surficial sediment and selected biota in the Arctic, including species that are harvested for subsistence use (anadromous fish, marine mammals, seabirds, and caribou). Using statistical records of subsistence harvests in the North Slope Borough and radionuclide activity in specific tissues and whole animals, the study results demonstrated that there is a very small radiation dose from typical consumption of caribou meat and a virtually negligible dose from consumption of marine foods. These results were instrumental in alleviating widespread public concerns about the quality of traditional food resources in the region following disclosure of widespread dumping of radioactive wastes in the Arctic seas by the former Soviet Union. In addition, separate reports have been prepared on the levels of radionuclides and other contaminants in the Beaufort Sea, the Russian Far East, and the eastern Bering Sea.

NOAA, through ongoing cooperative efforts with the Environmental Protection Agency and the U.S. Air Force, is involved in contamination assessment and recommendations for remedial action at several contaminated sites at Elmendorf Air Force Base, located near Anchorage, Alaska. Similar cooperative efforts are envisaged during clean-up and remediation activities at other contaminated sites in Alaska that are included in the National Priority List.

NOAA/NOS took the lead in synthesizing and reporting on data on petroleum hydrocarbon and PAH contamination in the Arctic. A comprehensive chapter on this subject is included in *AMAP Assessment Report: Arctic Pollution Issues*, published by the Arctic Monitoring and Assessment Program in 1998. A summary of that report, entitled *Arctic Pollution Issues: A State of the Arctic Environment Report*, was published in 1997.

Office of Oceanic and Atmospheric Research

Aeronomy Laboratory

The stratospheric ozone layer protects the earth's ecosystems from biologically harmful solar ultraviolet (UV) radiation. Changes in the nature of the ozone layer could alter the UV radiation reaching complex ecological environments such as those of the Arctic.

The abundance of stratospheric ozone is set by a balance of photochemical production and loss processes and transport of air within the stratosphere. The photochemical processes involve naturally occurring chemicals in the stratosphere, such as nitrogen species, and chemicals released at the earth's surface by human activities, such as chlorofluorocarbons (CFCs). In recent years, anthropogenic emissions of CFCs have caused depletion of the total column of ozone in several regions of the globe. For example, the springtime abundance of polar stratospheric ozone in Antarctica has been perturbed because of the influence of anthropogenically released chlorine in the special conditions of the Antarctic polar climate. Although the springtime Arctic ozone column has not reached the same low values that have been observed in the Antarctic spring "ozone hole," extremely cold northern winters in six of the last nine years have led to unusually low Arctic ozone values. If current international control measures of the Montreal Protocol are followed, CFCs are expected to reach their peak in the stratosphere in about the year 2000. The Arctic stratosphere,

therefore, will remain susceptible to the influence of elevated atmospheric abundances of anthropogenic chlorine for several more years.

Scientists in NOAA's Aeronomy Laboratory (AL) and Climate Monitoring and Diagnostics Laboratory (CMDL) participated in a NASA-sponsored experiment to study the seasonal loss of ozone that occurs during spring, summer, and fall in the Arctic. The field campaigns of the Photochemistry of Ozone Loss in the Arctic Region In Summer (POLARIS) experiment were concluded in September 1997 with the last of 33 flights of the NASA ER-2 high-altitude research aircraft. On-board were NOAA instruments that measured ozone, reactive nitrogen compounds, and tracer species such as halocarbons and nitrous oxide. The Observations of the Middle Stratosphere (OMS) balloon gondola was also deployed and carried NOAA instruments to measure vertical profiles of trace gases and meteorological parameters. A NOAA/AL researcher was mission scientist for POLARIS. Scientists from NOAA, NASA, academia, and other agencies participated in the experiment.

Arctic stratospheric ozone decreases to a minimum value in spring and increases to a maximum in late summer or early fall. Ozone loss results from catalytic loss cycles involving reactions of chemically active nitrogen (NO_y), hydrogen (HO_x), and halogens (chlorine and bromine). The enhanced summertime polar loss is attributed to the increased role of reactive nitrogen [nitric oxide (NO) + nitrogen dioxide (NO_2)] in ozone loss cycles during periods of prolonged solar illumination that occur at high latitudes during summer. The accuracy with which current photochemical models can describe this large natural ozone loss serves as an indication of how well the role of increased stratospheric reactive nitrogen from human emissions (such as aviation) can be quantified. A major objective of POLARIS was to evaluate the level of agreement between model predictions and observations, providing a test of our understanding of the Arctic ozone layer's chemistry and dynamics.

In FY 98 and 99 the comprehensive suite of POLARIS measurements has been analyzed and the findings presented in a special session of the 1998 Fall Meeting of the American Geophysical Union and in several papers in the peer-reviewed literature. A special section of *Journal of Geophysical Research* will publish additional POLARIS findings in FY 00. AL scientists are lead authors of papers that compare observations and model simu-

lations of reactive nitrogen-containing compounds (NO_y). Understanding the mechanisms controlling the abundance of NO_y and its partitioning into component species is essential for understanding the stratospheric ozone layer. Analysis of the POLARIS results shows that the photochemistry of nitrogen oxides is not what it was assumed to be, and nitrogen-containing compounds make a larger contribution to ozone loss than previously thought. Calculations show that very reactive nitrogen dominates the destruction of ozone in the summer polar stratosphere, with significant contributions from the odd hydrogen cycle. This result is notable because earlier studies have shown that other cycles dominate in the midlatitude stratosphere. The outcome modifies estimates of how stratospheric aviation influences the ozone layer.

In another paper first authored by AL scientists, the suite of POLARIS measurements is analyzed with an emphasis on understanding the behavior of nitrogen dioxide (NO_2) in the Arctic stratosphere. NO_2 is an important reactive species in the ozone balance of the lower stratosphere because catalytic cycles involving NO_2 destroy ozone. Quantitative understanding of their role is needed for future predictions. POLARIS measurements of nitric oxide (NO), ozone, chlorine monoxide (ClO), hydroperoxyl radical (HO_2), and radiation were combined with laboratory rate constant measurements to formulate a steady state expression that constrains the abundance of NO_2 . The estimated values in the seasonal POLARIS dataset were in generally good agreement with values inferred from the steady-state expression. The POLARIS measurements and interpretation reveal the validity of the current understanding of reactive nitrogen photochemistry in the Arctic spring/summer/fall stratosphere.

CMDL and AL scientists used the balloon-borne Lightweight Airborne Chromatograph Experiment (LACE) instrument to make measurements of long-lived tracer species at northern high latitudes. The tracers measured by LACE [sulfur hexafluoride (SF_6), chlorofluorocarbons, and halon-1211] provide insight into issues of stratospheric transport, particularly related to the transport of aircraft exhaust. Results, which will be published in the *Journal of Geophysical Research* special section on POLARIS, show that the air in the lower stratosphere is dominated by advection from the stratospheric overworld. The findings also confirm the basic Brewer-Dobson circulation pattern of transport from the tropics to the poles. An additional result is the observation of Arctic polar filament

structures very late in the season (June). Very low tracer values were observed in some air parcels, which are believed to be remnants from a major ozone depletion event formed in a strong and stable vortex over the Arctic in late March 1997. Tracer measurements from ER-2 flights of POLARIS are the subject of another paper by CMDL to be published in the *Journal of Geophysical Research* special section. Results give the first-time observation that the late-1991 tropospheric maximum of an anthropogenic pollutant, in this case methyl chloroform, has propagated into the mid- and high-latitude lower stratosphere.

CMDL scientists and colleagues have published findings from POLARIS and the 1995-96 Stratospheric Tracers of Atmospheric Transport campaigns that have established closure in the total hydrogen budget of the northern extra-tropical lower stratosphere. The measurements provide the first simultaneous observation of all of the main hydrogen reservoirs of the stratosphere (methane, molecular hydrogen, and water). The analysis of the data confirms our picture of photochemistry in the lower stratosphere and reveals no significant trend in lower stratospheric H₂O from 1993 through 1997. The findings have implications for both climate and the ozone layer.

The successful SAGE-III Ozone Loss Validation Experiment (SOLVE) in the winter of 1999-2000 offered another opportunity to examine polar stratospheric ozone loss, but this time during late winter and early spring. This loss was substantial, approaching 50% of the available ozone.

NOAA scientists played prominent roles in the international scientific assessment of the ozone layer. The document, World Meteorological Organization/United Nations Environment Programme's *Scientific Assessment of Ozone Depletion: 1998*, was completed in FY 99 in accordance with the Montreal Protocol on Substances that Deplete the Ozone Layer. Over 300 scientists contributed to the planning, preparation, reviewing, and publication of this document. NOAA scientists participated as co-chair (AL), chapter authors and contributors (AL, AOML, ARL, CMDL, GFDL, NWS), reviewers (AL, ARL, CMDL, GFDL, OGP, NWS), and coordinating editor (AL). The assessment gives "state-of-scientific-understanding" information regarding the earth's ozone layer, including information concerning the Arctic polar region. The executive summary of the document states that "The late-winter/spring ozone values in the Arctic were unusually low in 6 out of the last 9 years, the 6 being years that are

characterized by unusually cold and protracted stratospheric winters. Elevated stratospheric halogen abundances over the next decade or so imply that the Arctic will continue to be vulnerable to large ozone losses." The assessment also points out that it is not possible to predict the behavior of Arctic ozone for a particular year, because the large year-to-year variability in temperature and meteorology in the Arctic stratosphere affect the rate of chlorine-caused ozone destruction.

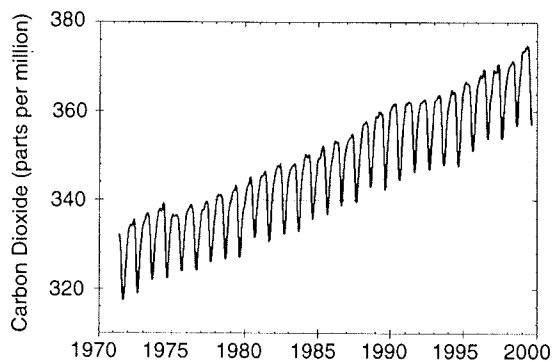
Climate Monitoring and Diagnostics Laboratory

The mission of NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL), which has its main office in Boulder, Colorado, is to conduct monitoring and research related to atmospheric constituents that are capable of forcing change in the climate of the earth through modification of the atmospheric radiative environment and those constituents that may cause depletion of the global ozone layer. This mission is accomplished primarily through long-term measurements of atmospheric trace gases such as carbon dioxide, methane, carbon monoxide, halogenated compounds, nitrous oxide, surface and stratospheric ozone, aerosols, and solar radiation at sites remote from local and regional air pollution. The resulting data are used to assess climate forcing and stratospheric ozone depletion as well as the strength of ultraviolet radiation reaching the surface in response to decreases in stratospheric ozone. These data are used to develop and test predictive models and to keep scientists, policy makers, and the public abreast of the current state of the chemical and radiative balances in the atmosphere.

Monitoring Atmospheric Trace Constituents.

CMDL has operated a manned, atmospheric background monitoring station at Barrow, Alaska, for 27 years. Similar NOAA stations are located at Mauna Loa, Hawaii; American Samoa; and the South Pole that together form the backbone of a global atmospheric monitoring network. Other manned background stations in the Arctic component of the international network are Alert, Northwest Territories (Canada) and Ny-Alesund, Svalbard (Norway). In addition, air is collected in flasks on a weekly basis in a 50-site global network operated by CMDL that includes Arctic sites at Cold Bay and Shemya, Alaska; Ocean Station "M"; Iceland; central Greenland; and Spitzbergen. Vertical profiles of a large suite of trace gases are conducted near Fairbanks, Alaska, on a biweekly basis with an aircraft flying profiles to 8 km (26,000 ft) above sea level. Taken together, data

Carbon dioxide record from the CMDL Baseline Station at Barrow, Alaska, showing the effects of the annual growth of plants (the saw-tooth pattern) on the increasing trend in carbon dioxide concentrations due mainly to fossil fuel combustion.



from these measurements document global changes in key atmospheric species, which are all affected by mankind, and identify causes of inter-annual variability.

Continued Carbon Dioxide Increase in the Arctic. Within CMDL, the Carbon Cycle and Greenhouse Gases group determines the magnitudes and trends of regional-scale sources and sinks of several primary carbon cycle trace gases important in climate change. In addition, air samples are analyzed for the isotopic composition of carbon dioxide and methane to learn about their respective sources. Over the past decade the growth of global atmospheric carbon dioxide continued unabated in the Arctic, but the rate of increase was slightly slower than expected in recent years based on the known increases in emissions from fossil fuel burning. Data from the overall global sampling network have allowed us to conclude that the recent uptake of carbon dioxide by ecosystems in the Northern Hemisphere was significantly higher than during the preceding decades. The reasons for this increased carbon dioxide uptake are not clear, however. One possible factor could be that, as records of the seasonal cycle of carbon dioxide show, the onset of the summer drawdown of carbon dioxide by photosynthesis at high latitudes has shifted earlier into the spring, which is consistent with the observed warming over a large region of the western Arctic.

Earlier Springtime in the Arctic. Using an assimilation of climate data from the Barrow Observatory, the National Weather Service, and other North Slope Alaskan monitoring sites, CMDL conducted detailed process studies to develop a better physical understanding of why the climate of the western Arctic is changing. One important process that occurs over the Arctic tundra is the melting of the seasonal snowpack. Partly in response to warmer winter and spring conditions, the melt in northern Alaska is occurring earlier in the year, with an increase of about 10% in

the length of the snow-free season in the vicinity of Barrow.

This earlier melting of snow has in turn enhanced the absorption of solar energy at the surface by about 10% through a dramatic decrease in average solar reflection from the tundra during a period when the annual cycle of solar insolation is at a maximum. CMDL's analysis shows that the primary factors influencing snowmelt in northern Alaska are related to large-scale changes in circulation patterns that favor decreased snowfall during the winter months and warmer and cloudier conditions during early spring. Whether or not these changes are the consequence of greenhouse warming on a global scale is the focus of ongoing research.

Carbon Dioxide and Methane Emissions Estimates for Siberia. Long-term measurements at Barrow Observatory allow empirical estimates of carbon dioxide and methane emissions from Siberia, a region where reliable emission information is difficult to obtain. CMDL's meteorological and chemical analyses of the continuously dark winter periods show that the relationships among the trace gases are driven by Siberian pollution transported to the Alaskan region. Positive correlations among carbon dioxide, methane, and carbon monoxide and derived emission factors are indicative of industrial activity. The correlations between ozone and these gases are negative because of nitrogen oxide chemistry in the dark and cold. The strong positive correlation between methane and carbon dioxide seen in the data argues for a source that is collocated and continuous with combustion. CMDL attributes the CH₄ excess to leakage at natural gas compression sites and pipelines in northwestern Siberia, where most of Russia's natural gas is produced. Their leakage estimate of 0.7–1% per year of natural gas production is modest compared to most previous estimates for Russia because it represents only the area influencing Barrow. This area does not extend south or west of about 60°N or 155°W, where most population is located and hence where most natural gas distribution and utilization occurs.

CMDL Ozone and UV Monitoring in the Alaskan Arctic. In the last decade, CFCs in the stratosphere have catalyzed ozone depletion in the Arctic region just as they have in the Antarctic. One of the more dramatic recent Arctic ozone depletion events occurred during an approximate two-week period in March 1997, when a satellite-based total ozone mapping spectrometer instrument observed that the ozone levels over a large region centered

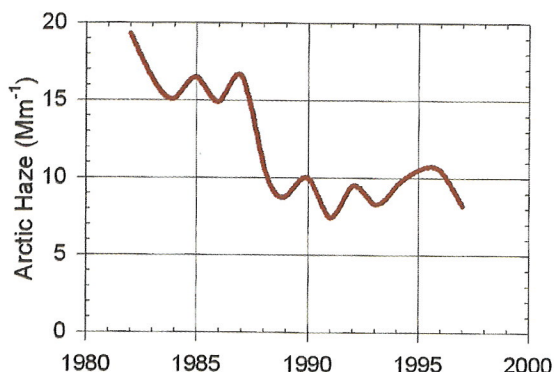
on the North Pole were as much as 40% below normal for that time of year. These reduced stratospheric ozone levels have the potential of allowing more ultraviolet radiation to reach the earth's surface.

At lower Arctic latitudes, observations of total column ozone for winter and spring at Barrow and Fairbanks, Alaska, measured with a Dobson spectrophotometer, exhibit a decreasing trend averaging 6–7% per decade. On an annual basis the decrease is 4–5% per decade in the Alaskan Arctic compared to Northern Hemisphere midlatitude declines of about 3% per decade. Particularly severe years of ozone depletion are associated with cold winter and early spring stratospheric temperatures that favor polar stratospheric cloud formation, which is an important step in the ozone destruction reaction. The somewhat warmer winter temperatures in the stratosphere for 1997–1998 and especially 1998–1999 showed much less ozone loss than was noted in recent prior winters.

In response to this Arctic stratospheric ozone depletion, CMDL recently installed suites of UV monitoring instrumentation at the CMDL Barrow Observatory and at the National Weather Service forecast offices at Nome and St. Paul Island in a cooperative project with the University of Alaska Fairbanks and the NOAA Air Resources Laboratory. Funding from NOAA's Arctic Research Initiative supports this program. Data from the UV instruments are automatically downloaded and sent to Boulder for monitoring and analyses and to the University of Alaska Fairbanks for applications in radiative transfer modeling. The Barrow site complements the radiation monitoring instrumentation and research activities of the adjacent Department of Energy's Atmospheric Radiation Monitoring

(ARM) site. All the UV instruments are calibrated annually when the sun disappears below the horizon for the winter. A NOAA/CMDL web page is available to any user (on a restricted basis) who wishes to use the data from these sites (<http://www.cmdl.noaa.gov/star/arcticuv2.html>).

Aerosol Monitoring at Barrow. Aerosol monitoring at the Barrow Observatory has been in operation since 1974 and provides data useful for detecting changes in the sources of aerosols in the Arctic and for quantifying radiative forcing of climate by aerosols. In 1997 and 1998 the aerosol monitoring system was substantially upgraded with support from the Department of Energy's ARM program. This enhanced aerosol monitoring system is functionally identical to the systems that CMDL operates at regional monitoring sites at Bondville, Illinois; Lamont, Oklahoma; and Sable Island, Nova Scotia.

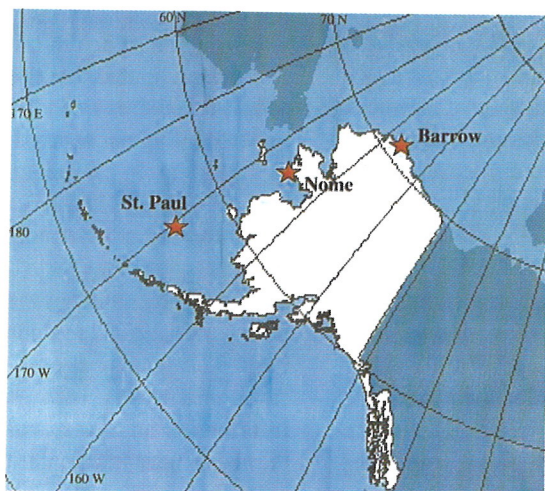


Relative decrease of Arctic haze, which is air pollution from Eastern Europe and the former Soviet Union, measured in the spring at the CMDL Baseline Station, Barrow, Alaska. The haze units on the y-axis are a measure of the light scattering or "haze." The decrease in Arctic haze is attributed to a combination of less pollution in the source regions and a recent change in airflow patterns in the Arctic.

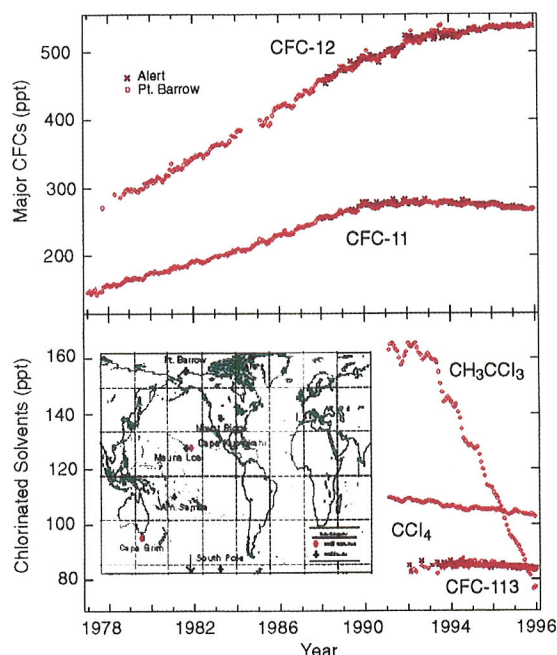
Each spring, air pollution from Russia and Eastern Europe flows across the Arctic Basin to Alaska and is measured in the form of increased aerosol mass and aerosol light scattering at the Barrow baseline station. This air pollution, which is clearly visible to the eye, is known as Arctic haze. Springtime concentrations of Arctic haze have decreased in recent years. This decrease is attributed to both a decline in pollution emissions in Russia and Eastern Europe and a shift in the springtime airflow patterns in the Arctic, possibly related to Arctic warming.

Halocarbon Trends in the Arctic. CMDL monitors the atmospheric trends of chemicals, chlorofluorocarbon (CFCs), and chlorinated solvents

Locations of the UV instrumentation in the new CMDL/University of Alaska/ARL network.



Atmospheric trends of chemicals controlled under the Montreal Protocol measured at the CMDL Baseline Station, Barrow, Alaska, and the Canadian Atmospheric Environment Baseline Station, Alert, Canada. The positive response of the atmosphere to the phasing out of these chemicals is apparent.



controlled under the Montreal Protocol to Reduce Substances that Deplete the Ozone Layer from two locations in the Arctic (Barrow, Alaska, and Alert, Canada) within a larger global network. The atmospheric growth rate of CFC-12 is decreasing with time as a result of voluntary and mandated emission reductions under the Montreal Protocol. CFC-12 was used in pre-1993 auto air conditioners, as aerosol propellant, and in refrigerators. The accumulation of CFC-11 in the atmosphere peaked during 1993–1994. CFC-11 was used as a cell-blowing agent for manufacture of foams, in large building air conditioning, and in refrigeration. Methyl chloroform (CH_3CCl_3), which was used as a metal degreaser in manufacturing, is decreasing at 14% per year. Carbon tetrachloride (CCl_4), which was used in dry cleaning and as a feedstock to produce the CFCs, is decreasing in mixing ratio at a rate of 0.8% per year. CFC-113 has leveled off and is decreasing at 1% per year. It was used as a solvent degreaser in the manufacture of circuit boards. CMDL airborne measurements of halocarbons in the Arctic are discussed in the Aeronomy Laboratory section of this report under the POLARIS project.

Arctic halocarbon research by CMDL scientists included participation in the airborne campaigns for the SAGE-III Ozone Loss Validation Experiment (SOLVE) starting in November 1999 and ending in April 2000. SAGE-III is the new Stratospheric Aerosol and Gas Experiment space instrument, which was scheduled for launch from Russia in early 2000 but was delayed. CMDL pro-

vided two airborne gas chromatographs for SOLVE, including a balloon gas chromatograph to measure many of the CFCs and other trace gases to over 32 km, and an aircraft version flown on the NASA ER-2 aircraft.

Air Resources Laboratory

During the last few years, scientists at NOAA's Air Resources Laboratory (ARL) have been active in three separate but interconnected Arctic studies: ultraviolet radiation, airborne mercury, and carbon dioxide.

Ultraviolet Radiation. ARL serves as one of the coordinators of the U.S. national interagency effort to study ultraviolet radiation. Moreover, ARL provides leadership of the UV component of the international Arctic Monitoring and Assessment Program (AMAP).

Alaska has many UV monitoring sites, operated by the Environmental Protection Agency, the National Science Foundation, and the U.S. Department of Agriculture as well as by NOAA. Most of the measurement sites are south of the Arctic Circle, but all share a common feature: they focus on measurements of the incoming UV radiation alone, with no accompanying program to make the results appropriate for studies of the scattered and reflected UV radiation that affects eyes. The methodologies for monitoring UV radiation are as yet poorly developed, and there are several alternative approaches that are being explored. The U.S. Arctic serves as a demanding outdoor laboratory for testing alternative measurement approaches. So far, high-latitude UV measurement programs have been driven by the need to refine understanding of the ozone hole. The focus has not yet been broadened to the near-horizontal component of reflected and scattered UV, even though it is acknowledged that this is the component likely to be of greatest health concern in the Arctic.

It is anticipated that the NOAA program will soon start studies intended to provide the data and understanding necessary for health effects studies in the Arctic. In the meantime, the emphasis of ARL UV studies in the Arctic has been on the total dose received at a horizontal surface, integrated over the spectrum of wavelengths affecting humans, plants, and animals. In a joint program with CMDL, ARL personnel have started extending the programs ongoing in the southern tier of states into Alaska, with emphasis on the need for information on how to satisfy the data needs related to near-horizontal UV radiation that affects eyesight.

Airborne Mercury. The NOAA Arctic research program has taken the lead in establishing a program of atmospheric mercury sampling at Barrow. ARL scientists, in close collaboration with colleagues from CMDL, have now completed nearly two years of measurement of airborne mercury at Barrow. The data obtained confirm an important finding from similar studies conducted at Alert, Canada: gaseous mercury concentrations decrease rapidly from normal background levels (1.5–1.8 ng/m³) to levels below 0.1 ng/m³ during polar springtime. At Barrow, episodic depletions and enhancements begin suddenly at local polar sunrise. These sudden changes occur at the same time as sudden increases in surface concentrations of ozone.

Airborne mercury originates with the combustion of coal from agricultural chemicals and from the disposal of medical waste. The source regions can be quite distant from where measurements are made. A major goal of the study is to try to identify the regions from which the mercury in the air originates. Although positive identification of source regions cannot be made, the results suggest some likely sources in northern Siberia.

Carbon Dioxide. For many years, ARL scientists have been conducting studies of the rate of exchange of CO₂ between the air and the Arctic biosphere along the North Slope of Alaska. The measurements have used a specially designed fast-response infrared CO₂ sensor, mounted on strategically located towers and operated aboard small aircraft making traverses across the tundra. These studies have been in cooperation with San Diego State University and the National Science Foundation. The results have shown that on the average the Alaskan tundra is more of a source of CO₂ than a sink. The results have also demonstrated that the oil industry in northern Alaska serves as a considerable source of CO₂. The gas appears to be released from oil wells.

Pacific Marine Environmental Laboratory

NOAA's Pacific Marine Environmental Laboratory (PMEL) conducts fisheries oceanography and ecosystem studies in the Bering Sea and western Gulf of Alaska. Fisheries–Oceanography Coordinated Investigations (FOCI) is a cooperative program among PMEL, the NMFS Alaska Fisheries Science Center, the NOS Coastal Ocean Program, and the University of Alaska. FOCI's goals are to increase understanding of the Alaskan marine ecosystem, to document the role of walleye pollock in the ecosystem, to determine factors that

affect pollock survival, and to develop and test annual indices of pre-recruit pollock abundance. FOCI scientists conduct research on the character and dynamics of the biophysical environment through field and laboratory experiments, computer simulations, and conceptual models. In the Gulf of Alaska, FOCI predicts pollock recruitment from relationships of fish survival to baroclinicity, transport, wind mixing, and climate forcing. In the Bering Sea, a FOCI component, Southeast Bering Sea Carrying Capacity, has monitored strong inter-annual ecosystem variability, including two recent near-shelf-wide blooms of coccolithophores, and has demonstrated that the seasonal ice pack directly affects primary productivity of the shelf. From these and other findings, FOCI is developing predictive ability for Bering Sea pollock.

Environmental Technology Laboratory

NOAA's Environmental Technology Laboratory (ETL) is conducting atmospheric studies in the Arctic, particularly in the areas of clouds, radiation, and surface fluxes.

Observations in the Arctic Ice Pack. SHEBA is an interdisciplinary, interagency program, primarily supported by the National Science Foundation and the Office of Naval Research, designed to study the thermodynamic coupling among the ocean, ice, and atmosphere of the Arctic Ocean. During the year-long field experiment (1997–1998) the Canadian Coast Guard ship *Des Groseilliers* was frozen into the ice pack and allowed to drift on a random walk path of 2800 km. This platform provided the necessary power and housing to deploy a large and comprehensive suite of instruments and personnel for measuring properties of the ocean, ice, and atmosphere simultaneously. Additional support measurements were made throughout the year with instrumented aircraft, submarines, and satellites. The NOAA/ETL radar, lidar, and meteorological tower system constituted a major fraction of the atmospheric measurements for SHEBA.

Although the analysis phase is just beginning, there are already significant scientific results. The Arctic ice pack was 1 m thinner than expected, and the SHEBA melt season was unusually long and warm. The upper ocean was warmer and fresher than 20 years earlier, and Arctic clouds were thicker and more prevalent than expected. Clouds could change near-surface temperatures by as much as 10–20°C through radiative effects, and ice albedos showed surprising amounts of short-term and spatial variability. The results from

SHEBA are also being used to adjust parameterizations in forecast and climate models, as well as to validate and improve satellite measurements in the Arctic.

Poker Flat Research Range. In February 1996, ETL, the Communications Research Laboratory (CRL) of Japan, and the Geophysical Institute at the University of Alaska Fairbanks signed an agreement to cooperate on remote sensing of the Arctic atmosphere. This agreement primarily supports research of mutual interest in a large program involving multiple sensors deployed at the Poker Flat Research Range near Fairbanks, Alaska. As part of this cooperative international program, CRL worked with the University of Denver and ETL to install a Fourier transform infrared (FTIR) spectrometer at Poker Flat. A unique feature of the CRL spectrometer is that it splits its operation time between a solar-tracking transmission-measuring mode and a vertically viewing emission-measuring mode. The spectral region of primary interest is approximately $1250\text{--}500\text{ cm}^{-1}$ (8 to $20\text{ }\mu\text{m}$). This contains the important window regions of relatively high atmospheric transmittance, as well as useful emission bands from water vapor, ozone, carbon dioxide, and other trace gases.

Barrow, Alaska. The Department of Energy's Atmospheric Radiation Measurement (ARM) program began intensive cloud and radiation measurements in Barrow in the spring of 1998. ETL has been closely involved in the process, since it was the organization that designed and built the 35-GHz cloud radar operating at that site; many of the DOE/ARM radiometers are modeled after ETL prototypes. The 35-GHz cloud profiling radar is designed for unattended, long-term cloud monitoring. It is a vertically pointing, low-peak-power, pulsed Doppler system with excellent resolution and sensitivity for observing the structure of almost all clouds overhead. It uses a traveling-wave tube amplifier and pulse compression technique. Its data system includes a commercial boundary-layer wind profiler processor. The radar can cycle through different operating modes that emphasize low or high altitudes and different sensitivities. When used in combination with the radiometers at the North Slope of Alaska site, this system provides highly detailed properties of cloud geometry, and microphysics can be determined using retrieval techniques. ETL is funded by the NASA Clouds and the Earth's Radiant Energy System program to develop a long-term climatology of clouds and cloud properties at the North Slope site.

ETL also operated the Depolarization and

Backscatter Unattended Lidar (DABUL) system in Barrow during February and March 1999 with partial funding by NOAA's Arctic Research Initiative. The system, developed between 1994 and 1996 at ETL, is designed to operate in the harsh Arctic environment, obtaining continuous profiles of atmospheric backscatter and depolarization ratio. DABUL provides range-resolved information on cloud and aerosol distributions and phase. DABUL's optics and electronics are housed in a weatherproof container that is environmentally controlled for temperature and humidity.

In March 1999, NOAA/ETL and NASA Goddard Space Flight Center participated in an Arctic experiment focused on measuring water vapor during very cold and dry conditions, with a secondary goal of measuring microwave radiometric properties of Arctic clouds. This experiment was funded by the DOE/ARM program and was conducted at their North Slope of Alaska/Adjacent Arctic Ocean site near Barrow. A total of 30 radiometric channels of greatest interest during this experiment were those close to the 183-GHz water vapor absorption line, a line that has been shown to be sensitive to low concentrations of water vapor. ETL developed and successfully deployed its circularly scanning radiometer, which has seven channels operating near the 183-GHz line. Experimental data showed greatly enhanced sensitivity to water vapor relative to ARM's operational instrument that operates at 23.8 GHz. In addition, some of the more transparent channels showed a high sensitivity to low concentrations of cloud liquid water.

University of Alaska Cooperative Institute for Arctic Research

The Western Arctic/Bering Sea region, which is vital to many nations because of its fisheries, oil and gas resources, and Native communities, is becoming the focus of increased international attention and research. While uncertainties exist about the future, changes in the region during the past few decades have occurred at a rapid pace. Both natural environmental fluctuations and human activities have caused biological changes in the Bering Sea ecosystem. On land and sea, substantial climate warming has taken place, leading to major changes in this high-latitude environment with societal impacts that will become even more pronounced if present climatic trends continue.

To address some of the concerns, a number of major research projects have focused on the Western Arctic/Bering Sea region and will continue

over the next few years. They include studies of marine and terrestrial ecosystems and their transitions as the climate changes, regional feedbacks on the global climate, and assessments of present and future environmental and socioeconomic consequences of these changes. Several Federal agencies are playing leading roles in this research, international partners are involved, and steady progress is being made toward the goal of promoting and facilitating research among all organizations active in the Western Arctic. The University of Alaska Fairbanks (UAF) is helping to bring these diverse research efforts together through its Cooperative Institute for Arctic Research (CIFAR).

The objectives in creating CIFAR are spelled out in the Memorandum of Understanding between NOAA and the University of Alaska establishing the cooperative institute. They emphasize the fostering of collaboration among NOAA, the university, and others doing research in the Western Arctic (Alaska and the Bering, Chukchi, and Beaufort Seas). The research topics of greatest interest to CIFAR include atmospheric research; climate dynamics and variability; hydrographic studies and sea ice dynamics; tsunami research and prediction; fisheries oceanography; and environmental assessment, monitoring, and numerical modeling.

A major new research program, NOAA's Arctic Research Initiative, was first funded in FY 97 through CIFAR. Its major research thrusts were:

- Natural variability of the Western Arctic/Bering Sea ecosystem;
- The Bering Sea green belt: processes and ecosystem production;
- Atmosphere-ice-ocean processes that influence ecosystem variability;
- Anthropogenic influences on the Western Arctic/Bering Sea ecosystem;
- Arctic haze, ozone, and ultraviolet flux and their potential impacts; and
- Contaminant inputs, fate, and effects on the ecosystem.

About half the Arctic Research Initiative projects are concerned with the natural variability of the Bering Sea ecosystem and the atmosphere-ice-ocean interactions that control this variability. The other half deal with anthropogenic influences, including atmospheric and marine contaminant studies and their effects on biota and eventually on humans.

With its funding through CIFAR, NOAA is strengthening U.S. marine ecosystem and meteorological/oceanographic research in the Bering Sea, as well as continuing contributions to the study of

atmospheric pollutants such as Arctic haze. Studies of the Bering Sea "green belt," meteorological processes associated with the Aleutian Low, and the oceanographic processes in the Bering Strait are emphasized. Interdecadal variations in atmosphere-ice-ocean interactions are beginning to shed new light on climate change. Fisheries studies are contributing vital knowledge to an important sector of the Alaskan and national economy. Studies of marine contaminants and their effects, for example mercury, begun modestly in 1997, have been strengthened, and there is a new emphasis on contributions to the international Arctic Monitoring and Assessment Program. Studies of contaminants and their effects are also establishing new and much closer links with Arctic Native communities.

National Undersea Research Program

The NOAA National Undersea Research Program (NURP) has the responsibility to establish programs for the assessment, protection, development, and utilization of U.S. underwater resources. In meeting this responsibility, NURP has established six regional centers for support of in-situ research and technological development. The West Coast and Polar Regions (WCPR) Center, which serves the entire West Coast and polar regions, was established at the University of Alaska Fairbanks following a competitive process. This center promotes, facilitates, and supports undersea research along the west coast of the United States, including Arctic and Antarctic regions.

The object of a recent WCPR Center research effort was to investigate benthic dynamics early in the season (May-June) on the shelf and slope of the northern Chukchi Sea before ice breakup. The principal investigator was William Ambrose of Bates College. Ice algae are expected to be the dominant source of carbon to the benthos at this time. The distribution of ice algae, both under the ice and on the seafloor, were examined using a combination of remotely operated vehicle (ROV) transects to determine spatial coverage and core collection (ice cores and sediment cores) to quantify algal concentrations. In addition to visual and fluorometric analyses, the composition of ice algae, phytoplankton, and surficial sediments were determined by:

- Microscopic examination of algal species;
- Measurement of naturally occurring carbon and nitrogen radioisotopes;
- High-performance liquid chromatography pigment analysis; and
- Lipid analysis.

Preliminary data collected earlier indicated that the

proposed cruise track would cover areas with a large range in the amount of ice algae still attached to the ice and in fresh chlorophyll on the seafloor.

The second major focus of this research effort was to determine the effects of early-season deposition of pigments on benthic respiration and activity. Rates of benthic oxygen consumption and specific estimates of sedimentary microbial activity were compared between areas that have high concentrations of pigments on the seafloor and areas where pigments have not yet sedimented. Community respiration rates were determined with onboard incubations at in-situ temperatures. In addition, ice algae were added to incubation cores as a direct test of the importance of this food source to infaunal biota. Earlier data had indicated that total sediment oxygen demand and bacterial activity both respond rapidly to an input of photosynthetic material. Finally the rate of oxygen consumption for the dominant epifauna found in the Chukchi Sea was determined using incubation experiments and density estimates. Recent data from the Barents Sea, the Laptev Sea, and the Greenland Shelf indicate that the epifaunal component can play an important role in remineralizing carbon yet are seldom included in studies of benthic carbon cycling. ROV images were essential in determining the densities of epifauna because collections made with an otter trawl in ice-covered waters are not quantitative.

To understand the annual cycling of carbon in the Arctic, studies took place in the early season as well as in the late season of 1998. The work contributed to our understanding of carbon cycling on Arctic shelves. The work was the first to examine the early-season response of Arctic benthic communities to deposition of labile organic matter, and the first study in the Chukchi Sea (and only the fourth in the Arctic) to determine the role of mobile epibenthic organisms in carbon remineralization. Without such information, which is still being analyzed, models of carbon flow and ecosystem dynamics in the Arctic Ocean will remain incomplete.

In another recent research effort supported by the NURP WCPR Center, Tim Hight and Jeff Ota of Santa Clara University worked at developing MarineMap, an underwater three-dimensional mapping system for marine research. In cooperation with the NASA Ames Research Center, the U.S. Coast Guard, and Deep Ocean Engineering, the Santa Clara Remote Extreme Environment Mechanisms (SCREEM) Laboratory at Santa Clara University is developing an underwater 3D

mapping system for marine research. The research includes using two high-resolution black-and-white cameras mounted for stereo vision on a Deep Ocean Engineering ROV to capture a pair of images that will be "pushed" through the Mars Pathfinder stereo pipeline to create a virtual environment 3D mesh/terrain. Once the terrain is built, MarineMap, a derivative of the highly successful MarsMap program used for the Mars Pathfinder mission, will be used to analyze the 3D models and perform size and volume measurements from within the virtual environment.

As a result of this technology and of the Arctic and Antarctic Workshop held in April 1998, the U.S. Coast Guard and Santa Clara University performed a marine archaeology mission to the Arctic in search of the sunken 1871 New Bedford Whaling Fleet. Deep Ocean Engineering offered the use of a Phantom XTL vehicle for test use by the Coast Guard, and NASA joined the effort to both test the 3D image capture technology and assess ROV operations for future missions. The final product became known as the Jeremy Project, where Santa Clara University student Jeremy Bates would use the Phantom XTL with the stereo vision enhancements and NASA's Mars Pathfinder technology to capture the first vision-based 3D underwater images of one of the sunken ships. This successful mission hopes to not only further the development of the NASA technology but also help the State of Alaska research the history of the whaling industry in the 1800s.

National Sea Grant College Program

Walleye pollock supports one of the world's largest commercial fisheries. Over the past decade, annual harvests have ranged from 4 to 7 million tons in the North Pacific Ocean. In U.S. waters, catches reach 1.5 million metric tons, with a dollar value exceeding hundreds of millions, clearly making this natural resource critical to the health of domestic fisheries. Recent developments in DNA technology can advance the understanding of the processes that create and maintain genetic structure in pollock populations. Through the application of high-resolution molecular analysis of microsatellite DNA markers in pollock, Washington Sea Grant researchers are studying the North Pacific walleye pollock population structure to provide information that will be used to develop sustainable harvest strategies.

By analyzing acoustic survey data collected by NOAA survey ship echo-sounder systems for 1994–1996, researchers are correlating the loca-

tions of pollock schools to those of pollock predators, prey, and environmental conditions in the vicinity of the Pribilof Islands in the southeast Bering Sea. Information from this study will advance understanding of the importance of environmental factors in concentrating and sustaining aggregations of juvenile pollock and their food sources. The study is being conducted with support from the National Marine Fisheries Service.

In another study by Washington Sea Grant, researchers are analyzing abundance, size, growth, and condition of juvenile pollock and correlating them with environmental conditions. The shallow waters around the Pribilof Islands are home to juvenile pollock during a critical stage in their life history. A better understanding of the food supplies available to these pollock and the predation pressure on them will aid in the overall understanding of factors affecting this important commercial fishery. This research is also being conducted with support from the National Marine Fisheries Service.

Arctic Research Office

NOAA's Office of Oceanic and Atmospheric Research has recently established an Arctic Research Office (ARO) to provide a focal point for NOAA research in the Arctic, Bering Sea, and North Pacific regions. The new office manages the Arctic Research Initiative and other funds allocated to it, supporting both internal and extramural research activities. ARO represents NOAA on the Interagency Arctic Research Policy Committee, leads U.S. involvement in the Arctic Monitoring and Assessment Program (AMAP) of the Arctic Council, and promotes coordination of AMAP with other working groups of the Arctic Council.

National Environmental Satellite, Data, and Information Service

NOAA's National Environmental Satellite, Data, and Information Service manages the U.S. civil operational earth observing systems. NESDIS is also responsible for collecting, archiving, processing, and disseminating environmental data; developing analytical and descriptive products to meet user needs; and providing specialized data analyses and interpretations. As part of this overall responsibility, NESDIS maintains a variety of Arctic environmental data sets. The data holdings of the National Geophysical Data Center (NGDC) in Boulder, Colorado, which includes World Data Center-A for Glaciology, are relevant to Arctic studies. Information on those activities are pro-

vided under the National Snow and Ice Data Center (NSIDC) below.

Instruments carried on NOAA's polar-orbiting environmental satellites are a valuable source of Arctic environmental data. These include

- The TIROS operational vertical sounder (TOVS), which provides vertical temperature and moisture atmospheric soundings for Arctic weather analyses;
- The solar backscatter ultraviolet spectral radiometer, which produces total ozone measurements and ozone profiles;
- The space environment monitor, which determines the energy deposited by solar particles in the upper atmosphere and provides a solar warning system;
- The ARGOS data collection system, which collects environmental information from in-situ platforms such as Arctic ice buoys; and
- The advanced very high resolution radiometer (AVHRR), which is used by the National Ice Center for generating ice analyses and forecasts by interactive analysis of digital infrared and visible imagery.

These satellite data sets, available since 1979, are archived by the NESDIS National Climatic Data Center in Asheville, North Carolina, and copies can be obtained on magnetic tapes. AVHRR and TOVS data from January 1996 to the present are available on-line via the NESDIS Satellite Active Archive.

NESDIS, in partnership with the U.S. Navy, operates a near-real-time processing, communications, and access system for synthetic aperture radar (SAR) data from the Canadian Radarsat satellite. SAR data are high-resolution (10–100 m) active microwave backscatter measurements that can be used to monitor and study the ocean environment as well as for other applications of interest to U.S. government agencies. The National Ice Center (NIC), for example, routinely uses Radarsat data to determine ice edge location, ice concentration, stage of development, and frequency/orientation of leads and polynyas in the Great Lakes and frozen seas of the polar regions. Arctic data are acquired, processed, and delivered electronically in near real time (less than three hours) to the NIC from satellite readout stations in Tromsø, Norway; Gatineau, Canada; and West Freugh, Scotland; and from the Alaska SAR Facility (ASF) located at the University of Alaska Fairbanks. All U.S. government agencies and/or organizations under U.S. government sponsorship that have signed an affiliated user agreement may submit

operational SAR data requests through the Radarsat order desk located at NIC. NESDIS handles communications for ASF SAR data, while Canadian SAR data are delivered to the NIC from the Canadian Ice Service via a dedicated communications link known as the North American Ice Link. NESDIS provides on-line electronic access to SAR data for all approved U.S. government users via the Satellite Active Archive (http://www.saa.noaa.gov/help/radarsat_faq.html).

The latest area of Arctic research at NESDIS involves the use of SAR measurements. This work is being performed by scientists in NESDIS's Office of Research in collaboration with scientists at ERIM, Johns Hopkins University, and the NASA Goddard Space Flight Center.

Instruments on the Defense Meteorological Satellite Program (DMSP) satellites are also an important source of Arctic environmental data for NESDIS and the NIC. Passive microwave data from the special sensor microwave/imager (SSM/I) are received on a near-real-time basis from the U.S. Navy's Fleet Numerical Meteorological and Oceanographic Center (FNMOC) under the aegis of the Shared Processing System (SPP). The SPP encourages the sharing of data between all of the operational environmental data processing centers of the U.S. government. SSM/I brightness temperatures, or sensor data records, are converted by the FNMOC into ice concentration maps using the CAL/VAL and NASA Team ice algorithms. These maps provide the NIC with a global all-weather data source that is integrated with other remotely sensed data to produce weekly composite Arctic and Antarctic ice analyses. The World Data Center-A for Glaciology is responsible for archiving and distributing historical gridded SSM/I brightness temperatures and ice concentration products for the polar regions. Fine-resolution (0.5 km) visible/infrared data from the DMSP Operational Linescan System are also used in the ice analysis process at the NIC. These data are delivered to NESDIS from ground stations via an asynchronous transfer mode communications link from the Air Force Global Weather Center at Offutt Air Force Base, Nebraska.

NESDIS also participates in the Search and Rescue Satellite Aided Tracking (SARSAT) system, an international program using emergency position location instruments on polar-orbiting spacecraft to detect distress signals from emergency locator transmitters on aircraft and emergency position-indicating radio beacons on boats and ships.

Since FY 94, NESDIS has managed the NOAA CoastWatch program. This cooperative program has participation from NESDIS, the National Marine Fisheries Service, the National Weather Service, the National Ocean Service, and the Office of Oceanic and Atmospheric Research. The goal of CoastWatch is to provide coastal managers, decision makers, and researchers with timely satellite imagery and other NOAA environmental data and information for the entire U.S. coast through a network of regional nodes. The Arctic regions of Alaska are served by the Alaska CoastWatch Node located at the National Weather Service's Alaska Region Office in Anchorage. Alaska CoastWatch users have access to near-real-time AVHRR, DMSP, GOES, and Radarsat data. The Alaska CoastWatch node (<http://sgiot2.wwb.noaa.gov/COASTWATCH/cwdirect.htm#alaska>) provides real-time access to NOAA POES and GOES imagery and products. In addition, approved researchers and users have real-time access to DMSP imagery and products via password. Along with the satellite products, a suite of real-time weather observations, forecasts, and numerical predictions are available. A special hazards section provides real-time access to derived satellite products such as red-tide, airborne volcanic ash, forest fires, sea ice, and sea surface temperatures.

As part of NOAA's CoastWatch program, the SAR instrument aboard Radarsat has been used in a demonstration mode for coastal monitoring. Techniques have been developed to apply SAR measurements for vessel detection and wind derivation around the Bering Sea. A Constant False Alarm Rate (CFAR) algorithm is used for vessel detection and a modified scatterometer algorithm is used to derive wind speeds. Beginning in the fall of 1999, a select group of operational agencies in Alaska have been able to use near-real-time SAR data to identify vessel positions and winds.

In addition to the use of SAR for vessel detection and wind determination, SAR applications include ice analysis and storm location. Analysis of coastal ice cover was initiated using ERS-1 SAR data. Techniques were developed to monitor coastal ice in the Bering Sea, icebergs from calving glaciers in Prince William Sound, and lake ice in the Great Lakes. Results showed that, depending on ice size and sea state, icebergs could be detected from background and computer enhanced imagery. The all-weather day/night viewing capabilities of SAR make it a unique and valuable tool for operational ice detection and monitoring.

National Ice Center

The National Ice Center is a cooperative, inter-agency organization responsible for providing Arctic, Antarctic, and Great Lakes ice information to U.S. and allied armed forces, U.S. government agencies, and various segments of private industry. Manpower and fiscal resources for the NIC are provided by the U.S. Navy, NESDIS, and the U.S. Coast Guard. Real-time global, regional, and tactical-scale ice guidance products are generated in support of mission planning, safety of navigation, and climate research. Routine products include satellite-derived sea ice analyses of current ice conditions and forecasts depicting future changes to the sea ice pack. Ice analyses are distributed in graphics interface format (gif) and as files compatible with geographic information systems (GISs) via the NIC World Wide Web page (<http://www.natice.noaa.gov>). Tailored support messages are also sent electronically via Autodin to DoD users. Sea ice features of most frequent interest to operational and research interests include ice edge position, ice thickness, ice concentration, areas of compression or heavy deformation, and location and orientation of open water or thin ice-covered leads and polynyas. Metadata, which detail the data sources integrated into routine ice analysis products, are available on the NIC WWW page. Historical (1972–1994) data of weekly ice analyses and multiyear climatologies of ice extent and coverage are also available from NIC.

Approximately 95% of all data used in producing ice analyses at the NIC are derived from satellites. The largest sources of these remotely sensed data are visible and infrared imagery from the TIROS very high resolution radiometer (AVHRR) and the DMSP operational linescan system instruments. These data are of sufficient resolution (1.0 and 0.6 km, respectively) to produce regional-scale maps of ice conditions and produce rough ship track route recommendations. Unfortunately these data suffer from the limitation cloud cover imposes on ice detection. DMSP SSM/I passive microwave data provide an all-weather detection capability but are of relatively coarse resolution (25 km) for all applications except for global-scale ice mapping. Over the past several years the NIC has integrated SAR data in ScanSAR wide mode (100-m resolution; 500-km swath width) into select operational ice analysis products. SAR imagery is the only high-resolution remotely sensed data source that is capable of penetrating the perpetual cloud cover and restricted illumina-

tion conditions characteristic of the polar regions. NIC has also found SAR data to be extremely useful in classifying ice types (first-year vs. multiyear ice), detecting open water or new ice-covered polynyas, and assessing the severity of surface deformation.

The NIC established a Science Program in the spring of 1997 when a Senior Scientist was added to the NIC staff. The main goals of the program are to:

- Improve efficiency of data processing and analysis through the development of automated data fusion techniques;
- Automate the analysis and classification of SAR data;
- Improve the operational ice forecasting models;
- Optimize SSM/I algorithms for operational sea ice analysis; and
- Develop new ice products by applying new techniques and by incorporating data from new sensors.

One of the first accomplishments of the science team was the creation of a science plan (available at <http://www.natice.noaa.gov>). This document outlines future goals for scientific development and ties into the planned evolution of the NIC sea ice product suite. In 1998, two sea ice classification systems were delivered. The Multi-Year Ice Mapping System quickly maps old ice in uncalibrated SAR images. Also transitioned into operations was a knowledge-based system that uses artificial intelligence techniques to combine SAR with ancillary data sources to classify sea ice type.

The NIC science team evaluated the existing suite of sea ice concentration algorithms for the special sensor microwave imager and modified the operational sea ice algorithm. A passive microwave algorithm was developed that uses a principal components combination of SSM/I brightness temperatures and NIC-provided local ice conditions from visible and infrared data to provide improved global sea ice concentrations.

In 1999, two post-doctoral fellows and a new Chief Scientist were added to the program. An early accomplishment was the implementation of an algorithm to track ice motion using 85-GHz SSM/I. These ice motion vectors will be assimilated into the next-generation sea ice forecasting model.

Drifting buoys are also an important source of surface meteorological data and ice drift information in the Arctic. Since its inception in 1991, the mission of the U.S. Interagency Arctic Buoy Pro-

gram (USIABP) has been to establish and maintain a network of 40 evenly spaced meteorological buoys on the drifting Arctic ice pack. As manager of the USIABP, NIC achieves this goal through coordinated deployments and international cooperation by participants in the International Arctic Buoy Program (IABP). During 1998-99, nearly 95% of all Arctic drifting meteorological buoys reported data in real time over the Global Telecommunications System. Real-time buoy data are used to initialize operational weather and ice forecast models. All buoy data are quality controlled within six months of receipt and then assembled into a historical (1979-1998) database, which is archived by the Polar Science Center of the University of Washington (<http://iabp.apl.washington.edu>) and NSIDC. These data have been useful in the initialization of global circulation models and in climate change research. Buoy data are also used to generate a three-hour spatially and temporally interpolated data set of surface pressure and temperature.

National Snow and Ice Data Center

The National Snow and Ice Data Center (NSIDC) was chartered by NOAA/NESDIS in 1982 to provide a focus for NOAA cryospheric data management activities. NSIDC is operated under a cooperative agreement between NOAA and the University of Colorado's Cooperative Institute for Research in Environmental Sciences. Within NOAA, NSIDC is affiliated with the NESDIS National Geophysical Data Center. NSIDC is also the home of the World Data Center for Glaciology, Boulder, and is the NASA "Snow and Ice" Distributed Active Archive Center (DAAC) for Earth System Enterprise (ESE) era data sets.

NSIDC receives funding for research and data management activities primarily from NASA, NSF, and NOAA. NOAA-sponsored work at NSIDC has centered on data rescue. Funding from the Environmental Services Data and Information Management program has resulted in the publication of over 30 snow, glacier, and sea ice data sets. In FY 98 and 99, additions included the on-line World Glacier Inventory (in cooperation with the World Glacier Monitoring Service); Submarine Upward Looking Sonar Ice Draft Profile Data and Statistics (notable for being the first large release of previously classified data from U.S. Navy submarines and recently expanded to include data from U.K. submarines); the Circumpolar Active-Layer Permafrost System (CAPS) CD-ROM (in

cooperation with the International Permafrost Association); and a new release of the Historical Soviet Daily Snow Depth archive on CD-ROM (with snow data dating back to the late 1800s).

NSIDC is distributing the U.S.-Russian Joint Commission Environmental Working Group (EWG) Arctic atlases on CD-ROM. Available now are two oceanography atlases. These atlases are newsworthy because they contain products based on a wealth of previously classified hydrographic data from U.S. and Russian navies. An Arctic meteorology and climate atlas is under development at NSIDC, with funding from NOAA and the EWG.

The NASA-sponsored NSIDC DAAC has been preparing for the imminent launch of Terra, which will be the first satellite of the Earth Observing System. NSIDC will archive and distribute snow and ice products from the moderate resolution imaging spectroradiometer (MODIS) in level 2 (swath) and level 3 (gridded) format. These products will extend the existing 30-year record of passive-microwave-derived snow and sea ice products at greatly improved spatial and spectral resolution. Several widely used DAAC passive microwave data sets were updated in FY 98 and 99. These include global brightness temperatures from the Defense Meteorological Satellite Program (DMSP) special sensor microwave imager (SSM/I) instruments F-11 and F-13, and sea ice concentrations from two different SSM/I algorithms. The Near Real Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent product combines snow and ice information in one grid that is convenient for modelers. Also of note is the publication of new digital elevation model and topographic data for polar ice sheets. In addition to work with data sets, NSIDC DAAC compiles the DAAC yearbook, a collection of articles highlighting scientific applications of DAAC data written for the general public.

The NOAA/NASA Pathfinder Program has supported the development of a quality-controlled 20-year passive microwave temperature time series and of NOAA-satellite advanced very high resolution radiometer (AVHRR) data sets including Arctic albedo, surface temperature, clouds, and ice motion. In FY 99 *The Polar Pathfinder Sampler: Combined AVHRR, SMMR-SSM/I, and TOVS Time Series and Full-Resolution Samples* was published on CD-ROM.

NSF sponsors the Arctic System Science (ARCSS) Data Coordination Center at NSIDC. ARCSS researchers (over 120 in number) submit

More information on NSIDC activities, and access to NSIDC's data catalog, can be found at NSIDC's Web site (<http://www.nsidc.colorado.edu>).

their data sets to the Data Coordination Center for archiving, documentation, and redistribution to other researchers. In FY 98 and 99 the most significant ARCSS products were the Greenland ice cores (GISP and GRIP) data on CD-ROM, and a CD-ROM for educators based on the Greenland ice core data (*Into the Arctic: Information and Educational Activities for Studying Climate*).

NSIDC functions as a successful data center in part because investigators associated with NSIDC are active in their fields and bring a polar scientist's perspective to data management. In FY 98 and 99, NSIDC scientists worked on 16 new and 14 continuing research projects. For example, new work is being done with passive microwave data on how the timing and extent of snowmelt varies on the Greenland and Antarctic ice sheets. Variations in snowmelt influence surface albedo and the infiltration of meltwater into deep snow and ice layers and thereby have a strong effect on the surface heat budget. Passive microwave data find a new application in related work on detecting the onset, duration, and areal extent of near-surface soil freezing and thawing. Other research topics range from using SAR data for detecting permafrost to a study of trends in Russian ground temperatures during the last century. NSIDC researchers are participating in the provision of Arctic sea ice data for the European Reanalysis Center (ERA)- 40 Project.

NSIDC is involved in the Global Climate/ Terrestrial Observing System (GCOS/GTOS) and Arctic Climate System (ACSYS) activities of the World Climate Research Program (WCRP). NSIDC Director Roger Barry is a member of the Scientific Steering Groups of the Terrestrial Observation Panel for Climate (TOPC) and for ACSYS. Climate and Cryosphere (CLIC) is a new WCRP initiative developed by an ACSYS Task Group co-chaired by Barry. Currently there is no global program focusing on the role of the cryosphere in the global climate system. The CLIC Science and Coordination Plan addresses this gap by laying a path for the coordination of the cryospheric elements of existing projects of the WCRP.

National Weather Service

The Alaska Region of the National Weather Service conducts a number of collaborative projects with universities and government and private researchers to improve its warnings and forecasts programs. Efforts with the Scripps Institution of Oceanography, the Jet Propulsion Laboratory, and the University of Alaska have involved such

projects as satellite data fusion, Arctic cloud satellite detection technique, detection and monitoring of airborne volcanic ash, climate assessment of temperature and precipitation using a new robust multivariate alteration detection algorithm, and the effects of El Niño on fire weather conditions in Alaska. A SAR demonstration project with NESDIS and the University of Alaska continues to show the operational utility of SAR for providing critical data on sea ice distribution and concentration, river ice jams, river flooding, and marine winds.

A new Alaska Experimental Forecast Facility (AEFF) is being established at the Aviation Technology Center, University of Alaska Anchorage, to facilitate the transfer of pertinent research and technology into the operational forecast environment. Initial efforts will be concerned with aviation issues such as mountain-induced turbulence, aircraft icing, and precipitation patterns. Meso-scale numerical modeling efforts using MM% and RAMMS are producing high-resolution forecasts and examining atmospheric forcings. Future studies will examine the use of new satellite sensors to detect and monitor hazards. The AEFF will also generate educational and training tools on a number of Arctic and sub-Arctic topics.

Office of Marine and Aviation Operations

The Office of Marine and Aviation Operations (OMAO) supported Arctic research during the past two fiscal years primarily through the shipboard operations of the NOAA ship *Miller Freeman* and secondarily through aircraft support in Alaska and Iceland.

OMAO's fisheries and oceanographic research vessel *Miller Freeman* is a 215-ft, 1515-gross-ton stern trawler that operates a variety of biological and oceanographic sampling gear. The *Freeman's* primary Arctic accomplishments have been as a working platform for the study of the Arctic's living resources in the Bering Sea.

OMAO's ships and aircraft are operated and managed by a combination of NOAA commissioned officers, wage licensed civilians, and general service employees. On the ships the wage marine personnel include licensed engineers and other members of the engine, stewards, survey, and deck departments. Aviation personnel are licensed as engineers and technicians by the Federal Aviation Administration. Many of the administrative and navigation duties of the ships and air-

craft are performed by the commissioned officers. The aircraft and ship's complements provide mission support and assistance to the scientists from various NOAA laboratories as well as the academic research community.

The *Miller Freeman*, in conjunction with scientists from the Alaska Fisheries Science Center (AFSC), conducted echo integration trawl (EIT) surveys of walleye pollock in the southeastern Aleutian Basin near Bogoslof Island (March 1998) and on the eastern Bering Sea shelf (June–August 1999). The objective of these studies was to analyze the acoustic data and determine the population distribution and abundance of spawning pollock. The geographic distribution of pollock was similar to that observed in 1996 and 1997.

Miller Freeman also conducted numerous oceanographic observations and biological new tows as well as deploying and recovering weather, temperature, current meter, and biophysical surface and subsurface moorings in the vicinity of Bristol Bay. These cruises were in support of the Southeast Bering Sea Carrying Capacity project, which is part of the Fisheries Oceanographic Coordinated Investigations (FOCI). FOCI uses these data to better understand the effects of abiotic and biotic variability on ecosystems of the North Pacific Ocean and the Bering Sea in order to discern the physical and biological processes that determine

recruitment variability of commercially valuable finfish and shellfish stocks in Alaskan waters.

During the past two years NOAA's aircraft continued to support the Scatterometer High Ocean Wind Speed (SHOWS) project in Greenland and Iceland, as well as the Air Photo Mission-1 (APM-1) along the Alaskan coastline. The WP-3D Orion (N43RF) research aircraft supported the SHOWS project, which is a continuation of validation and wind retrieval development work for the operational satellite scatterometers being utilized by NOAA. Continuing the work from previous experiments in 1996 and 1997, scientists from NESDIS validate scatterometer programs from sensors aboard the European Remote Sensing Satellite (ERS2) and NASA's QuickScat Satellite. The instruments aboard the aircraft are designed to measure the roughness of the ocean surface in order to determine surface wind speed over the open ocean and in areas of high winds (greater than 50 knots). The Citation II (N52RF) research aircraft supports APM-1, a mobile field unit of the NOAA Aircraft Operations Center (AOC) dedicated to supporting the photographic requirements of the National Ocean Service, National Geodetic Survey, Remote Sensing Division. The NOAA AOC aircraft completed photographic survey operations in support of nautical charting in Alaska's Arctic regions.

Department of Agriculture

The Department of Agriculture supports and conducts research to improve understanding, use, and management of natural resources at high latitudes. Research is directed toward solving problems in agriculture, forestry, and the environment and improving technology for enhancing the economic well-being and quality of life for Alaskans.

Agricultural Research Service

The research activities of the Agricultural Research Service (ARS) are focused on 25 multidisciplinary and cross-cutting National Program Areas of high priority designed to develop a knowledge base to promote timely responses to technical agricultural problems of broad scope and national interest. Programs in the Arctic or adjacent northern regions have recently been restarted after a lapse of several years, so results to date are limited. They are, however, providing critical information necessary to solve issues in such diverse areas as preservation of plant germplasm, effective and sound uses for fisheries byproducts, integrated pest management for grasshoppers, and biodiversity of pathogens and parasites in northern ruminants.

The Arctic Plant Germplasm Preservation Program is collecting and preserving high-latitude crop variants of worldwide distribution, including legumes, small grains, and potatoes. Attention is also given to preserving germplasm that demonstrates medicinal potential and native Alaskan and Russian species of all types that demonstrate potential for erosion control. The plant germplasm management effort in Alaska is centered at the Alaska Plant Materials Center (AKPMC), Alaska Department of Natural Resources, Division of Agriculture, Palmer. Research in FY 99 focused on the preservation, evaluation, regeneration, and storage of disease-free plant germplasm adapted to high latitudes. Investigations on plant pathogens emphasized those that might impede high-latitude germplasm management, reduce agricultural productivity at high latitudes, or interfere with revegetation of disturbed Arctic sites with native or introduced germplasm. The National Plant Germ-

	Funding (thousands)	
	FY 98	FY 99
Forest Service - Environment	700	700
Cooperative State Res - Environ	725	725
Cooperative State Res - Food/Saf	793	793
Natural Res Cons Svc S - Global C	560	560
Agricultural Research Service	650	2,000
Total	3,428	4,778

plasm System (NPGS) has funded plant explorations in FY 98 and 99 to the Falkland and South Georgia Islands, where the manager of AKPMC has collected native grasses of potential utility for revegetating disturbed Alaskan landscapes.

ARS Aquaculture and Fisheries By-Product Programs are newly initiated for Alaska and are designed to develop effective, safe, environmentally friendly, and economical byproduct utilization from Alaskan fisheries as an alternative source of ingredients for food in aquaculture and for other farmed animals. Existing Alaskan fisheries byproducts will be characterized for the quantity, sources, utilization, and value of commercial components that could be incorporated into animal feeds. The research effort is conducted through a cooperative effort with the University of Alaska Kodiak and University of Alaska Fairbanks.

The Integrated Pest Management (IPM) program for grasshoppers in Alaska emphasizes the development of biological control for grasshoppers. Grasshoppers are the most important insects affecting Alaskan agriculture, with estimates of potential crop loss exceeding 50%. Recent changes in plant communities caused by the opening up of new farmland in the Delta agricultural area have resulted in frequent grasshopper population explosions that threaten agriculture. The project studies the ecology, behavior, and reproductive characteristics, emphasizing the two-year

egg diapause cycle of grasshopper populations in the Delta Junction region to determine the factors regulating population outbreaks and to predict population explosions. Research is providing the knowledge for population prediction that allows land managers to prepare for grasshopper problems in even-numbered years. A grasshopper-specific fungus has recently appeared in some grasshopper populations. Fundamental studies are beginning to determine its impact and potential use. ARS is establishing a cooperative program with the University of Alaska on grasshopper management. Technical guidance and technology transfer are from the existing expertise at the ARS grasshopper project based in Sidney, Montana.

Parasite faunas in ruminants across the Holarctic are being studied using biotic surveys, inventories, and parasite biosystematics. The studies are conducted to assess emerging diseases and pathogen distribution and to recognize introduced species. Research emphasis is on linkages to global change, mediated by climate or human activity, and impacts on domestic, semidomestic, and wild ruminants as key or critical food resources for northern communities. This program is a cooperative program of the Biosystematics and National Parasite Collection Unit, Beltsville Area Research Center of ARS (BNPCU); the University of Saskatchewan; the Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories, Canada; Oregon State University; and the University of Alaska Museum (UAFM). There were three notable accomplishments in 1999:

- A previously unknown abomasal nematode parasite was discovered and described in muskoxen and caribou.
- Life history studies of the pathogenic lungworm in muskoxen were completed.
- Broader distributions, and new host and geographic associations, for pathogenic protostrongylid lungworms and muscleworms in Dall sheep were discovered from the Mackenzie Mountains, NWT and Alaska.

Significantly, a new genus and two new species of nematodes have been discovered in muskoxen and caribou since 1995, indicating the degree to which this fauna remains poorly documented. Ongoing research on the life history of lungworms and abomasal nematodes in the central Canadian Arctic serves as the basis for development of the first model systems to examine biotic impacts of global climate change in host-parasite systems involving Arctic ruminants. Mammalian parasite faunas in

Alaska and Chukotka, Russia, are being surveyed and inventoried in conjunction with UAFM and BNPCU through the Beringian Coevolution Project, funded by the National Science Foundation. This project will examine the history and patterns of faunal interchange and isolation for mammals and parasites lining the Palearctic and Nearctic through the Pleistocene. These studies will provide a robust understanding of the structure of parasite faunas in North American and Arctic ruminants, elucidate the potential for interaction at the interface of natural and agricultural ecosystems, and thereby support a predictive framework to understand the distribution and emergence of pathogens and parasites.

Cooperative State Research, Education, and Extension Service

The Cooperative State Research, Education, and Extension Service (CSREES) funds research projects at the University of Alaska's Agriculture and Forestry Experiment Station (AFES). AFES research projects are aimed at solving problems related to agriculture, forestry, and the environment. The AFES research objectives are to provide new information for managing renewable resources at high latitudes and to improve technology for enhancing economic well-being and quality of life at high latitudes. AFES is part of the School of Agriculture and Land Resources Management at the University of Alaska Fairbanks. This association provides direct linkage between research and teaching in forestry, agriculture, and natural resources. Scientists who conduct research at the experiment station also teach, sharing their expertise with both undergraduate and graduate students.

There are several ongoing projects supported by CSREES's Sustainable Agriculture and Research Education (SARE) Program, but the Arctic investigations deal with tundra revegetation and carbon sequestration in permafrost soils. Long-term management decisions have been influenced by research results from revegetation experiments that were started over 25 years ago. Studies of soil organic matter (SOM) quality and quantity in Arctic soils by C.L. Ping's group continue, with new findings relating the quantity and quality of SOM to respiration of carbon from soils under changing climate conditions. Soil respiration in the laboratory is correlated with the hydrophilic fraction content of SOM. Stocks of these hydrophilic fractions are found to be high in the upper permafrost zone of Arctic soils. SOM of the upper

permafrost has been found to respire about twice as much carbon when compared to SOM of the subsurface active layers. The relative activity of SOM within the various depths in Arctic soils will be information vital for modeling and predicting the response of tundra to various warming scenarios. Studies currently underway will yield data relevant to the modeling of respiratory response to temperature and moisture changes at various carbon-stock levels at depth in Arctic soils. Particular attention is being given to cold-season changes in both magnitude and duration of thawed zones in the subsurface soils and the lowering of the permafrost table relative to bioactive carbon stocks.

Forest Service

The USDA Forest Service Pacific Northwest Research Station (PNW) is responsible for boreal forest research in Alaska, through the Institute of Northern Forestry Cooperative Research Unit (INFCRU). The research activity of INFCRU is a commitment to Long-Term Ecological Research (LTER) conducted at the Bonanza Creek Experimental Forest (BCEF) LTER site, sponsored jointly by the National Science Foundation (NSF), the USDA Forest Service, and the University of Alaska Fairbanks (UAF). The BCEF-LTER seeks to understand the Alaskan boreal forest as an integrated regional system in which climate, disturbance regime, and ecological processes are interactive components, with the objective to document the controls over these interactions and their ecological consequences. Research focuses on four major disturbance types—fire, flooding, forest harvest, and beetle outbreaks—and is organized around three major themes:

- Forest dynamics;
- The changing boreal carbon cycle; and
- Landscape controls over changing disturbance regime.

These themes operate at different scales and have key societal relevance but require improved understanding of the basic scientific processes.

Forest dynamics research focuses on the interactions between population/community processes, disturbance regime, and ecosystem dynamics. Study of the changing boreal carbon cycle focuses on ecosystem processes. These changes hinge on interactions with the hydrologic cycle and other element cycles. Carbon balance depends on spatial and temporal variation in climate and disturbance regime and on population and community processes associated with succession. Landscape controls over

changing disturbance regime focus on landscape and regional processes such as disturbance spread. These landscape processes are a logical consequence of changes in population, community, and ecosystem processes occurring at the stand scale.

BCEF-LTER research has documented significant climatic changes since the research initiation, including warmer air and soil temperatures and drought that is unprecedented in the past 200 years. These trends correlate with increased frequency of thermokarst (melting of ice-rich permafrost), fire, and insect outbreaks, and reduced growth and seed production in white spruce. These changes suggest directional changes in the structure and function of the Alaskan boreal forest. However, within stands, the microclimate, stand structure, productivity, and biogeochemistry have been influenced more strongly by extreme events, such as snow breakage and local insect infestations, and by successional changes in browsing and vegetation than by broad climatic trends. Population, biogeochemical, and landscape processes are inextricably intertwined in the Alaskan boreal forest. Animal diversity and impact are greatest in early succession, where they respond to, and affect, the rates and patterns of plant succession, root allocation, and biogeochemistry. The associated changes in species composition from willow to alder to poplar to spruce during floodplain succession cause changes in nitrogen inputs, nitrogen mineralization and nitrification rates, microbial immobilization, and the degree of nitrogen limitation to primary production. The changing soil environment due to both plant and animal impacts alters microbial community composition, which determines the methane oxidation rate. At larger scales the effects of climate on insects and fire influence the size and frequency of disturbance and the competitive interactions between spruce and grass during early colonization. These interactions may be influenced by herbivores and pathogens sufficiently to influence the trajectory and rate of succession. The structure of the terrestrial ecosystems in turn is the primary determinant of the chemistry and community composition of streams and lakes.

A simulated insect outbreak was established in three old-growth white spruce stands to study bark beetle and other insect colonization in these stands as well as changes in microclimate and carbon and nitrogen cycling. Frostfire, an experimental burn of a 900-ha watershed, was completed during the summer of 1999, following a 30-year period of hydrologic measurements in the same watershed.

The fire history of the watershed, carbon and nitrogen stocks in soils and vegetation, and exchanges of water, energy, and CO₂ with the atmosphere were all documented prior to the fire. In the coming years, scientists will observe the changes caused by the fire. Mosses account for about half the production in black spruce forests, and a new moss study will document patterns of moss biomass and production along with observations and experiments on environmental controls over moss productivity and the impact of mosses on carbon and nutrient cycles.

An extensive collection of high-quality white spruce tree-ring cores was taken at the Denali National Park Long-Term Ecological Monitoring (LTEM) site as part of a BCEF-LTER regionalization effort, which is examining how processes dominating at BCEF change along latitudinal and climatic gradients. The LTEM site represents an extensive forest-to-tundra transition, including the central Alaska Range treeline, a habitat long proposed as part of the BCEF-LTER program.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) cooperates and coordinates with state, village, regional, and Federal landowners; NRCS field office personnel in Alaska; and other agencies in Alaska to provide technical resource planning and application assistance to these landowners, users, and planners. Coordinated resource management plans, allotment management plans, or interim plans are developed. Soil maps are made of Native lands along with other private and government lands in Alaska.

The NRCS has continued to work in cooperation with the University of Alaska Fairbanks (UAF), the University of Delaware, the University of Cincinnati, and Agriculture Canada to measure soil moisture and temperature along several

transects in areas extending from nonpermafrost zones to areas of intermittent permafrost to areas of continuous permafrost. Studies are also being conducted on the active layer in the permafrost zone.

The NRCS is also actively working with the National Science Foundation's (NSF) Arctic System Science (ARCSS) program on the North Slope and at new sites on the Seward Peninsula. These are areas where greenhouse gas fluxes and changes to carbon storage may be related to global climate change. In the summer of 1998, sensors for soil moisture were installed near Fairbanks, and modifications were made to sites at Barrow and along the Haul Road. In 1999, moisture and temperature sites were installed at sites on the Kenai Peninsula. Representative soils were sampled at six sites near Ivotuk and five sites near Council as part of the NSF project. These sites were sampled in conjunction with scientists from UAF. Complete characterization is being run on these samples at the laboratory in Lincoln, Nebraska.

Work on the soil map of the circumpolar region has continued, and an updated draft map was presented at a meeting in Denmark organized by the European Soil Bureau in March 1999. In May 1999, a group of scientists from NRCS, the National Aeronautics and Space Agency (NASA), the University of Alaska, the University of Delaware, the University of Wisconsin, and the University of Cincinnati worked with ground-penetrating radar at Barrow to test its use in characterizing peat depths as well as depths of the active layer.

NRCS scientists have also worked with scientists from NASA, New Zealand, and the University of Washington to expand the soil monitoring work to Antarctica. Four sites were established in January 1999. In addition, NRCS, working with University of Alaska scientists and scientists from China, installed six sites in the permafrost zone of northern Tibet.

Department of Energy

The Department of Energy has responsibility for providing for the long-term energy security of the United States. To carry out this responsibility, DOE's Arctic and sub-Arctic activities support the DOE mission by expanding our understanding for predicting the consequences of continued dependence on fossil fuels, including the potential effects on global and regional greenhouse warming.

DOE's Arctic research activities include operating a research site on the North Slope of Alaska for studying the influence of clouds on solar radiation transport, as well as determining levels and origins of anthropogenic and natural radionuclides in Arctic systems. DOE researchers also collaborate with other Federal and state agencies in developing new fossil-fuels and wind-energy resources.

Atmospheric Radiation Measurements Program

The Atmospheric Radiation Measurements (ARM) program is part of DOE's effort to resolve scientific uncertainties about global climate change with a specific focus on improving the performance of general circulation models (GCMs) used for climate research and prediction. The ARM program focuses on one critical feature of the GCMs: the transport of solar and thermal radiation (sunlight and radiant heat) through the earth's atmosphere to and from the earth's surface. Within this area the greatest uncertainties are associated with clouds: their formation, quantitative description, behavior, and optical characteristics as influenced by atmospheric and underlying surface conditions.

The ARM approach is to create a number of long-term, highly instrumented climate research sites in carefully selected locations around the world. The site locations proposed and under development were selected primarily on the basis of what needs to be learned about clouds and radiation to improve the models, but secondarily on the basis of cost and logistics. Three research installations, known as Cloud and Radiation Testbeds, or CART sites, were selected for ARM. The site locations and current status are as follows:

	Funding (thousands)	
	FY 98	FY 99
Nat Inst Global Env Change	186	186
Carbon Balance/Tundra Ecosystem	132	132
Atmos Radiation Program	3,200	3,200
Total	3,518	3,518

- The Southern Great Plains site in Oklahoma has been operating since 1992.
- The Tropical Western Pacific site began phased operations in 1996 and is planned to be fully operational by 2001.
- The North Slope of Alaska adjacent to the Arctic Ocean (NSA/AAO) site began phased operations in 1997 and will be fully operational in 2000.

The CART sites have a planned life of ten years. The rationale for their long duration is that virtually all process-focused meteorological and climatological efforts to date have been based on short-term field efforts (a few weeks to a few months). During these brief periods, particular meteorological phenomena of interest occur at most a few times. This restricts these efforts to one or two case studies, which, while they produce important qualitative understanding, are limited by the statistics of small numbers in the accuracy and precision with which the relevant phenomena can be quantitatively described. With all of its potential economic and other societal impacts, global climate change is nevertheless the result of small radiative effects—a difference of a few watts per square meter in the energy balance out of an average energy flow of several hundred. To improve our ability to predict climate change, the physical effects that must be measured and accurately modeled are small. Doing this requires the statistics of large numbers—many cases, not just a few.

Data from the North Slope site are available from the ARM archive (<http://www.archive.arm.gov/data/ordering.html>).

For more information about NSA/AAO, visit the web site at <http://www.arm.gov/docs/sites/nsa/nsaaa.html>.

The general point of contact for the ARM program is Dr. Wanda R. Ferrell, Manager, Atmospheric Radiation Measurement Program, Environmental Sciences Division, SC-74, U.S. Department of Energy, Washington, DC 20585; 301-903-0043.

For the North Slope of Alaska/Adjacent Arctic Ocean CART site, the points of contact are Dr. Bernard Zak, North Slope of Alaska/Adjacent Arctic Ocean CART Site Program Manager, Sandia National Laboratories, PO Box 5800, Albuquerque, NM 87185-0755; 505-845-8631; and Dr. Knut Stamnes, North Slope of Alaska/Adjacent Arctic Ocean CART On-site Scientist, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800; 907-474-7368.

For the Global Measurements of Radionuclides in the Atmosphere and Deposition projects, the points of contact are Matthew Monetti and Fabien Raccah, U.S. Department of Energy, Environmental Measurements Laboratory (EML), Environmental Sciences Division, 201 Varick Street, NY, NY 10014; 212-620-3625 and 212-620-3793.

On the other hand, climate monitoring efforts have been ongoing for decades. However, these efforts focus on measuring a few important climate-related parameters, not the full range of parameters needed for the process studies necessary to improve the GCMs. The ARM program fills the critical gap between field campaigns and monitoring.

On July 1, 1997, the NSA/AAO CART site was formally dedicated. The NSA/AAO became operational in December 1997 as a phased deployment in conjunction with SHEBA (Surface Heat Budget of the Arctic Ocean), a multi-agency program led by the National Science Foundation (NSF) and the Office of Naval Research (ONR). The NSA/AAO site is in close proximity to the National Oceanic and Atmospheric Administration's (NOAA) high-latitude climate monitoring facility near Barrow, Alaska. This placement allows ARM to take advantage of NOAA instrumentation already in place and avoid unnecessary duplication.

NSA/AAO currently includes a 130-ft meteorological tower, a 40-ft-long instrument shelter, and three instrumentation decks, all on pilings (because of the permafrost). In addition, laboratory and office space are also located in the former Naval Arctic Research Laboratory (NARL) complex a mile from the field site. The site data system (Nanuq, which means polar bear) is also located at NARL.

A second facility began phased operations in 1999 at Atkasuk. The instruments were part of the SHEBA project and were redeployed to create the second Arctic facility.

In addition to ground-based instrumentation for characterizing the atmosphere and the earth's surface, it will also be necessary to make occasional instrumented aircraft flights to measure conditions aloft, primarily over the central facility, and to depend heavily on data from polar-orbiting satellites. Whenever possible, ARM activities that require aircraft will be coordinated with other agencies. In 1999 ARM participated with NASA, NOAA, and other agencies in both the aircraft and satellite components through FIRE (First ISCCP [International Satellite Cloud Climatology Program] Regional Experiment).

Two intensive operational periods (IOPs) were completed in FY 99. The Millimeter-wave Radiometric Arctic Winter Measurements IOP investigated the utility of millimeter-wave radiometry for measuring atmospheric water vapor during extremely dry conditions such as those that exist during the Arctic winter. A three-week single column model (SCM) IOP for the North Slope of Alaska site was conducted in March 1999.

Because of crashes of the aerosondes, ARM was not able to obtain atmospheric profile data surrounding Barrow from which to construct an SCM data set. Lessons learned from this IOP will be incorporated in future activities.

Global Measurements of Radionuclides in the Atmosphere and Deposition

The objective of this program is to characterize, quantify, and model the environmental pathways, and to evaluate the environmental and human health impacts on regional and global scales, of natural and anthropogenic radionuclides deposited on the earth's surface. A component of this program is the operation of a high-quality global radioactivity sampling network by DOE's Environmental Measurements Laboratory, which includes stations in the Arctic and sub-Arctic (Alaska, Canada, Greenland, Iceland, and Norway). Through the global network, DOE is poised to react instantly to any new introduction of atmospheric radioactivity. It should be noted that EML has been selected by the U.S. delegation to the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty (CTBT) Organization, Vienna, Austria, as the U.S. radionuclide laboratory to be incorporated into the International Monitoring System (IMS). There are 16 IMS laboratories worldwide, and they provide confirmatory analyses of atmospheric radionuclides and quality control functions for the IMS sampling sites. The selection was made based on EML's long and distinguished 50-year history as an internationally recognized laboratory for environmental radiation measurements and monitoring systems and because of its experience in international laboratory quality assurance programs in nuclear measurements.

Neighborhood Environmental Watch Network

Related to the Global Measurements of Radionuclides in the Atmosphere and Deposition projects is the Neighborhood Environmental Watch Network (NEWNET). NEWNET is a network of environmental monitoring stations and data storage and data processing systems, with public access to the data through the Internet and environmental teller machines (ETMs). This allows interested members of the public to have constant access to the stations so they can observe

the results at any time. A station manager from each community is trained in station maintenance and has access to researchers and support organizations that can provide technical assistance if needed. Station managers serve as liaisons to their communities and can help citizens understand measurements.

NEWNET was started in 1993 with stations in Nevada, California, Utah, and New Mexico. It is based on concepts developed by the Department of Energy for the Community Monitoring Program at the Nevada Test Site Nuclear Testing Facility. These concepts date back to the Three Mile Island nuclear power reactor accident in the late 1970s. Five stations are located in Alaska: in Fairbanks, Kotzebue, Nome, Point Hope, and Seward.

Stations vary in configuration. Most NEWNET stations have sensors for monitoring wind speed and direction, ambient air temperature, barometric pressure, relative humidity, and ionizing gamma radiation. Some stations have tipping-bucket rain gauges and others have additional radiation sensors. Additional types of sensors are being investigated for air quality and water quality measurements. The DOE is funding research to develop a NEWNET station capable of operating remotely for long periods of time. Such equipment would be used at remote sites such as Amchitka Island in case this type of monitoring becomes necessary. The Alaska stations are being set up in collaboration with the Alaska Department of Environmental Conservation (DEC) and the University of Alaska Fairbanks. The project is funded by the Department of Energy, Nevada Operations Office (DOE/NV). This effort will strengthen collaborations between Los Alamos National Laboratory, the Alaska DEC, and the DOE/NV in studying the environment in Alaska. It will promote an understanding of radiological issues in Alaska and provide continuous monitoring of radiation levels, addressing concerns by Alaskan citizens about the Bilibino nuclear power reactors. In 1999 a training program was instituted for Alaskan residents who serve as station managers.

Amchitka Island, Alaska Project

Amchitka Island is located near the western end of the Aleutian Islands chain and is a portion of the Alaska Maritime National Wildlife Refuge. It was used during World War II as a military base by the Army and from 1988 to 1993 by the Navy as an over-the-horizon radar facility. The Atomic Energy Commission, the predecessor to the

Department of Energy, used the island for three underground nuclear tests between 1965 and 1971. Project Longshot, conducted on October 29, 1965, was about 80 kilotons. Project Milrow, conducted on October 2, 1969, was about 1 megaton. Project Cannikin, conducted on November 6, 1971, was less than 5 megatons. Cannikin was the largest U.S. underground nuclear test.

In preparation for the tests, intensive bioenvironmental studies were conducted. Follow-up radioecology studies were conducted during the 1970s, primarily by the University of Washington. The Environmental Protection Agency's Las Vegas Environmental Monitoring Systems Laboratory has been collecting surface water and groundwater samples subsequent to the cessation of the radioecology studies in the 1970s. Since the Navy base closed in 1993, EPA monitoring was scheduled for biennial periods.

Because of concerns brought up by Greenpeace, the 1997 sampling was expanded to include aquatic moss, marine algae, and sediments, in addition to groundwater and surface water. Some drilling mud samples were also collected to be analyzed for chemical contaminants.

During the summer of 1998, samples were collected for chemical analysis to characterize the DOE sites for surface chemical contaminants. Areas sampled included drilling mudpits, lakes and streams associated with drilling activities, areas of suspected drilling mud disposal, and a suspected debris disposal area. Media sampled for chemical analysis included sediments, water, fish, and benthic invertebrates. Some freshwater fish samples were also collected and analyzed for radionuclides.

The Alaska Department of Environmental Conservation worked with the Aleutian/Pribilof Islands Association (A/PIA), the cognizant Native American government organization for the region, to collect water, sediment, aquatic moss, and tundra vegetation. Samples were collected on Amchitka and Adak Islands and near Cold Bay (Alaska Peninsula). The intent of this work is to expand the 1997 sampling effort and to address some needs to increase the statistical rigor of the 1997 work. DOE supported the work through an Agreement in Principle grant, by a combination of funding, by providing expert staff support, and by accommodating the field crew in the Amchitka field camp.

Nearing completion is a draft model of groundwater flow at Amchitka in the areas of the underground tests. The model will also predict groundwater leaching and transport of test-related radionuclides. These data will enable DOE and the state to predict where

More information on NEWNET, including readings from NEWNET stations, can be found on the Web (<http://newnet.jdola.lanl.gov/>).

The point of contact for the NEWNET program is Larry Sanders, U.S. Department of Energy, Los Alamos National Laboratory, DX-7 Instrumentation and Control, NEWNET Project Leader, Los Alamos, NM 87545; 505-667-3492.

The point of contact for the Amchitka Island, Alaska Project is Monica Sanchez, U.S. Department of Energy, Environmental Restoration Division, Nevada Operations Office, Las Vegas, NV; 702-295-0160

groundwater from the vicinity of the detonation cavities is likely to discharge on the ocean floor near the island. It will also predict concentrations and breakthrough times. This information will then be used in a human health and ecological risk assessment.

Similarly the results of the 1998 sampling of the surface and the recently completed analyses will be used to complete a surface human health and ecological risk assessment. With completion of the risk assessments, decisions can be reached concerning future remediation and long-term monitoring needs.

A field trip to Amchitka is planned for the summer of 2000 to gather engineering data to facilitate the design of closures for mudpits. Construction to implement closures is scheduled for 2001.

Joint Coordinating Committee for Environmental Management Contaminant-Transport Studies

The former Soviet Union (FSU) has an extensive nuclear power program with numerous supporting waste management activities that currently involve ad hoc storage of low- and intermediate-level wastes by shallow land burial and in surface water impoundments, as well as storage of high-level wastes. The Mayak, Tomsk, and Krasnoyarsk sites all lie within a few kilometers of the edge of the West Siberian Plain and Basin, the largest basin and region of low relief on earth. Precipitation and potential evapotranspiration varies substantially from south to north within the basin, and permafrost is an important characteristic of the landscape north of about 61°N. Hydrogeologically the region is believed to be a single groundwater basin with pervasive artesian character. The surface water hydrology of the region consists of an extensive system of rivers, lakes, and swamps that generally act as sinks for runoff or any overland contaminant flow, and the great rivers of the basin (the Ob and Yenisey) are generally believed to be the ultimate sinks for any groundwater contamination sources. These rivers probably provide the main pathway to the Arctic Ocean to the north, although there has been some speculation that deep circulating supraregional groundwaters provide another potential pathway for contamination to reach the Arctic Ocean. Thus, past and continuing disposal of wastes at Mayak, Tomsk, and Krasnoyarsk to surface waters, to surface water impoundments, and by deep well injections at Tomsk and Krasnoyarsk have the potential for

contaminating the Arctic Ocean, the western Siberian oil and gas fields, and the regional water resources.

The DOE is sponsoring subsurface contaminant transport studies near the Mayak site in Russia under the auspices of the Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM) between the Office of Environmental Management (DOE-EM) and the Ministry of Atomic Energy (MINATOM) for the Russian Federation. The purpose of the work is to understand the "field scale experiment" of radionuclide-contaminated groundwater migration from a former surface repository at Lake Karachai towards the Mishelyak River. Field investigations of hydrogeological, geochemical, geophysical, and radiometric measurements are being conducted to characterize and model the subsurface migration of the groundwater plume.

These efforts bring together American and Russian researchers to develop the historical (30-year) Russian-contaminated groundwater plume data from the Mayak and Tomsk sites to calibrate and validate three-dimensional regional hydrogeological models in use at DOE sites, specifically for the Integrated Groundwater, Vadose Zone and River System at Hanford, Washington. In addition, 3-D contaminant migration models are being developed that include the geochemistry of contaminant solute-rock interactions of interest to vadose zone activities throughout the DOE complex.

American researchers in the program are from the Pacific Northwest National Laboratory, the Savannah River Laboratory, and the Environmental Measurements Laboratory. Russian scientists are from Hydrospeztzgeologiya, the Mayak Production Association, and the Institute of Physics and Power Engineering. Funding for the program comes from the Characterization, Monitoring and Sensor Technology Crosscutting Program (CMST-CP) in the DOE Office of Environmental Management.

North Slope of Alaska Methane Hydrate Resource Assessment

The Department of Energy's Office of Fossil Energy is assisting the U.S. Geological Survey (USGS) in an assessment of the recoverability and production characteristics of permafrost-associated methane hydrates and related free-gas accumulations in the Prudhoe Bay-Kuparuk River area of the North Slope of Alaska. Methane hydrate deposits in Alaska and surrounding waters are estimated to contain almost 170,000 trillion cubic feet

The point of contact for the JCCEM project is Dr. Adam Hutter, Environmental Sciences Division, Environmental Measurements Laboratory (EML), U.S. Department of Energy, 201 Varick Street, NY, NY 10014; 212-620-3576.

The points of contact for the North Slope of Alaska Methane Hydrate Resource Assessment are Edith C. Allison, U.S. Department of Energy, Office of Fossil Energy, Office of Product-Line Director (FE 32), Washington, DC 20585; 202-586-1023; edith.allison@hq.doe.gov; and Timothy S. Collett, Research Geologist, Energy Resources Program, U.S. Geological Survey, Denver Federal Center, P.O. Box 25046, MS 939, Denver, CO 80225; 303-236-5731.

of natural gas, hundreds of times greater than conventional gas resources. Methane produced from hydrates has near-term value for pressure maintenance of small, satellite oilfields. In the long term, methane from hydrates is expected to take on a greater role in power generation and transportation because of increasing pressure for cleaner fuels and reduced emissions of carbon dioxide.

Wind Activities in Alaska

The State of Alaska faces many unique challenges in helping to ensure that its citizens have access to affordable and reliable electric power. These challenges are particularly evident in rural areas of the state, where electricity is primarily produced by diesel power plants that are small, expensive, and difficult to operate and maintain. At present the cost of electricity for rural customers is eased somewhat by the availability of the Power Cost Equalization (PCE), an electric rate subsidy program administered by the Alaska Department of Community and Regional Affairs (DCRA). However, funds for the PCE are derived from the sale of oil from Prudhoe Bay and are projected to be exhausted in 2000 or 2001. When that occurs, electricity rates in rural areas could rise substantially. Faced with higher electricity costs and the potential danger of environmental damages related to the use of petroleum energy in a fragile Arctic ecosystem, various Alaskan entities are now exploring ways in which renewable sources of energy can aid in the production of electric power. To better understand the role that renewable energy can play, the DOE's Wind Energy Program is engaged in collaborative efforts with a number of Alaskan organizations at the state and local levels to determine how wind can make a greater contribution in the production of electric power. These efforts include the following examples.

The DOE Wind Program has provided funding to the Alaska Department of Community and Regional Affairs (DCRA) to support the Kotzebue Sustainable Technology Energy Partnerships (STEP) Wind Project, which involves the design and installation of a 300-kW wind energy project with the Kotzebue Electric Association (KEA) in Kotzebue, Alaska. The first phase of that project, the installation of three Atlantic Orient Corporation (AOC) Model 15/50, 50-kW wind turbines purchased by KEA and DCRA, took place in the summer of 1997. Those turbines are operating well and were augmented by three additional

STEP-purchased turbines installed in April 1999. The purpose of the project, which is cost-shared between DOE and DCRA, is to determine the feasibility of a wind system for augmenting an existing diesel power plant in a remote Alaskan community.

Under a DOE grant with Kotzebue Electric, funding has been provided to design, purchase, and install a 1.0- to 1.5-MW wind farm to supplement electricity produced by an existing 11.3-MW diesel power plant and a 300-kW wind energy system installed by KEA, DCRA, and the DOE-STEP program. In May 1999, four additional AOC Model 15/50 wind turbines installed under the windfarm project joined the six 50-kW wind turbines described under the STEP entry above. The next phase of the windfarm project (which now has a total installed capacity of 500 kW) will take place in 2000, when the installation of additional turbines is planned. When completed, the wind farm will have the capability of meeting a substantial portion of Kotzebue's electric power requirements, which are characterized by a daytime peak load of 3.6 MW and a nighttime base load of approximately 2.0 MW. The National Renewable Energy Laboratory (NREL) is providing technical support to KEA to aid it in project implementation.

The Village of Wales High-Penetration Wind Project is administered by the Alaska DCRA to determine if a high-penetration wind system—one capable of replacing most, if not all, diesel generation capacity for substantial periods—can allow a small rural village to substantially reduce its dependence on diesel fuel needed to produce electricity. The Wales project will involve the installation of 100 kW of wind energy capacity to augment an existing diesel power system. Current plans are for two 50-kW wind turbines to be installed by the end of autumn 1999. A successful Wales project can serve as a model to meet the needs of perhaps 50–100 remote villages in Alaska that have significant wind resources.

The DOE Wind Program, through its State Energy Program, has made funding available to the Alaska DCRA to support wind resource assessment (WRA) in remote Alaskan communities. The WRA work represents an important initial step to determine if sufficient wind resources exist to support economically feasible wind installations in such communities. DCRA selected five villages—Mekoryuk, Point Hope, Selawik, St. Michael, and Unalakleet—as the sites for the first resource assessment work to be completed under this

The points of contact for the Department of Energy Wind Activities in Alaska are Thomas J. Hall, Office of Geothermal and Wind Technologies (EE-12), Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, DC 20585; 202-586-8302; and Thomas Sacco, Office of Energy Efficiency and Renewable Energy (EE-14), U.S. Department of Energy, Washington, DC 20585; 202-586-0759.

project. In late January 1999, a training session was held in Kotzebue for representatives from the five villages who will install and maintain the WRA monitoring equipment and transmit the data collected to DCRA for analysis. The WRA work being conducted in the five villages will complement WRA work underway in Kotzebue, Wales, Yukutat, and Deering.

The DOE Wind Program funded an effort to characterize the potential size of the wind-diesel hybrid market in Alaska. The study data were delivered to the Alaska DCRA in October 1998 and will be used to help DCRA, the University of Alaska Anchorage, the Alaska Village Electric Cooperative, and others determine the most appropriate locations for additional wind/diesel village power systems. Approximately 90 villages were analyzed to provide information in selecting communities for project siting, which will accelerate the pace of wind energy use in the state.

In 1998 and 1999 the DOE Wind Program, in collaboration with the private sector, the National Aeronautics and Space Administration, and the National Science Foundation, provided support to develop a new 100-kW wind turbine specifically designed for use in cold climates. This unit is being developed in large measure to meet the need of Alaskan villages for additional U.S.-manufactured turbine options.

In 1998 the Kotzebue Electric Association was selected to participate in the joint DOE-Electric Power Research Institute (EPRI) Turbine Verification Program (TVP). The TVP is designed to help utilities gain experience in the operation of new wind turbine technologies. As a TVP-participating utility, KEA received system control and data acquisition equipment, as well as technical support, from NREL and EPRI. Under the TVP, KEA is also able to exchange performance, operating, and maintenance data with other electric utilities that participate in the program.

DOE and the State of Alaska Department of Community and Regional Affairs, Division of Energy, plan to design and install 100 kW of wind energy capacity in rural Alaska in 2000 to augment a community's existing diesel electric generation system. It is also anticipated that in the

2001–2002 time frame the electricity generated by the wind and diesel systems will be augmented by electricity produced by a reversible fuel cell system. The hydrogen needed for the fuel cell's operation will be produced by diesel fuel that will be converted to hydrogen. The fuel cell system will provide electricity to the community during periods when winds are not sufficient to produce power from the wind system. The combined wind/diesel/fuel cell concept will be evaluated to determine whether there is an economic benefit in the application of this combination of technologies in rural Alaska and, if so, what factors produce the highest benefits. A DOE Cooperative Agreement to implement the project was awarded to DCRA in 1998. In 1999, DCRA continued its examination of two potential project sites—the communities of Naknek and Unalaska.

The DOE National Renewable Energy Laboratory's National Wind Technology Center (NWTC), using funding provided by the DOE Wind Program, is conducting an analysis to fully document the configuration, performance, operational, and economic characteristics of a wind/diesel hybrid system that was installed on the island of St. Paul in the Bering Sea in late 1998. That system was installed by the Tanadgusix (TDX) Corporation, an organization established in 1973 under the Alaska Native Land Claims Settlement Act. TDX is pursuing various business development ventures and has established eight subsidiary corporations to accomplish this. One of these is TDX Power Inc., the owner and operator of the wind/diesel hybrid system, which consists of one Danish-manufactured, Vestas V-27, 225-kW wind turbine, augmented by two 150-kW high-speed (1800 rpm) diesel generator sets. This hybrid power system produces not only electricity, but also waste heat, both of which currently meet the needs of a warehouse facility and an airport on the island. The TDX Power, Inc. hybrid system, which competes with the local electric utility, is expensive, but unique and well designed, and the NWTC analysis is intended to yield data that may help in the design of wind/diesel hybrid systems in remote Alaskan communities.

Department of Health and Human Services

The Department of Health and Human Services supports and conducts Arctic health research through the Centers for Disease Control and Prevention and the National Institutes of Health.

Centers for Disease Control and Prevention

The Arctic research programs of the Centers for Disease Control and Prevention (CDC) are conducted by four of its components: the National Center for Infectious Diseases (NCID), the National Center for Environmental Health (NCEH), the National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP), and the National Institute for Occupational Safety and Health (NIOSH). These programs represent an excellent example of interagency cooperation and collaboration with the State of Alaska Division of Public Health, the Alaska Native Medical Center, the Alaska Native Tribal Health Consortium, the Alaska Area Native Health Service (AANHS) of the Indian Health Service (IHS), local and regional Native health corporations, universities, and other state and local agencies and organizations. Collaborative research has focused on four major areas of human health concern in Arctic communities:

- Prevention and control of emerging infectious diseases;
- Human health effects of exposure to environmental persistent organic pollutants;
- Prevention of chronic effects of micronutrient deficiencies; and
- Injury prevention.

National Center for Infectious Diseases

The Arctic Investigations Program (AIP) located in Anchorage, Alaska, is one of three U.S. field stations operated by the National Center for Infectious Diseases of the CDC. The mission of AIP is the prevention of infectious diseases among residents of the Arctic and sub-Arctic, with a focus on diseases of high incidence and concern among

	Funding (thousands)	
	FY 98	FY 99
National Institutes of Health	13,575	12,999
Centers for Disease Control/Prevent.	2,550	3,490
Total	16,125	16,489

the indigenous populations and more recently on emerging and re-emerging diseases. Research on the prevention and control of infectious diseases in these remote and widely scattered populations with limited resources is accomplished through partnerships with communities; local, regional, and Native health organizations; universities; other divisions, programs, and centers within CDC; the National Institutes of Health; the IHS; and the State of Alaska.

Emerging Infectious Diseases

Infectious diseases are a continuing menace to all peoples of the globe, regardless of age, gender, lifestyle, ethnic background, or socioeconomic status. Arctic populations have long endured the debilitating effects of both endemic and epidemic infectious diseases, the effects of which have adversely affected both social and economic development in circumpolar regions. With the advent of antibiotics, tuberculosis and other life-threatening infections seemed conquerable, and the incidence of diseases of childhood, such as diphtheria, whooping cough, and meningitis, were reduced dramatically through the use of vaccines. These advances, together with improvements in sanitation and water quality, dramatically lowered the incidence of infectious diseases throughout the developing world, including the Arctic. However, the specter of new virulent and antibiotic-resistant forms of old diseases, such as tuberculosis, measles, diphtheria, and meningitis, once again is threatening circumpolar communities. Newly emerging threats include HIV, hepatitis C, and food and waterborne illnesses, as well as a high

Arctic prevalence of infectious agents associated with malignancies, including hepatitis B and C viruses (liver cancer); *Helicobacter pylori* (gastric cancer); human papilloma virus (cervical cancer); and Epstein Barr virus (nasopharyngeal cancer). Factors that have contributed to this change in Arctic disease incidence include:

- Rapid population growth and familial crowding;
- Redistribution of population because of decreased employment opportunities in small Arctic communities;
- Urbanization of Arctic peoples and the resulting social and economic alienation, as well as changes in governments, self-governance, and fiscal policies;
- Increased global travel and potential for introduction of new infectious agents into naive populations;
- Mass production and globalization of the food supply;
- Changes in human behaviors, such as increased substance abuse, intravenous drug use, and risky sexual behavior;
- Elevated use of antibiotics in remote Arctic communities, hastening the development of antimicrobial resistance;
- Climatic fluctuations and shifts in animal, insect, and sea life habitats; and
- Contamination of the subsistence food supply with pesticide residues, resulting in deleterious effects on the developing immune system.

International Circumpolar Surveillance Initiative

With the heightened global concern about emerging and re-emerging infectious disease problems, the AIP, together with Health Canada's Bureau of Infectious Diseases, has initiated a pilot program linking public health laboratories in Alaska, the Yukon Territory, Northwest Territories, Nunavut, northern Quebec, and coastal Labrador to monitor invasive diseases among indigenous populations caused by *Streptococcus pneumoniae* and *Haemophilus influenzae*. The surveillance initiative is designed to capture results from diagnostic workups of clinically significant infectious diseases by all laboratories in each region and to express the cases identified as a population rate. This surveillance will be used to monitor common as well as unusual or emerging infectious diseases, to suggest special studies highlighting descriptive epidemiology and risk factors, to demonstrate the effects of vaccine or other control programs, and

to track antimicrobial resistance patterns. The North American surveillance system for *S. pneumoniae* may serve as a model for other circumpolar collaborations (Greenland [Denmark], Iceland, Norway, Sweden, Finland, and Russia) for surveillance of emerging infectious diseases in Arctic nations, as well as other health events of concern among Arctic communities.

The prevention and control of certain high-priority emerging infectious disease issues targeted by CDC include:

- Antimicrobial resistance;
- Food and waterborne diseases;
- Vector-borne and zoonotic diseases;
- Diseases transmitted through blood transfusions or blood products;
- Chronic diseases caused by infectious agents;
- Vaccine development and use;
- People with impaired host defenses;
- Diseases of pregnant women and newborns; and
- Diseases of travelers, immigrants, and refugees.

Antimicrobial Resistance

In recent years, among Alaska residents, antimicrobial resistance has emerged in a number of pathogens, including *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Helicobacter pylori*, and *Staphylococcus aureus*. Laboratory-based surveillance first detected strains of *S. pneumoniae* with decreased susceptibility to penicillin and other antimicrobial drugs in the Yukon-Kuskokwim Delta region in the 1980s. These moderately resistant strains have subsequently become widespread throughout the state. In the early 1990s, strains with greater levels of resistance to penicillin were identified in Alaska, concurrent with increasing rates of these strains in other parts of North America. In 1998 more than 6% of all pneumococcal isolates from patients with invasive disease were fully resistant to penicillin. Drug-resistant pneumococcal infections are of particular concern in Alaska because rates of pneumococcal meningitis and bacteremic pneumonia are up to ten-fold higher for Alaska Natives than for any other population in the U.S.

A number of epidemiological studies have shown that frequent or prolonged use of antimicrobial drugs is associated with greater risk of drug-resistant pneumococcal carriage and disease. A controlled intervention, consisting of an educational campaign targeting the public and health care providers in 17 rural Alaska villages, has shown that in the intervention villages, prescrip-

tions for respiratory tract infections were reduced by 22%, and carriage of *Streptococcus pneumoniae* with decreased susceptibility to penicillin fell by 28%. Among isolates of *Haemophilus influenzae* type b, a pathogen causing meningitis, 82% are resistant to ampicillin, and of isolates of *Helicobacter pylori*, a bacterium that causes stomach ulcers, 23% are resistant to clarithromycin and 79% are resistant to metronidazole, common drugs used to treat these infections. High re-infection rates occur among persons treated with antibiotics. Studies are underway to define and understand the mode of re-infection, as well as the mechanisms by which *Helicobacter pylori* becomes resistant to antibiotics.

Foodborne and Waterborne Diseases

Alaska has the highest rates of foodborne botulism in the U.S., and the rate more than tripled from 1950 to 1997. The majority of cases are associated with consumption of fermented foods prepared from fish or marine mammals. Improved recognition of mild cases has probably contributed to part of the observed increase in cases. Experiments performed in 1999 showed that *Clostridium botulinum* toxin production was greatest when fish head fermentations were carried out in sealed plastic buckets rather than via traditional methods, such as placing fish heads in a grass-lined hole in the ground.

Diseases Transmitted Through Blood Transfusions or Blood Products

In 1989, hepatitis C virus (HCV) was isolated and recognized as the predominant cause of transfusion-associated non-A, non-B viral hepatitis. HCV is the most common chronic bloodborne infection, and it is estimated that 3.9 million Americans (1.8% of the population) have been infected with HCV. Most of these persons are chronically infected and are capable of transmitting HCV to others, but they may not be aware of their infection because they are not clinically ill. The CDC, therefore, recommended HCV testing and counseling for persons at risk of infection, including all persons who received a transfusion, blood products, or organ transplant before routine screening of blood donors was implemented in July 1992. Improvements in donor screening throughout the U.S. have made the risk of acquiring HCV, as well as other known bloodborne pathogens including HIV, HTLV, and hepatitis B virus, extremely low. Injecting-drug use now accounts for 60% of HCV transmission in the U.S. A survey of injecting drug users in Anchorage

found 81% to be infected with HCV, a prevalence similar to that found in the inner city of other major U.S. metropolitan areas. The full public health impact of transfusion-associated HCV acquired before routine screening of blood products in Alaska is poorly defined. The hidden nature of the HCV epidemic is reflected by the near doubling in number of cases reported in Alaska, from 570 in 1997 to 1004 in 1998, likely because of increased testing of high-risk persons.

Chronic Diseases Caused by Infectious Agents

Several chronic diseases once attributed primarily to lifestyle or environmental factors are now known to be caused or intensified by infectious agents. Alaska Natives have high rates of chronic hepatitis B virus infection and associated hepatocellular carcinoma. Widespread use of effective hepatitis B vaccines has reduced the annual incidence of hepatitis B in certain Native populations up to 50-fold. The results of a 16-year prospective cohort study of Alaska Natives with chronic hepatitis B infection who were screened for early diagnosis of hepatocellular carcinoma showed an improved 5- and 10-year survival rate compared to historical controls.

Iron deficiency anemia has long been found to be common among Alaskan Natives despite a diet rich in bioavailable iron. In the 1990s it was found that fecal blood loss due to ulcers associated with *Helicobacter pylori* infection may be a contributing factor to iron deficiency anemia in Alaska Natives. A large population-based survey has shown that the seroprevalence of *Helicobacter pylori* in Alaska Natives is 75%. The rate increased with age. By 14 years of age, 78% of children were found to have evidence of infection. Iron deficiency was found in 20% of males and 36% of females. A significant association between iron deficiency and seropositivity for *Helicobacter pylori* was found in persons less than 20 years of age. Iron deficiency anemia remains common among Alaska Native preschool children. In one village surveyed in 1999, of 123 children between 1 and 5 years of age, 38% were iron deficient and 17% were anemic. Serologic evidence of *Helicobacter pylori* infection was found in 41% of these children, and there was a strong statistical association between *Helicobacter pylori* seropositivity and both anemia and iron deficiency.

Vaccine Use and Development

Rates of *Haemophilus influenzae* type b (Hib) meningitis and bacteremia among Alaska Natives

prior to routine infant immunization were the highest ever recorded. Routine immunization of all Alaska Native infants with a Hib conjugate vaccine, which began in 1991, reduced the incidence of invasive Hib infection more than ten-fold. Re-emergence of invasive Hib disease after a change to a less immunogenic vaccine for routine vaccination in 1996 highlights the importance of ongoing surveillance and of maintaining laboratory diagnostic capabilities for vaccine-preventable diseases, including those thought to be well controlled.

Studies carried out in 1998-1999 demonstrated that up to 9% of fully vaccinated children living in some rural regions of the Alaska were carriers of Hib. Because rates of Hib carriage in urban settings are as low as 0.9%, population factors such as household crowding and lack of indoor plumbing may be reasons for ongoing high Hib carriage in more rural communities. The childhood Hib vaccine programs in Alaska have been successful in preventing Hib disease, not only in infants and children who received the vaccine but also among adults who were never immunized. In a study reported in 1999 the incidence of invasive *Haemophilus influenzae* disease among Native and non-Native adults declined from 2.1 cases/100,000 in 1986-1990 to 1.4 cases/100,000 following the introduction of infant vaccine programs in 1991.

National Center for Environmental Health

Exposure to Persistent Organic Pollutants, Nonpersistent Pesticides, and Trace Metals

Recent evidence suggests that exposure to persistent organic pollutants (POPs) and heavy metals in the environment may increase a newborn's risk of developmental, reproductive, neurological, immunologic, and carcinogenic effects. Alaska Native women are potentially exposed to these chemicals through their subsistence diet of fish and marine mammals already documented to have high organochlorine and heavy metal content. A growing fetus is exposed to contaminants in the womb through transfer from the mother. Alaska Natives are concerned that organic and heavy metal pollutants are accumulating in subsistence foods. These populations have expressed a strong desire for programs to evaluate biological levels of these contaminants and associated health effects, especially in pregnant women and their newborn children.

The Alaska Native Cord Blood Monitoring Program is designed to monitor levels of POPs and heavy metals in a cohort of 180 pregnant women and their newborn infants each year. This will allow spatial and temporal trends in human tissue accumulations to be identified. Simultaneous examination of health records for maternal problems in pregnancy and infant problems in the first year of life will permit examination of data for associations between contaminant exposure and health outcomes. In 1999 a protocol was developed and approved by Native health boards and human subjects committees, and a sustainable network of collaborating agencies and institutions was created. These include the Alaska Native Tribal Health Consortium (lead agency), the Environmental Protection Agency, the National Center for Infectious Disease's Arctic Investigations Program, the Alaska Area Native Health Service, the University of Alaska's Institute of Circumpolar Health Studies, the Alaska Native Health Board, and the State of Alaska. Data will be provided to agencies responsible for reducing transboundary pollution, to international groups monitoring circumpolar pollution, and to Alaska Native communities to allow them to create acceptable strategies to reduce exposure while maintaining their subsistence lifestyle.

Breast Cancer and Environmental Organochlorines among Alaska Native Women

Environmental exposure to chlorinated organic chemicals may increase a woman's risk of developing breast cancer because these chemicals appear to be capable of disrupting normal hormonal relationships. These chemicals can increase estrogen exposure by acting like the hormone estrogen or by blocking naturally occurring androgen (anti-estrogen) activity. Alaska Native women are presumably exposed to these endocrine-disrupting chemicals through a subsistence diet of fish and marine mammals.

This project evaluates the relationship between exposure to environmental organochlorines and the development of breast cancer in Alaska Native women by collecting biologic samples (serum, urine, and adipose tissue) from women undergoing breast biopsy or surgery at the Alaska Native Medical Center (ANMC). Samples are analyzed for endocrine-disrupting chemicals. Interviews are planned for all participating women to identify potentially confounding risk factors for breast cancer (for example, reproductive and family history) and to collect dietary information that will aid in

interpreting laboratory values and in defining routes of exposure. Sera collected from participating women at earlier times will be used to evaluate the accumulation of organochlorine chemicals over time (and in relation to dietary patterns) as well as any decrease in body burden associated with lactation. All data will be analyzed using conditional logistic regression to determine if the amount of organochlorine chemicals in a woman's serum and adipose tissue is associated with biopsy outcome. The results will be directly useful to local and circumpolar public health officials targeting early detection and prevention of cancer in the Arctic.

National Center for Chronic Disease Prevention and Health Promotion

Iron deficiency anemia has been recognized as a persistent problem among Alaska Natives. Surveys conducted from the 1960s through the 1990s consistently show a prevalence of 10–35% among Alaska Native children. By contrast, the prevalence of anemia among preschool children in the U.S. has been declining, reaching levels of 5–8% for those under age 5. Among Alaska Native adults, up to 25% of women and 9% of men are iron deficient. Because intakes of bio-available iron and iron-enhancing foods are higher for Alaska Natives than the general U.S. population, the mechanism underlying this widespread iron deficiency is unknown, but its distribution suggests a shared etiology that is independent of age and sex.

In 1999 the National Center for Chronic Disease Prevention and Health Promotion's Division of Nutrition and Physical Activity staff, together with NCID's AIP, NCEH, the Yukon Kuskokwim Health Corporation, and the State of Alaska, conducted an investigation in one village in western Alaska that reported rates of anemia among 2–4 year olds of 31%, more than three times the overall U.S. prevalence of 10% for children aged 1–5 years. This study confirmed that iron deficiency anemia continues to be a significant public health problem among young children living in villages of western Alaska. The prevalence, however, was lower than the 31% initially reported. This discrepancy may be related to the different blood collection methods used. Anemia appears to be unrelated to iron intake, but low consumption of iron-enhancing foods, such as citrus, and seropositivity for *H. pylori* appeared to be risk factors.

National Institute for Occupational Safety and Health

Injury Prevention

The National Institute for Occupational Safety and Health (NIOSH) found that for the 10-year period between 1980 and 1989, Alaska experienced 34.8 worker deaths for every 100,000 workers employed in the state, a rate approximately five times the national rate of 7.0 per 100,000. After identifying Alaska as the highest-risk state in the U.S. for job-related traumatic fatalities, NIOSH established a research field station, as part of its Division of Safety Research, in Anchorage in 1991.

The major research questions addressed by the project are:

- How many severe occupational injuries occur in Alaska?
- In which Alaskan industries and occupations do they occur?
- What risk factors are identifiable for these events?
- Which of these risk factors can be eliminated or mitigated?
- How can this be accomplished most effectively?

The NIOSH Alaska Field Station designed and implemented a comprehensive surveillance system for fatal and nonfatal occupational injuries, the Alaska Occupational Injury Surveillance System (AOISS). AOISS obtains risk factor information and permits quantitative epidemiologic analyses to be used for sound public health and prevention planning. The AOISS database contains more than 600 fatality records, along with 3000 nonfatal injury records from the Alaska Trauma Registry.

The Alaska Field Station has established strong relationships with many other Federal, state, municipal, and nongovernmental agencies that are engaged in detecting, investigating, and preventing occupational injuries and fatalities. These relationships, formalized within the Alaska Inter-agency Working Group for the Prevention of Occupational Injuries, have fostered injury surveillance, a broader understanding of occupational injuries in the state, and an opportunity to effectively influence the immediate response to emerging occupational injury problems (such as helicopter logging fatalities, drownings from boating accidents, and occupational homicides).

Thus far, surveillance and investigations indicate that between 1990 and 1998, 603 Alaskan workers died, an average of one every five days,

from job-related injuries. They died from drowning, in aircraft crashes, by being crushed, from falls, in motor vehicle crashes, and from homicide. Many of these deaths were among young people, resulting in over 16,150 worker years of potential life lost before age 65. The dollar cost to society in lost future productivity (wages) due to these 603 premature work-related deaths is estimated to be \$668,665,000.

The combined intervention efforts of many agencies and individuals have contributed to a 43% decline in work-related deaths in Alaska in 1998 compared to 1991. Commercial fishing deaths in 1998 were down 64% from 1991; in 1998, 93% of commercial fishermen survived vessel sinkings/capsizings, whereas in 1991 only 73% survived. NIOSH published *Commercial Fishing Fatalities in Alaska: Risk Factors and Prevention Strategies* in September 1997 to foster further progress in this area.

For the 18-month period of January 1, 1992, to June 30, 1993, helicopter logging pilots had the highest-risk occupation in Alaska. Following implementation of an interagency intervention for this problem in July 1993, Alaska has experienced a marked decrease in helicopter logging-related fatalities.

After their analysis of severe injury events, the Alaska Field Station has proposed a number of technologic innovations (such as log truck stake extensions and fishing vessel retrofit sponsons) and procedures (such as fail-safe communications in logging transport operations and encouraging the wearing of personal flotation devices during commercial fishing operations) to improve worker safety in Alaskan industries.

The surveillance technology developed by the NIOSH Fatality Assessment and Control Evaluation (FACE) program has now been transferred to the Alaska Department of Health and Social Services, Division of Public Health, Section of Epidemiology, Occupational Injury Prevention Program via the state-based FACE program, with technical assistance and collaboration by the Alaska Field Station.

Alaska Trauma Registry

The following data are for injuries requiring hospitalization as recorded in the Alaska Trauma Registry. The occupation field in the registry was reworked in January 1997 to NIOSH specifications and will permit future classifications of injuries by occupation as well.

Industry	Injuries 1991-1997	Injury rate/ 100,000
Logging	273	2,280
Water Transportation	160	1,250
Wood Product Manufacturing	36	860
Construction	533	630
Fishing	536	440
Land Transportation	80	250
Oil and Gas	153	240
Mining	55	220
Seafood Processing	208	200
Military	277	180
Air Transportation	857	160

Special Populations: Alaska Natives

Alaska Natives have a drowning rate that is more than 17 times the national average. The rate is high, particularly for young adult males, because the rivers are used as highways in bush Alaska. Dozens of Alaska Natives drown each year as a result of boating incidents and breaking through the ice while traveling on snowmobiles. The NIOSH Alaska Field Station has worked in conjunction with the AANHS to set up a surveillance system for drownings in Alaska. As part of this effort, Alaska death certificates are reviewed annually to abstract demographic information. Follow-up reports are requested from state troopers, police departments, and medical examiner offices to collect risk factor information such as personal flotation device usage and alcohol involvement. The data from this system are used by the AANHS to evaluate their programs in the different service units.

The NIOSH Alaska Field Station, in conjunction with the AANHS, has developed a surveillance definition for subsistence activities, including hunting, fishing, and trapping. This case definition is being used by the Alaska Field Station and the AANHS to gather subsistence-related injury and fatality information for Alaska Natives. This surveillance for severe subsistence-related injuries and their risk factors in Alaska is forming the basis for future prevention strategies for these events. During 1991-1995, Alaska Native subsistence-related injuries requiring hospitalization included 47 during hunting, 28 during fishing, 4 during whaling, and 3 during gathering activities. The causes of these injuries included the use of tools and implements such as knives (24), guns (18), and snowmobiles (7), as well as exposure to cold (5). These data have been shared with the Alaska Native Epidemiology Center and will be used by AANHS injury practitioners in community-based injury prevention activities.

International and Circumpolar Collaboration

The NIOSH Alaska Field Station continues its active international collaboration in circumpolar health research through direct interagency relationships and via the Injury Prevention and Occupational Safety and Health Working Groups of the International Union for Circumpolar Health. This collaboration led to special sessions on cold injury and hypothermia and commercial fishing industry injury prevention at the Eleventh International Congress on Circumpolar Health held in Harstad, Norway, in May 2000. NIOSH also participated as a cosponsor of the International Symposium on Problems with Cold Work held in Stockholm in November 1997 and is collaborating with the U.S. Coast Guard and Harvard University in planning the International Fishing Industry Safety and Health Conference to be held at Woods Hole, Massachusetts, in October 2000.

Workshop

The NIOSH Alaska Field Station conducted the Second Fishing Industry Safety and Health (FISH II) Workshop in Seattle, Washington, in November 1997. The two-day workshop consisted of presentations on the first day from scientists, researchers, regulators, educators, health care providers, and commercial fishermen, and of working groups on the second day tasked with identifying root causes of specific injuries (fatal and nonfatal) and corresponding countermeasures. The FISH II Workshop presentations and working group recommendations have recently been published and disseminated through a proceedings volume.

National Institutes of Health

The National Institutes of Health, comprising 25 institutes and centers, is headquartered in Bethesda, Maryland, and has satellite facilities elsewhere in Maryland and in North Carolina, Montana, and Arizona. The NIH's mission is to uncover new knowledge that will lead to better health for everyone. NIH supports research on Arctic-related health issues through grants and contracts to non-Federal scientists and through the projects carried out by scientists in NIH laboratories.

National Institute on Aging

The National Institute on Aging funds the Native Elder Research Center, located within the

Division of American Indian and Alaska Native Programs of the Department of Psychiatry, School of Medicine, University of Colorado Health Sciences Center in Denver. The center coordinates a culturally relevant, scientifically meritorious research career development program targeted at American Indian and Alaska Native investigators, focusing on aging, health, and culture. The center augments ongoing partnerships with American Indian and Alaska Native communities to ensure access to and involvement of elders, their families, and local systems of care in aging research. The aim is to increase the pool of talented investigators committed to research that holds promise for reducing the differentials in health status and access to health care that now plague this special population.

National Institute on Alcohol Abuse and Alcoholism

NIAAA is the lead Federal agency responsible for supporting and conducting biomedical and behavioral research on the causes, consequences, treatment, and prevention of alcohol-related problems affecting the Nation's health. In 1994 a five-year grant was awarded to the University of Connecticut Health Center to conduct a collaborative study with the University of Alaska Anchorage to examine the genetic, biological, and behavioral characteristics of Native Alaskans receiving treatment for alcoholism. The project has begun its fourth year and has met several objectives. Research assistants, who are Native Alaskans, have been trained in procedures using standardized methods to obtain clinical assessment and laboratory data. To date, 330 subjects (168 women and 162 men) have been recruited into the study. Preliminary analyses of data collected to date indicate that subjects are typically affected with a very severe form of alcohol dependence. The age of onset of alcohol dependence ranges from 12 to 49 years. However, most males have an onset around age 18, while the onset age for females is about 20 years of age.

The clinical assessment battery used in this study is identical to that used in the Collaborative Study on Genetics of Alcoholism (COGA), which contains a sample of approximately 10,000 subjects collected at six sites in the continental U.S. The COGA sample represents a range of alcohol problems and contains a sufficient number of Hispanic and African-American subjects for comparison across different ethnic groups. Comparisons

with the sample of Native Alaskans can help to determine if there are specific differences in the development of alcohol problems among these groups.

A treatment study has recently been funded to test the efficacy of pharmacological adjuncts in augmenting the existing alcoholism treatment for Native Alaskans. An opioid antagonist (naltrexone) and a selective serotonin reuptake inhibitor (sertraline) will be evaluated alone and in combination in a double-blind, placebo-controlled study of 198 alcohol-dependent individuals of Alaskan heritage. The goal of the study is to determine whether these two medications can reduce the risk of alcohol relapse when used in conjunction with alcohol counseling. This project has the enthusiastic support of the Southern Alaska Regional Health Consortium, the Native health care consortium that will be the site for the study.

A third project was supported by a grant awarded to the Prevention Research Center in 1997 to determine whether alcohol availability control can change alcohol-related outpatient visits at the area hospital in an isolated geographic community. Findings from this project, *Impact of Banning Alcohol on Outpatient Visits in Barrow, Alaska*, were recently published in the *Journal of the American Medical Association*. During a 33-month period, possession and importation of alcohol were legal, banned, legal again, and banned again. Based on review and analyses of outpatient records, there was a substantial decrease in alcohol-related visits during the ban periods. When the ban was lifted, alcohol-related visits showed a substantial increase. In a geographically isolated community, control of alcohol availability can be an effective public health intervention in reducing problems associated with alcohol abuse.

A recently funded three-year study, the People Awakening Project, is a two-phase collaborative study between Alaskan Natives and university researchers designed to obtain an indigenous understanding of the sobriety process. The goal of this study is to develop a foundation for cross-sectional and longitudinal studies with large representative samples of Alaska Natives to investigate predictors of sobriety as a basis for prevention and treatment of alcohol abuse in this population. In gaining understanding of the sobriety process among Native Alaskans, the investigators hope to develop culturally and linguistically appropriate psychometric instruments for future prevention research with Native Alaskans. Phase One of the project will involve collecting in-depth life histories from

individuals as well as conducting focus groups and tribal meetings with members of the five culturally distinct Native groups in Alaska. This phase will identify factors that facilitate or interfere with the sobriety process. Phase Two will involve adaptation of existing standardized measures and development of new measures to address the factors identified in Phase One. In light of the paucity of data and previous research on the prevention of alcohol problems in Native Alaskans, the project offers a unique opportunity to build a solid research base to address these problems.

National Institute of Allergy and Infectious Diseases

In FY 98 the National Institute of Allergy and Infectious Diseases supplemented funding to an existing grant, Pandemic Influenza, under the auspices of the Expanded International Research on Emerging and Re-emerging Diseases Program Announcement. The primary goal of this application is to establish the complete nucleotide sequence of the influenza virus strain responsible for the devastating 1918 influenza pandemic, the Spanish flu, which was responsible for at least 20 million deaths. This will be accomplished by studying the exhumed bodies of seven Norwegian sailors who died of the Spanish flu in early October 1918. These sailors were buried in the tiny mining town of Longyearbyen, located on one of the Norwegian Svalbard islands north of the Arctic Circle. These bodies present a unique opportunity in that they are buried in the permafrost layer and may be cryogenically preserved along with the deadly influenza virus.

It is important to understand the origin of this virus and the molecular basis for its high virulence. To date, only one of 28 formalin-treated paraffin block lung samples from a person with a respiratory infection in 1918 has yielded nucleotide sequences representative of influenza viruses. This virus has been identified as a novel H1N1 strain related to early classical swine influenza isolates. It is necessary to obtain the complete nucleotide sequence of the 1918 influenza virus from different geographical locations to validate the initial findings and to use the information for developing prospective vaccine(s), designing antiviral drugs, and explaining the origin and high virulence of these viruses.

Funding of this supplement was recommended in two phases. The first phase provided funding to detect the presence of the buried bodies using

ground-penetrating radar. Upon the detection of the bodies, full funding was released to exhume the bodies, obtain frozen tissue samples, isolate the infectious virus, and extract the viral RNA sequences. Frozen tissue samples were obtained at the burial site under strictly controlled conditions that protected the investigators and the environment. The frozen samples were then transported to laboratories for biological and molecular analyses. Results of the on-going analyses will be published when available.

National Cancer Institute

The National Cancer Institute coordinates the National Cancer Program, which conducts and supports research, training, health information dissemination, and other programs with respect to the cause, diagnosis, prevention, and treatment of cancer; rehabilitation from cancer; and continuing care of cancer patients and the families of cancer patients. Through a variety of programs, NCI:

- Supports and coordinates research projects conducted by universities, hospitals, research foundations, and businesses throughout the U.S. and abroad through research grants and cooperative agreements;
- Supports education and training in fundamental sciences and clinical disciplines relating to cancer through career awards, training grants, and fellowships;
- Supports research projects in cancer control;
- Collaborates with voluntary organizations and other national and foreign institutions engaged in cancer research and training activities;
- Encourages and coordinates cancer research by industrial concerns where such concerns evidence a particular capability for programmatic research; and
- Collects and disseminates information on cancer.

Alaska Native Tumor Registry

NCI began in 1999 to provide funds to the Indian Health Service (IHS) through an inter-agency agreement to support the Alaska Native Tumor Registry (ANTR) as a part of the Surveillance, Epidemiology and End Results (SEER) Program of the Surveillance Research Program. The project will be managed by the Epidemiology Center of the Alaska Native Health Board in collaboration with the University of New Mexico SEER registry.

The Alaska Native Tumor Registry was initiated

in 1974 in collaboration with NCI investigators. Results of the mortality and incidence studies confirmed the marked differences in cancer patterns in the Alaska Native population in comparison with other populations in the U.S. and elsewhere. NCI entered into an agreement with CDC's Arctic Investigation Division to prospectively identify newly diagnosed invasive cancer patients for the years 1974–1978 among Natives who were residents of Alaska at the time of diagnosis.

Efforts at identification and registration of Alaska Native cancer patients were facilitated by the fact that the IHS is responsible for providing medical care to Alaska Natives. From the outset of registry efforts in Alaska in 1974, the procedures and policies followed were those of the NCI SEER program. Case identification, abstracting, coding, analysis, and reporting by the Alaska Native Tumor Registry have been compatible with SEER. Initial efforts focused entirely on incidence data; no information on staging, treatment, and follow-up was collected.

From 1984 to 1988 there was no outside funding, and the registry functioned as a hospital registry for the Alaska Native Medical Center (ANMC). ANMC is the tertiary referral hospital in Anchorage for most Alaska Natives with major illnesses. In 1989 the NCI entered into an interagency agreement with the Alaska Native Medical Center and the University of New Mexico SEER program for a five-year registry project.

Additional demographics and other data fields were added to PC DASH (Patient Cancer Data System for Hospitals) to meet Alaskan needs. A unique modification to the software was made at the request of clinicians working within the Alaska Area Native Health Service. It was important to make the registry as current and clinically relevant as possible. Therefore, the software was modified to allow immediate entry of new patients, and a special data field was added to schedule a date for the patient's follow-up visits. The Alaska Native Tumor Registry takes an active role in management and follow-up care of cancer patients. From 1996 to 1999 the Alaska Native Tumor Registry (ANTR) received support from NCI's Surveillance Research Program.

There is great benefit to the patients by being included in the registry. All patients are tracked and notified of recommended follow-up appointments. Accurate information on the unique cancer patterns occurring in this population is useful for provider education and training, program planning, studies of cancer etiology, evaluation of

screening programs, interventions to improve patient care, and programs for cancer prevention and risk reduction.

The objectives of this agreement are to collect and report complete, accurate information on cancer in Alaska Natives according to SEER guidelines and procedures; to annually submit data to SEER to include newly registered Alaska Native cancer cases and update patient status of all incident cases diagnosed 1984 to present; and in collaboration with SEER and other cancer investigators, to conduct special studies of cancer in Alaska Natives.

Colorectal Cancer Screening Behaviors among Alaska Natives

Alaska Natives have the highest incidence of colorectal cancer of all racial and ethnic groups in the U.S. The incidence and mortality rates among Alaska Natives exceed those for U.S. whites as well as those reported from all other Indian Health Service areas.

Funding has been provided through the Office of Research on Minority Health, NIH, for a one-year contract to investigate colorectal screening practices. To understand the current practices implemented within the health care systems serving Alaska Natives, investigators will abstract the medical records of 500 Alaska Natives from an urban site (Anchorage) and 500 Yupik Eskimos from a rural site in the Yukon-Kuskokwim Delta region. The objectives are to:

- Document the screening recommendations of health care providers;
- Identify the screening procedures performed;
- Compare rural and urban screening practices;
- Compare screening practices of patients at greater risk due to a history of polyps;
- Analyze screening rates and build a database that will support a cancer screening program; and
- Make recommendations for implementing a statewide colorectal cancer screening program.

The project will be performed in collaboration with the Alaska Native Medical Center and the Yukon-Kuskowim Health Corporation, which fully support the project. The proposal has been submitted to the Alaska Area and National Indian Health Service Institutional Review Boards.

EBV Expression in Nasopharyngeal Carcinoma

The University of North Carolina-Chapel Hill is conducting research to determine the role of the Epstein-Barr virus (EBV) in the etiology of nasopharyngeal carcinoma (NPC), an epithelial malignancy that develops with high incidence in southern China, in northern Africa, and among Eskimos.

To investigate the high incidence in specific populations and to explore a possible genetic contribution to NPC, additional NPC samples will be obtained from Chinese, Caucasian, Black, and possibly Inuit Americans.

Exposure to Organochlorines in Alaska Native Females

Recent studies have reported associations between breast cancer and elevated levels of organochlorines (such as DDT and PCBs) in adipose tissue and serum. Alaska Natives may be at increased risk of exposure because their diets are disproportionately high in protein and fat from marine sources established as having high concentrations of organochlorines. Alaskan Natives are covered by a cancer registry; a banked serum repository of samples collected since 1967 in conjunction with a variety of health investigations exists for this population.

NCI, in collaboration with the Centers for Disease Control and Prevention and the Alaska Area Native Health Service, has initiated a pilot study to assess the Alaska Native population, the variability of organochlorine levels in the serum, and the extent and quality of data in the Indian Health Service medical records on known breast cancer risk factors. Components of the pilot study include analyses of previously collected serum samples and a medical records review for 60 breast cancer cases and 60 controls; new collections of serum, urine, and adipose tissues from Alaska Native women undergoing breast biopsy or surgery at the Alaska Native Medical Center; and a quality assessment/quality control evaluation beneficial to the Alaska Area Native Health Service. Sera that participating women have stored in the Indian Health Service/CDC Serum Bank have been analyzed for DDT, DDE, other chlorinated pesticides, and PCBs. A manuscript describing the exposure levels in sera from Alaska Native women in comparison to women from the contiguous U.S. has been submitted for publication. Another manuscript, which compares levels between Alaska Native women with breast cancer and women without breast cancer, is in preparation. The second pilot component, consisting of collection of biological specimens from women undergoing breast biopsy or surgery, began recruitment in February 1999. Data collected in this pilot project will guide decisions regarding a proposed full-scale investigation of breast cancer among Alaska Natives.

Community Clinical Oncology Program

The Virginia Mason Research Center (VMRC) Community Clinical Oncology Program (CCOP) has a component in Anchorage, Alaska, that allows Alaskans with cancer to have access to the NCI Clinical Trial Network. The VMRC CCOP brings the advantages of state-of-the-art cancer treatment and cancer control trials to patients in metropolitan Seattle and in smaller communities in western Washington and Alaska through its component institutions—Valley Medical Center (Renton, WA), Evergreen Medical Center (Kirkland, WA), Olympic Memorial Hospital (Pt. Angeles, WA), and Providence and Humana Hospitals (Anchorage, AK).

Native Researchers Cancer Control Training Program

Marked contrasts in cancer incidence and mortality rates have been documented among Native peoples in the U.S. and its territories. Although high rates for site-specific cancers are reported among many Native groups, few cancer prevention and control projects or etiologic studies have been directed toward cancer among Native peoples, and involvement by Native researchers in cancer studies has been particularly infrequent. Because cultural factors are central to the design and implementation in cancer studies, increasing the involvement of Native peoples in carrying out effective research in Native populations should be viewed as a priority.

NCI grantees have developed a new program that will increase the abilities of Native researchers to carry out well-designed cancer prevention and control studies within Native populations. Experienced epidemiologists and biostatisticians at the University of New Mexico's Center for Population Health, the University of Arizona's Native American Research and Training Center, and the Cancer Prevention and Control Program of the Indian Health Service will offer an intensive training program for qualified Native researchers. The training program will introduce participants to cancer prevention and control research strategies, principles of epidemiology, study design considerations, data management, data analysis, grant preparation, and manuscript preparation. Demonstrations and workshops will be tailored to students' needs. Following the intensive training sessions, faculty will provide consultation for grant writing and project implementation and will be available for on-site problem solving.

This innovative program will further cancer

prevention and control efforts by working with Native researchers in capacity building and research skill development. This effort will ultimately serve to reduce cancer incidence and mortality among diverse, high-risk Native populations, including Alaska Natives.

Natural-Product Drugs from Cold-Water Marine Organisms

The goal of this project is to screen material from Antarctic, Arctic, and temperate Pacific Northwest regions that have been overlooked in previous drug discovery efforts. Researchers will pursue the preclinical development of 10 active leads with selective cancer cell cytotoxicity. Previously, extracts of 160 biologically diverse temperate and polar marine macroorganisms, representing regions largely unexplored by other discovery programs, were evaluated in a preliminary study. Promising compounds were identified by random screening against a panel of human and mouse cancer cell lines. In Phase I of this study, researchers will purify sufficient material from frozen archive raw tissue. Active leads will then be evaluated in an animal model, and their chemical structures will be characterized. Phase II will extend the effort by moving active leads forward in the drug-development pipeline.

National Institute on Drug Abuse

The National Institute on Drug Abuse (NIDA) supports over 85% of the world's research on behavioral, psychological, biological, medical, and sociological aspects of drug abuse and addiction, including the correlates and consequences of drug abuse, such as HIV and other infectious diseases, violence, and crime. NIDA has funded several recent extramural initiatives at the University of Alaska Anchorage (UAA).

One project is an evaluation of the benefits of needle exchange programs (NEPs) and/or pharmacy distribution of syringes by intervening with injection drug users (IDUs) to try to reduce hepatitis B (HBV), hepatitis C (HCV), and HIV (1996–1999). This research is a clinical trial in which current IDUs have been randomly divided into two groups: one that is able to use NEPs (at any one of three locations), and one that does not have access to the NEPs and is being instructed how to use legal pharmacy sales instead. Data being monitored include results of urine testing for amphetamines, cocaine metabolites, and morphine, as well as serological testing for the presence of the

HBV, HCV, and HIV viruses. It is estimated that approximately 80–85% of current injectors are positive for HCV. An objective of the research is to refer drug injectors who are recruited into the study for a free HBV vaccination series. Efforts have been successful in enrolling over half of the active drug users participating in this research project into HBV vaccination programs. As of July 1999, there were 652 participants in the project.

A First Independent Research Support and Transition (FIRST R29) award (1997–2001) has been granted to UAA to study ecologies of risk in order to develop a model to predict and identify subgroups of women and their risk behaviors and potential for diseases relative to the use of drugs and condoms. The research study uses individual level predictors, contextual variables related to sexual decision making, psychosocial constructs, and selected demographic variables to develop subtypes of women and to better understand their pattern of drug use and sexual behaviors (particularly among Alaska Native women) that put them at risk for sexually transmitted and other blood-borne diseases.

The NIDA-supported extramural research initiatives at the UAA have also benefited from UAA's Telemedicine Project, which helps bridge the great geographic expanse of Alaska in a series of "research at a distance" projects. These projects use desktop videoteleconferencing technology to investigate the transformation of epidemiological and health-related research from a model based on physical proximity to one that can be shared over great distances. In collaboration with the NIDA-supported research, the Telemedicine Project is continuing to explore the uses of narrow-band telecommunications and information technology to improve the delivery of health care to all citizens of Alaska.

In other Arctic-related research matters, NIDA staff, in conjunction with National Institute of Allergy and Infectious Diseases staff and Russian counterparts, organized the second U.S.–Russian meeting on Emerging and Re-emerging Infectious Diseases (EREIDS), held in St. Petersburg, Russia, in May 1998. This meeting followed up on the recommendations from the first meeting in December 1996, with the express purpose of developing joint EREIDS research teams comprising scientists from the U.S. and the former Soviet Union (FSU) and planning for a U.S.–Russian EREIDS conference, which took place in May 1999. Support for the May 1998 meeting was provided by the U.S. government (the Office of AIDS

Research, the National Institutes of Health, and the White House Office of National AIDS Policy) and the Russian Ministry of Science. The first and second EREIDS meetings and the collaborative process that came out of them were recognized as an important part of the Vice President Gore/Premiers Chernomyrdin/Prymakov accords for greater cooperation between the U.S. and the FSU. The St. Petersburg meetings were also recognized as helping to implement the Presidential Decision Directive on EREIDS that was released in June 1996 by Vice President Gore and that emphasized greater focus on EREIDS, including focus in an international context. FSU participants at the St. Petersburg meetings included researchers from Siberia and the Russian Far East. Discussions included, but were not limited to, Arctic EREIDS research and future U.S. and FSU collaborations.

Future NIDA Arctic research plans include expanding the substance abuse and health and social consequences research portfolio, including infectious diseases, violence, and crime, and developing prevention and treatment strategies.

National Institute of Environmental Health Sciences

NIEHS provided the University of Washington Environmental Health Sciences Center supplemental funding to support Alaskan scientists. With the funding, UW is financing a project that examines methyl mercury concentrations in subsistence freshwater fish found in streams contaminated by gold mining practices.

The investigation has accomplished many of its objectives. Researchers from the University of Alaska Fairbanks have equipped a laboratory with state-of-the-art mercury analysis instrumentation, trained Alaskan investigators in the use of the equipment, and established a laboratory advisory board consisting of Alaskan researchers and public health officials. In addition, researchers are collaborating with the Yukon–Kuskokwim Health Corporation in Bethel, Alaska, to develop procedures for conducting a population-based study that would evaluate mercury levels in Alaska Natives who may be exposed to mercury through the fish they consume.

The UW Environmental Health Sciences Center, with NIEHS supplemental funding, is also backing the research of two Alaskan scientists who are investigating the impact of ultraviolet radiation on mutant cells.

Faculty at the UW Environmental Health Sciences Center have trained 16 teachers from Alaska

directly in a comprehensive environmental health sciences curriculum, with an NIEHS K–12 education grant. Each of these teachers is required to provide in-service training to five other teachers in their district, so indirectly nearly 100 Alaskan teachers have been trained to use this curriculum. If all of the trained teachers teach some of the environmental health science curriculum to all of their classes, the potential exists to reach thousands of Alaskan students per year.

An Environmental Justice: Partnerships for Communication award has been made to the Council of Athabascan Tribal Governments in Yukon Flats, Alaska. This project, entitled Network for Responsible Stewardship, has made tribal villages more aware of environmental health issues affecting their collective communities, as well as documenting environmental health risks in contaminated areas.

A conference called Arctic Development, Pollution and Biomarkers of Human Health was held in Anchorage, Alaska, on May 1–3, 2000. The conference was organized by NIEHS and the Arctic Monitoring and Assessment Program (AMAP) and was sponsored by NIEHS, HHS, the Environmental Protection Agency, the National Science Foundation, and the National Oceanic and Atmospheric Administration. The objectives of the conference were:

- To increase the visibility of Arctic environmental health issues;
- To promote the use of biomarkers for assessing environmental impacts at the level of the individual;
- To enhance international collaboration on Arctic environmental health;
- To develop strategies to reduce exposures and their associated risks; and
- To attract international support for research on the Arctic environment.

National Institute of Mental Health

The National Institute of Mental Health supports a variety of research projects that have an impact on Arctic populations. The institute's goals and objectives include support of mental health services research as it relates to Arctic, ethnic, minority, and other rural populations. Many of the Arctic mental health research activities are part of the general American Indian and Alaska Native programs supported by NIH. They include:

- Continued support of an American Indian

and Alaskan Mental Health Research Center;

- Support of a five-year large-scale assessment of the prevalence rates for major mental disorders among Native Americans, their mental health service utilization patterns, the impact on psychiatric morbidity of selected risk factors, and the cross-cultural generalizations of the results;
- Program announcements on research on mental disorders in rural populations and American Indian, Alaska Natives, and Native Hawaiian mental health research; and
- A recent meeting held by NIMH in Alaska on mental health at the frontier.

The NIMH meeting in Anchorage, held in August 1999 focused on a variety of issues concerning how best to organize, finance, and deliver care to underserved frontier regions of the state. Before the meeting, two teams of government scientists and researchers in the mental health field traveled from Anchorage to villages in rural Alaska. One team flew to Kotzebue and then to Selawik, an Inupiat village near the Arctic Circle; the other flew to Bethel and then to Kwethluk, a Yupik village in the Yukon delta. The purpose was to experience firsthand the challenge of mental health issues in frontier Alaska and to have NIMH research reflect the real lives of people who live there.

The meeting was attended by researchers, administrators, members of advocacy groups, and other interested members of the public. Challenged by Senator Ted Stevens to come to Alaska and deepen the understanding of mental health in the frontier, NIMH's Office of Rural Mental Health Research planned a comprehensive meeting. Topics included how to apply for an NIMH research grant, telemedicine, mental disorders (including depression, and depression combined with alcoholism and substance abuse), and suicide. It is anticipated that this meeting will help to form partnerships between many community groups and scientists across Alaska and the rest of the U.S. A summary of the conference's major recommendations will be prepared. It also is anticipated that these important issues will be incorporated into the NIMH's strategic planning for future research, which will be designed to help Alaskans understand how to organize more effectively, finance, and deliver care to remote areas across the state.

National Institute of Neurological Disorders and Stroke

For many years, NINDS has been involved in a research study on Viliuisk Encephalomyelitis (VE) in the Yakut People of Siberia in collaboration with researchers from the Sakha Republic of Russia. VE is a slow, progressive neurological disorder with a fatal outcome; it is seen only among the Yakuts. This project has involved training several Russian researchers in NINDS laboratories, as well as on-site data collection and evaluation. Funding has come from the Sakha government and from NINDS, with support for training Rus-

sian researchers at NIH provided by the Debeers Centennial Diamond Syndicate VE Fellowship program. During 1998 a NINDS scientist who is an appointed World Health Organization (WHO) expert spent a month in Russian Siberia studying this contagious fatal disorder, which has recently spread an additional 600 miles from its original focus. A program to further investigate the disease has been developed and approved by WHO. The program includes clinical criteria, as well as attempts to isolate the causative agent and analyses of mechanisms of disease transmission within families and villages, to prevent further spread through human migration.

Smithsonian Institution

The Smithsonian Institution's mission in Alaska is primarily carried out through the Arctic Studies Center, which promotes the study of Arctic peoples, cultures, and environments.

The Arctic Studies Center (ASC) of the Smithsonian Institution's National Museum of Natural History was established in 1988 with the mission to promote the study of Arctic peoples, cultures, and environments. The ASC is the primary U.S. government program with a special focus on Arctic cultural research and education. Under its highly diversified agenda, the ASC:

- Conducts field research and museum studies throughout the circumpolar area, particularly in Alaska;
- Builds and maintains collections and archives;
- Produces exhibitions, including traveling exhibits aimed for northern areas and rural Arctic communities; and
- Conducts education, outreach, and other public-focused programs.

Overall, the ASC work is dedicated to the documentation and preservation of cultural legacies of the Arctic people. As such, it is multidisciplinary, circumpolar, international, and community-based.

Recently the ASC pioneered several new fields of activities, such as training in museum anthropology and community archaeology for northern residents; "knowledge repatriation," that is, the return of "culturally translated" historical sources, old photographs, and documents to northern communities; and production of educational films and videotapes. It also maintains a website (<http://www.nmnh.si.edu/arctic/>) and produces an annual newsletter with a circulation over 1000. Both offer easy access to the ASC's current activities, research staff, publications, and public programs.

Research

ASC research explores problems and topics of the Arctic and sub-Arctic world, with primary focus on ethnology, archaeology, ethnohistory, and related aspects of biology and natural science. The ASC researchers also investigate modern pro-

	Funding (thousands)	
	FY 98	FY 99
Anthropology	450	400
Arctic Biology	50	50
Total	500	450

cesses of cultural interaction and culture change from perspectives of historical legacies, contemporary politics, demography, geography, and ecology.

Over the past several years, Smithsonian Arctic studies have concentrated on research in various circumpolar regions, including the North Pacific (Bering Strait, the Aleutians, Chukchi Peninsula, and southwestern Alaska), the eastern Canadian Arctic (Labrador, Newfoundland, and Baffin Island), and northern Siberia (Yamal Peninsula). In 1997–1999 the ASC research was increasingly focused on Alaska.

The Beringian (Siberian–St. Lawrence Island) Yupik Heritage Project is a pioneer two-year research venture (1998–2000) sponsored by a grant from the National Science Foundation. It targets related Yupik (Eskimo) communities from St. Lawrence, Alaska, and the nearby coastal region of Siberia. A joint project team includes Igor Krupnik from the ASC; Willis Walunga, a respected elder and local historian from Gambell, St. Lawrence Island; Lyudmila Aynganga, a Yupik



Willis Walunga (right) and Igor Krupnik examine historical photographs from Saint Lawrence Island.



Beda Slwooko, a Gambell resident born in 1918, being interviewed as part of the Beringian Yupik Heritage Project.

educator and President of the Yupik Association from Siberia; and Vera Kingeekuk-Metcalf, Yupik cultural coordinator from the Bering Strait Foundation in Nome. The aim of the project is to collect historical documentary data related to the Beringian Yupik communities, such as old village censuses, historical photographs, archival records, diaries and early publications by missionaries and visiting scientists, and oral histories recorded from elders. These materials will undergo "cultural translation" and verification for eventual "return" to the local Yupik communities for use in heritage, educational, and other locally based programs. Computer databases of some 1500 historical names listed in old documentary sources and genealogies have been produced for both Siberian and St. Lawrence Island Yupik constituencies. This cooperative heritage project will boost the common legacy and historical roots of the Beringian Yupik communities separated by decades of the Cold War and political isolation. The ASC sees this new venue of "knowledge repatriation" as a valuable input into its general efforts in bringing cultural resources back to the northern residents and Native communities of the Arctic.

An interdisciplinary research project called Ecosystem Variability and Subsistence Hunting in the Bering Strait Area targets historical sea mammal hunting records from Native communities along the northern Bering Sea/Chukchi Sea coastline of Alaska and Siberia. The three years of research (1997–2000) are sponsored by a grant from the U.S. National Oceanic and Atmospheric Administration (NOAA) and the University of Alaska Fairbanks. The project team includes an anthropologist (Igor Krupnik, ASC), a northern subsistence specialist (Henry Huntington, Alaska), two marine biologists (Lyudmila Bogoslovskaya and Nikolay Mymrin, Russia), and several local Native consultants. This survey is organized as a study of medium-term (historical) variations in the health and numbers of marine mammal populations as these are reflected in local catch statistics, oral history, and subsistence hunting practices of Native communities. The aim of the project is to use the records of Native sea mammal catch that go back to the 1920s in Russia and late 1950s in Alaska as valuable indicators in tracing changes in Arctic climate and sea ice as well as in documented shifts in local governmental policies and game management regimes.

Years 1997–1998 concluded an ASC six-year prehistory research program in the western Russian Arctic (Yamal Peninsula and Lower Ob' River

Basin in west Siberia). While major fieldwork and site surveys were conducted in 1994–1996, the last two years were devoted to data processing and publications. A joint monograph and several articles were produced by the ASC team, headed by William Fitzhugh, and its Russian collaborators from the Institute of History and Archaeology in Ekaterinburg, Russia.

As part of a study of archaeology in northwest Alaska, during the summer of 1998, Dennis Stanford (Smithsonian Paleo-Indian Program) and Daniel Odess (Smithsonian Arctic Studies Center) worked in cooperation with Bob Gal (National Park Service) and Vladamir Pitul'ko (Russian Academy of Science) to return to the Primus Creek area in the Noatak National Preserve. Work focused on excavating Irwin's Sluiceway, a previously identified late Pleistocene/early Holocene overlook site, and identifying and testing new sites in the area. Sluiceway produced additional basally ground lanceolate points and a well-defined hearth dated to ca 10,000 BP but no evidence that core and blade technologies are associated. The team found and tested the Richard's Blade site, a core and blade locality with a substantial hearth or burned structure dated to ca 8,000 BP and an artifact density exceeding 500 specimens per square meter, and the Hicks site, a Denbigh Flint complex structure with an axial feature similar to those seen in pre-Dorset sites in Canada and Greenland.

During the summer of 1998, Stephen Loring worked with the Innu Nation on two archaeological projects in Labrador, a survey along the Churchill River to mitigate the impacts of a proposed dam at Muskrat Falls and a reconnaissance project on the north shore of Kamishtashtin (Lake Mistastin) in central interior Labrador that combined research with training opportunities for Innu students. In 1999 Loring and graduate student Leah Rosenmeier worked with students and other members of the Inuit and Settler community of Makkovik to test early historic-period house floors and associated middens at Southern Island on the south-central Labrador coast. Analysis is ongoing, and plans for continued work with the community include additional excavation and work with the Jens Haven School District and Labrador Integrated School Board to develop related curriculum materials.

Exhibitions and Museum Research

Collection studies and exhibit development is essential to Smithsonian scholarship and public educational programs. The Smithsonian possesses

one of the world's finest anthropological collections from Arctic regions. Museum objects, both prehistoric and ethnographic, as well as other holdings stored at the museums, such as historical photographs and documents and archival documentary records, are now considered as invaluable resources for supporting the cultural traditions and ethnic legacies of the Arctic people. This is why the ASC exhibit and collection programs involve close collaboration with northern communities and Native groups in areas of exhibition, museum training, and research.

The years 1997–1999 witnessed a genuine boom of the Smithsonian museum activities. Major museum projects covered almost the entire circumpolar area, including Alaska, Siberia, the eastern Arctic, northern Europe, the North Pacific, and Japan.

Two small permanent exhibit cases relating to Alaska Natives went on display at the National Museum of Natural History in March 1999. “Raven’s People: Native Peoples of Alaska” depicts the cultural diversity of Native Alaska. “People of the Sea: Native People of the Aleutian Islands” was designed as a collaborative effort between Stephen Loring (ASC) and members of various Aleut communities to tell the Aleut story. The resulting exhibit is the first time the Aleut people have been represented in the Smithsonian.

“Inua: Historic World of the Bering Sea and Arctic Alaska Eskimo” is a traveling exhibit made of objects from the Smithsonian’s priceless collections made by Edward Nelson in Alaska in the late

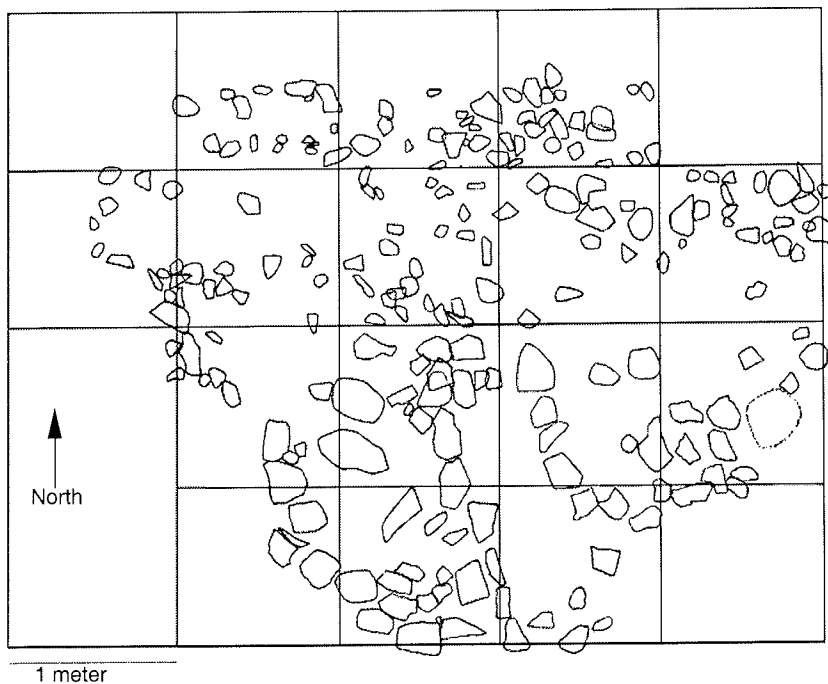
1800s. These were originally displayed in a show prepared in the 1980s; a smaller version traveled widely across the U.S. and Europe. The present Inua exhibit was installed in Barrow in time for the grand opening of the local Inupiat Heritage Center on February 3, 1999. Objects in the show were “premounted” at the Smithsonian before shipment, thus simplifying the task of installation into the exhibition cases. The practice of pre-mounting objects should make it easier to loan objects from the Smithsonian’s collections to smaller, local museums in the future.

“Looking Both Ways: Heritage and Identity of the Alutiiq People,” a community-based exhibition of archaeological and ethnographic material from the Kodiak archipelago (based on the Smithsonian’s collection made by William J. Fisher in the 1880s) is moving forward, directed by Aron Crowell of the Arctic Studies Center’s Anchorage office. A collaborative effort involving representatives of the Kodiak area communities, it is scheduled to open at the Alutiiq Museum in Kodiak, Alaska, in 2001. The preparation of the exhibit also has included several public events, such as an Alutiiq Elders Planning Workshop (in late 1997) and the presentation of historical photographs from the Alutiiq region (1997–1998).

“Agayuliaraput – Our Way of Making Prayer” is a traveling exhibit of over 200 historical Yupik masks and associated objects from western Alaska that was on display at the Smithsonian National Museum of Natural History from December 1997 to April 1998. The exhibit was designed by a joint team of local Yupik elders and cultural workers, under the leadership of Dr. Ann Fienup-Riordan, an ASC Associate, and the Anchorage Museum of History and Art. This exhibit also toured several other cities, including Seattle, Anchorage, and New York, as well as local towns and rural communities, such as Bethel and Toksook in Alaska. An illustrated catalog has been produced by the University of Washington Press in association with the Anchorage Museum of History and Art.

“Ainu: Spirit of a Northern People” opened at the National Museum of Natural History in April 1999 as a temporary exhibit (through January 2000) under the cocuratorship of William Fitzhugh and Chisato Dubreuil. Designed to incorporate “an Ainu perspective,” the show portrays Ainu culture and history, as well as current issues and contemporary art. The Ainu people, who once inhabited the Sakhalin and Kurile Islands now within Russia’s borders, as well as the islands of Hokkaido and Honshu of Japan, present an intriguing cultur-

Partially disturbed tent ring with axial feature, Hicks site, Northwest Alaska. Similar structures were built in northern Canada and Greenland by Arctic Small Tool tradition people who predate the Inuit by at least 3000 years.



al and geographical crossroad of various ancient traditions originating from Siberia, the north Pacific, east Asia, and the southwest Pacific rim. An illustrated catalog of some 400 pages and over 50 contributed articles (*Ainu: Spirit of a Northern People*, edited by William W. Fitzhugh and Chisato O. Dubreuil) was produced by the Arctic Studies Center, Smithsonian Institution in association with the University of Washington Press.

"Vikings: The North Atlantic Saga," which has consumed the energies of the Arctic Studies Center for much of 1999, will open at the National Museum of Natural History at the end of April 2000. It will remain on display there until August 13th, after which it will visit New York, Los Angeles, Chicago, Houston, and Hull, Quebec. The exhibition will present Vikings "in the round." In addition to featuring the origins and history of the Norse in Scandinavia and their interactions with

Cover of the recently published exhibition catalog.



and impact on the rest of Europe, the show will discuss the colonization of the North Atlantic, Greenland, and North America, their contacts with Native peoples, and the place of Vikings in contemporary popular culture. The accompanying illustrated catalog, co-edited by William Fitzhugh and Elisabeth Ward, was published by the Smithsonian Press in April 2000.

"Mini-Crossroads," a five-year traveling exhibit made of unique miniature objects, toys, and ethnographic models from several indigenous nations of Alaska and Siberia, completed its Siberian tour in Russia on December 20, 1997. Its Alaskan tour of 1993–1995 covered some 15 venues in major towns and cities in Alaska, including Juneau, Fairbanks, Anchorage, Sitka, Barrow, Bethel, Nome, and Kodiak. The Siberian tour of one year (December 1996 to December 1997) had four venues in the major cities of the Russian Far East: Khabarovsk, Vladivostok, Yuzhno-Sakhalinsk, and Blagoveshchensk. A twin set of English and Russian catalogs, *Crossroads Alaska-Siberia. Native Cultures of Alaska and the Russian Far East*, have been produced by Valerie Chaussonnet and Igor Krupnik of the ASC. Some 4000 Russian catalogs have been delivered to the Russian sites, courtesy of the U.S. Information Agency, for free distribution among local schools, colleges, libraries, Native associations, and cultural centers.

The ASC contributed an insightful display of cultural legacies of the Arctic people at the international Arktis-Antarktis (Arctic and Antarctic) staged at the Federal Art Exhibit Hall in Bonn, Germany, in December 1997–April 1998. Some 500 objects, both prehistoric and modern, were arranged to present major cultural transitions across the Arctic. The ethnographic portion, "The Living Yamal," was a joint venture with the Yamal-Nenets Regional Museum from Salekhard, a local administrative capital in Arctic Russia. The small Yamal museum contributed its best ethnographic objects, including a full-size nomadic tent, for their first-ever display in western Europe. A 10-minute educational video, *Northern Cultures, Northern Races*, has been produced by the ASC, and an illustrated bilingual catalog, *The Living Yamal*, was published in 1998 in Moscow, under the editorship of Igor Krupnik and Natalya Narinskay, the Yamal museum director. Under the same program, *The Land of Yamal*, an earlier catalog of the Yamal historical photographs of the early 1900s, has been published in Moscow in 1998 as a bilingual, English–Russian edition.

Environmental Protection Agency

The U.S. Environmental Protection Agency's Arctic research program is designed to protect the health of Arctic residents and safeguard the Arctic environment. EPA research targets contaminant sources, fate and transport, and effects; subsistence issues; global climate change and UV-B radiation; and the combined effects of multiple stressors.

EPA research focuses on three primary objectives:

- Improving basic knowledge about Arctic stressors and effects;
- Understanding and reducing risk to Arctic residents and the Arctic environment; and
- Implementing innovative technologies to solve environmental problems.

These primary objectives are being addressed through a variety of research and management efforts. The following discussion provides a brief summary of EPA-sponsored research projects, each highlighted under a particular objective.

Arctic Stressors and Effects

The EPA has traditionally focused on contaminant stressors. The EPA also has interests in multiple stressors that are studied under risk assessment programs.

AMAP Heavy Metals

In 1999 the EPA agreed to serve as lead country author for the heavy metals report under the Arctic Monitoring and Assessment Program (AMAP) Phase II. To that end the EPA organized and sponsored a workshop entitled Heavy Metals in the Arctic, September 1999, to produce a final AMAP Phase II heavy metals research plan and to establish an international heavy metals team. The plan addresses both exposure and effects issues. Continued identification of sources of heavy metals and development of tools to better model mercury exposure were emphasized. A principal recommendation under effects was to form a cross-cutting effects group that will consider all stressors consistent with the AMAP mission. Specific recommendations for research were also highlighted. As part of

	Funding (thousands)	
	FY 98	FY 99
Research and Development	300	200
Regional	80	825
International	100	100
Total	480	1,125

the U.S. effort, the EPA committed to produce a Phase II report in 2003 that will include unreported U.S. data from AMAP Phase I and new data collected during AMAP Phase II on heavy metals.

Mercury

The EPA is investigating the nature and geographical extent of a phenomenon termed the Arctic sunrise, where atmospheric elemental gaseous mercury levels have been shown to drop drastically during the Arctic spring when sunlight returns. The majority of atmospheric mercury is present in elemental form, but reactive gaseous mercury has much higher wet and dry deposition rates. Thus speciation of mercury is of particular interest in the Arctic because of the sunrise phenomenon and the greater local impact of reactive forms. Measurements of mercury during Arctic sunrise will help elucidate the transformation processes leading to the mercury depletion. Atmospheric trace metals will also be analyzed.

The EPA is partnering with the National Oceanic and Atmospheric Administration and the Department of Energy's Oak Ridge National Laboratory (ORNL) to conduct research at NOAA's monitoring site in the U.S. Arctic at Barrow, Alaska. NOAA's Climate Monitoring and Diagnostics Laboratory operates the site. NOAA has maintained a continuous total gaseous mercury analyzer since January 1999. With this instrument the Arctic sunrise phenomenon, first observed at a station in Alert, Canada, has been confirmed at

Barrow. The EPA provided funding and expertise to purchase and evaluate automated mercury speciation equipment for the Barrow site, trained NOAA and ORNL personnel on the use and maintenance of the instrumentation, and is funding ORNL to set up and run the instrumentation at Barrow for one year. The gas-phase mercury speciation equipment was installed in September 1999 and is now operational. This cooperative research will help close a gap in the identification of patterns of transboundary atmospheric mercury transport. Additional information on the Barrow station and isentropic plots are available at www.cmdl.noaa.gov.

Alaska Native Cord Blood Monitoring Program

Recent evidence suggests that exposure to persistent organic pollutants (POPs) and heavy metals in the environment may increase a newborn's risk of developmental, neurological, and immunologic effects. Alaska Native women are potentially exposed to these chemicals because their subsistence diet of fish and marine mammals has been shown to contain bioconcentrated organochlorine chemicals and heavy metals. A growing fetus is exposed to contaminants through transplacental transfer from the mother during this critical life stage. Alaska Natives have expressed a strong desire for research to assess the biological levels of these contaminants, especially in pregnant women and their newborns, and to look for associated health effects in children.

The EPA is sponsoring the Indian Health Service, in collaboration with local tribal organizations, to collect blood samples from Alaska Native mother-infant pairs. Levels of POPs and heavy metals will be measured in the blood of pregnant women and in their newborn infants. The levels of individual contaminants or groups of contaminants will be correlated with pregnancy outcome and risk of infectious disease in the infant, as well as growth and development during the child's first year of life. This program is planned to continue for at least five years. The program is being conducted in consultation with the Alaska Native Tribal Health Consortium, the Alaska Native Health Board, the Institute for Circumpolar Health Studies, and the Alaska Department of Health and Social Services' Section of Epidemiology. Results will be provided to Alaska Native communities to help them create acceptable strategies to reduce exposure while maintaining their traditional diet.

In 1998 the EPA, along with the Centers for Disease Control and Prevention (CDC), in response to

Alaska Area Native Health Service (AANHS) concerns with Arctic contaminants, began supporting this project as part of the Arctic Monitoring and Assessment Program to monitor selected heavy metals and POPs in umbilical cord blood and maternal blood of indigenous groups of the Arctic, with a focus on Alaska Native populations. In 1999 the AANHS completed the detailed protocol that describes the project, including the importance of the project, the general approach, procedures and methods, and reporting of results, and they included consent forms, a dietary history questionnaire, a prenatal history form, medical records collection forms, and a list of the environmental contaminants to be analyzed.

The Indian Health Service and the EPA will coordinate data analysis with Canada, Denmark, Greenland, and the Faroe Islands. The Indian Health Service will coordinate interpretation and presentation to Native groups and the other countries involved.

Other Arctic Stressors

Global climate change and increasing UV-B radiation are stressors of interest to EPA, although most work is being conducted outside of the Arctic. Work ongoing in the Denali National Park on air quality and UV-B radiation is worthy of mention. Denali National Park was selected as one of 14 sites nationally where air and water quality will be intensively monitored and effects research conducted related to air and water quality stressors.

Understanding and Reducing Risk

Risk assessment has a varied history of development and use in the EPA. Within the last 10 years the process and its application have broadened dramatically from single-stressor-driven assessments to complex integrated ecosystem assessments for multiple stressors and combined effects. EPA has found the broadened risk assessment approach to be very effective in bringing together scientific research and management strategies to enhance risk reduction. Specifically it allows communities to use available scientific information (and, particularly in the Arctic, traditional knowledge) to better understand what complement of stressors may be causing undesirable change in important values. Communities also identify key scientific questions that need to be investigated and develop alternative problem solving strategies designed to achieve environmental results.

A significant focus in all EPA work described here is the use of traditional knowledge and Native interests to understand risk, define research directions, and shape management. These activities will provide significant lessons learned within the Arctic about how to establish management direction, identify data gaps and research opportunities, link research to management concerns, and provide a legitimized use of traditional knowledge.

Bering Sea Regional Geographic Initiative

The Bering Sea Regional Geographic Initiative was established in November 1998, sponsored by EPA Region 10 and the EPA National Center for Environmental Assessment (NCEA). The initiative was an outgrowth of initial work on an integrated assessment for the Bering Sea by NCEA. The initiative is focused on planning (to establish a set of goals and outcomes shared among the very large and diverse community) and problem formulation (to help make sense of the enormous amount of existing scientific and traditional knowledge about Bering Sea resources and to give direction to future research).

To initiate planning the EPA worked in partnership with the Alaska State Governor's office to conduct preliminary outreach to all major interest groups during 1998, contributing to the document *Bering Sea*. The EPA targeted Alaska Native communities and interests by contacting all Alaska villages and key Native organizations. As followup the EPA is about to release for review the document *Interested Parties Conceptual Model: Bering Sea Ecosystem*. The conceptual model will be instrumental in designing the framework for a Bering Sea summit in 2001. In March 1999 the EPA co-sponsored Wisdomkeepers of the North: Vision, Healing and Stewardship for the Bering Sea, a Native-led workshop organized by the Bering Sea Coalition to establish a Native voice in the Bering Sea. Work with commercial interests was begun through an EPA grant to The Nature Conservancy in 1998 to conduct outreach, particularly with the fishing industry. A grant to the Center for Marine Conservation initiated a focused process in September 1999 to identify shared values for the Bering Sea within the diverse conservation community. The EPA is also conducting outreach with Federal and state agencies, establishing partnerships to work toward management goals that can be harmonized across agencies. All of these efforts are designed to generate goals that will form the foundation for an integrated assessment for the Bering Sea watershed ecosystem.

The EPA targeted the Pribilof Islands for an integrated assessment of risk to ecological, economic, cultural, and health concerns. Early efforts focused on establishing partnerships with the city, corporation, and tribal government of St. Paul Island. In 1999 the EPA, in partnership with the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Alaska Department of Environmental Conservation, and St. Paul community, established an interdisciplinary interagency Pribilof Island team to begin processing available information (both scientific and traditional knowledge) at the Arctic, Bering Sea, and Pribilof Island scales, all of which are relevant to an assessment of risk to the Pribilofs.

Traditional Knowledge and Radionuclides Project

The Traditional Knowledge and Radionuclides Project is co-sponsored by EPA Region 10 and the EPA Office of Radiation and Indoor Air and is being conducted by the University of Alaska's Institute of Social and Economic Research and the Alaska Native Science Commission. The goals of the project are to build capacity among Federally recognized Alaska tribes and to take effective action to clearly identify and address concerns about radionuclides, other contaminants, and adverse changes Native peoples are observing in the environment.

A principal focus during 1999 was to conduct regional meetings within Native communities across Alaska. These are being conducted according to Native ways of knowing and building consensus. Regional meetings, conducted over three days, involve inviting community residents to share their knowledge about environmental changes. This information is being combined with a Contaminants and Native Foods Database developed through earlier work to identify use of subsistence foods. A summary of progress is available in *Traditional Knowledge and Radionuclides Project: Progress Report*, published by the Alaska Native Science Commission in May 1999. The Traditional Knowledge and Radionuclides Project is helping redefine the risk management process with tribes and may offer new ways to reframe how risk assessment is used in the Arctic.

Implementing Technologies

Introducing and implementing innovative technologies and management opportunities has been a significant cornerstone within the EPA. In the Arctic the focus is on reducing contaminants reaching the Arctic through long-range transport and build-

An overview of the Contaminants and Native Foods Database is available on the Web (www.nativeknowledge.org).

ing capacity within the U.S. Arctic to reduce potential environmental impacts.

Reducing PCBs in Russia

The Russian Federation is the only Arctic country that may still be producing PCBs. Russia has stated in the Convention on Long-Range Transboundary Air Pollution (LRTAP) Persistent Organic Pollutants (POPs) Protocol negotiations that it is unable to phase out PCB production and use because of critical national uses for which it currently has no substitutes. Consequently it is uncertain whether Russia will be a signatory to the LRTAP POPs Protocol. To assist Russia in phasing out PCB production and use and to encourage Russia to be a signatory of LRTAP, the EPA proposed a multilateral technology transfer and demonstration project initiative under the auspices of the Arctic Monitoring and Assessment Program (AMAP). The objective of this multilateral cooperative pilot program is to protect the Arctic ecosystems and indigenous U.S. populations by assisting the Russian Federation to:

- Cease production and use of PCBs;
- Develop and construct or retrofit facilities for production and use of PCB alternatives;
- Decommission PCB facilities and provide safe disposal of PCBs and PCB-contaminated equipment and material; and
- Remediate PCB sites that have the greatest potential to impact the Arctic.

In February 1998 the Russia PCB initiative was further developed at an informal meeting between the EPA and the Swedish Chair of AMAP in Stockholm. In April 1998, Russia indicated strong support for the project. The project was approved at the Senior Arctic Officials meeting of May 9–11, 1998, in Whitehorse, Yukon Territory. In subsequent meetings the funding, work planning, and Russian support details were worked out among and approved by the AMAP member countries. In February 1999 the AMAP member countries for-

mally commenced the multilateral cooperative pilot project. In August 1999 the first work product was produced according to the approved timetable, a draft report outlining the beginnings of an inventory for PCBs produced and used in the Russian Federation. At the August 1999 meeting in Moscow, plans were discussed for negotiating the second phase of the project: development of a feasibility study for converting or retrofitting facilities for production and use of PCB alternatives.

General Assistance Program Grants

The EPA is investing heavily in building capacity within Alaska villages to promote village management of their own environmental protection programs and to implement sustainable technologies amenable to the Arctic bush that can achieve local environmental goals. From this investment and a Sustainability Grants program, the EPA anticipates seeing emerging management strategies and technologies that will reduce local environmental pollution and improve quality of life. This investment is not included in the research budget but represents over \$12 million annually.

Arctic Strategy

The ORD National Center for Environmental Assessment established an Arctic Program Office in Anchorage, co-located with the Region 10 Alaska Operations Office. A principal goal of the Arctic Program Office is to develop an EPA Arctic Strategy. Preliminary work has begun to identify the dimensions needed for a strategy that will meet the needs of different offices within the agency working in the Arctic. A central theme within the strategy is the protection of subsistence foods. Assessments targeted under the program will use both scientific and traditional knowledge. Finally, research will be prioritized based on its relevance to the concerns of Arctic peoples.

Department of Transportation

DOT supports Arctic research through the U.S. Coast Guard and the Federal Highway Administration. The U.S. Coast Guard operates polar icebreakers as national polar research assets for Arctic oceanographic expeditions of both government and nongovernment researchers. The Federal Highway Administration is studying a variety of highway problems in the Arctic.

U.S. Coast Guard Icebreakers

The Coast Guard supports Arctic research by operating three polar icebreakers: the *Polar Sea* and the *Polar Star*, which serve as high-latitude research platforms in both the Arctic and Antarctic, and the new polar icebreaker *Healy*, which will serve as a research platform in the Arctic beginning in 2001. Support of Arctic research by the U.S. Coast Guard dates back to the 1880s, when voyages on revenue cutters were made by scientists, including the renowned naturalist John Muir on the revenue cutter *Corwin* in 1881 and others on the revenue cutter *Bear*, commanded by Captain Michael Healy in the 1880s and 1890s. Arctic research aboard Coast Guard icebreakers intensified in the late 1960s and early 1970s when the prospect of increased oil and gas exploration in the Alaskan Arctic required ecological baseline surveys in the Chukchi and Beaufort Seas. These cruises were supported by the Coast Guard icebreakers *Northwind*, *Burton Island*, and *Glacier*. In the 1980s these vessels were phased out as the Polar-class icebreakers joined the fleet.

The two Polar-class icebreakers were designed to carry out a range of missions in the Arctic, including escorting non-icebreaking vessels through the ice, resupplying military and research bases, and supporting scientific operations. In recent years the role of the Polar-class vessels in research has expanded as more complex projects and larger science teams have placed added requirements on these ships. This led to a major upgrade of their capabilities in 1987 through the Polar Science Upgrade Project, a five-year, \$14 million program to enhance the scientific support capabilities of these vessels. Laboratories and living areas were expanded to allow

	Funding (thousands)	
	FY 98	FY 99
Test and Evaluation	3400	3400
Extramural Science Support	30	30
Total	3430	3430

up to 32 scientists and technicians to embark on scientific cruises. Upgraded oceanographic winches, new cargo and science gear handling systems, expanded lab spaces, new oceanographic instrumentation, and new communications and satellite data acquisition systems significantly improved the research capabilities of the Polar-class vessels. To meet the expanding needs of the future, the Coast Guard will soon commission a new research platform dedicated to Arctic science.

The new vessel, the USCGC *Healy*, was built by Avondale Industries in New Orleans, Louisiana, and delivered to the Coast Guard in November 1999. *Healy*'s first unrestricted science cruise is scheduled for 2001, after completion of maintenance and warranty work resulting from shake-down operations. The *Healy* is 420 feet long, has a beam of 82 feet, and displaces 16,000 long tons. The maximum speed will be 17 knots, with a range of 16,000 nautical miles at 12.5 knots. *Healy*'s primary mission will be to function as a world-class, high-latitude research platform. The *Healy* will be able to conduct scientific operations during all seasons in the Arctic, with the ship's systems designed to function during extended winter operations, including wintering over for planned missions.

The scientific support capabilities of the *Healy* substantially surpass those provided by the Polar-class icebreakers. The ship is able to accommodate 35 scientists on a routine basis and provide surge accommodations for up to 50. Over 5,000 square feet of science lab and support space is provided,



Scientists from USCGC Polar Sea taking ice core samples.

including a main science lab, a wet science lab, a biological and chemical analysis lab, an electronics lab, a meteorology lab, and a photography lab. In addition the *Healy* has five hydraulically operated cranes, two oceanographic winches, and a double-drum core/trawl winch. It also provides over 4,000 square feet of open deck space and 20,000 cubic feet of scientific storage space in three cargo holds. Installed bathymetric and oceanographic instrumentation includes a bottom profiling system, a Seabeam bottom mapping sonar system, an XBT data acquisition unit, and an acoustic doppler current profiler. Lab spaces are equipped with a science data network providing 120 dual fiber-optic connected Ethernet ports throughout the science spaces for real-time data transfer between data processors, workstations, and printers. In addition there are dedicated Inmarsat-B high-speed data transmission and e-mail capabilities for scientists.

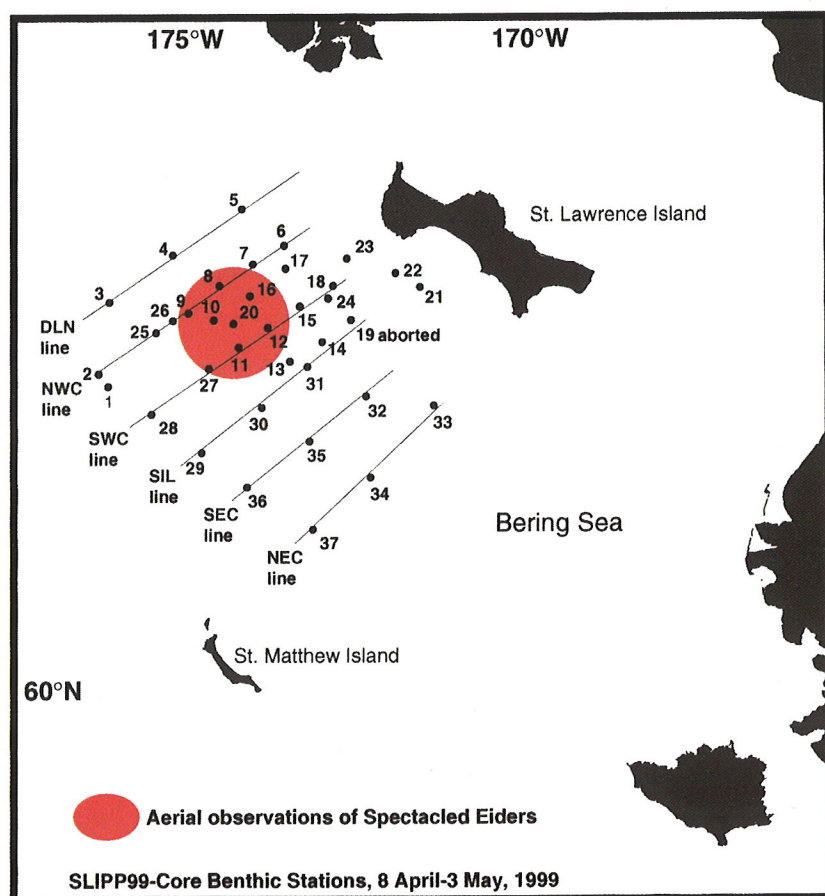
The Coast Guard's major Arctic research efforts supported during the past two years were the Arctic West Summer cruises aboard the CGC *Polar Star* and CGC *Polar Sea*. *Polar Sea* deployed on 29 April 1998 for a three-month Arctic West Summer cruise. In May the ship participated as the command and control platform for the first U.S./Russian/Japanese oil spill exercise off Sakhalin Island. After picking up a 15-member science

party in Nome, the icebreaker proceeded to the Arctic for 20 days of multidisciplinary science operations. *Polar Sea* completed her assignments in July by assisting the Canadian Coast Guard with logistics support at the SHEBA site after the ice runway alongside the CCGS *Des Groseilliers* became unsuitable for fixed-wing aircraft because of warm temperature deterioration. *Polar Sea* also played a key role in intercepting and apprehending a high-seas drift net boat shortly upon departing from the exercise.

Arctic West Summer 98 science of opportunity operations on the *Polar Star* involved four main efforts: SHEBA support, including two personnel transfers from the CCGS *Des Groseilliers*; NASA educational outreach programs; NASA testing of ROV stereo-video cameras and 3D conversion software; and marine chemical sampling. Science efforts involved collaborative efforts/sponsorship/participation of NASA, NOAA's National Undersea Research Center, the National Park Service, the Minerals Management Service, the Naval Arctic Submarine Lab, the State of Alaska, Santa Clara University, the U.S. Geological Survey, and Texas A&M University. The cruise was accompanied by a reporter from *The Economist* magazine and a videographer from the television Discovery Channel, and it was visited by news teams from NBC and ABC.

A collaboration between NASA Ames Research Center, NOAA's National Undersea Research Program West Coast and Polar Regions Center, and the U.S. Coast Guard was initiated in April 1998 at the Arctic and Antarctic Access Conference with the goal of improving technology for high-latitude research and educational outreach. The first cruise in this effort was on the *Polar Star* off northern Alaska in August 1998 and involved searching and locating evidence of the Lost Whaling Fleet of 1871, a fleet of 32 whaling ships that sank after being crushed by heavy ice off Barrow, Alaska. Live video and audio transmissions from the *Polar Star* via Internet satellite link was sustained to 78°North latitude, and video transmission was achieved from a small boat operating miles from the ship, with signals conveyed via a 2.4-GHz antenna. From the *Polar Star* the signal was routed to Inmarsat, downlinked to NASA Ames Research Center, and transmitted to ten repeater stations nationwide, making hundreds of live streams available to the educational community. The ability to transmit live video and audio from ships, and even ROVs operating remotely from a ship, provides new high-latitude education-

Location of benthic stations occupied by USCGC Polar Sea during SLIPP99. The shaded circular area in the benthic station grid is the general location of the spectacled eider observed from 12 to 20 April 1999.



al capabilities and demonstrates the potential for future real-time scientific access to and control of instrumentation in these environments.

Polar Sea sailed for Operation Deep Freeze in the Antarctic in early November 1998. Upon completion of that five-month deployment, the ship transited to the Arctic for a spring science mission in the Bering Sea near St. Lawrence Island in April 1999. The St. Lawrence Island Polynya Program (SLIPP99) embarked 17 scientists for a two-week study of biological, physical, and chemical processes in the polynya, an area of open water within the ice-covered sea south of St. Lawrence Island. In the polynya, which forms every winter, are found walrus, bowhead whales, bearded seals, and several species of ducks, including the spectacled eider, a threatened species. The polynya is also important to two Native communities on St. Lawrence Island that rely on this oceanographic feature for subsistence hunting and fishing.

The following organizations were supported during the SLIPP99 cruise: the University of Tennessee; Oak Ridge National Laboratory; the University of Wyoming; the Institute of Energy, Problems of Chemical Physics, Russia; the University of Alaska Fairbanks; the University of Mississippi; the U.S. Fish and Wildlife Service; the Alaska Department of Fish and Game; Anglia Polytech University, U.K.; and the University of Miami. The purpose of the research was to understand seasonal changes in the benthic community and carbon cycling and how this affected the population of the spectacled eider. A series of measurements were made at 35 stations involving light meter casts, CTD/water collecting casts for salinity and primary productivity measurements, vertical tows for zooplankton, van Veen grabs, and benthic corer deployments. Measurements at 20 of these stations were done at locations that have been periodically occupied for benthic sampling since 1988. Measurements at 15 stations were made southwest of the island in a zone where the spectacled eiders were observed during the cruise. In addition, seabird observations and collections were made from helicopters. Seabird and marine mammal observations were also made from the ship during transits between stations.

International Ice Patrol

In addition to the Arctic West Summer Cruises of 1998 and 1999, the Coast Guard was involved in another Arctic-related effort. The Coast Guard International Ice Patrol (IIP), located in Groton,

Connecticut, participated in a joint U.S./Canadian research effort to evaluate and refine the capability to detect and track icebergs using remote sensing. Although this research occurred south of the Arctic Circle, it has direct relevance to high-latitude navigation and is an integral part of the Coast Guard's Marine Science Program. During 1999, IIP began a three-year research program with the Canadian Ice Service (CIS), Environment Canada to evaluate the effectiveness of Radarsat for operational iceberg detection and classification. Radar-

sat is an earth-observing satellite with a synthetic aperture radar developed and operated by Canada to monitor environmental change and natural resources. CIS routinely uses Radarsat data for sea ice monitoring, but this system has not yet been used for operational iceberg tracking. Over the course of this project, CIS and IIP will compare Radarsat data with data acquired during IIP reconnaissance flights to determine the effectiveness of the new remote sensing tool in locating and tracking icebergs.

Federal Highway Administration

The goals and objectives of the Federal Highway Administration (FHWA) in the Arctic are to develop and maintain safe and cost-effective surface transportation facilities, primarily for highways and highway vehicles, just as anywhere else in the U.S. In the Arctic, however, there is a need to assure that highways are compatible with severe constraints imposed by weather conditions, the impacts of severe climate, and the fragile ecology of the area, as well as other normal environmental compatibility concerns.

The FHWA has been monitoring and conducting research in the Arctic for many years, in addition to the numerous investigations conducted elsewhere in the U.S. that are often relevant to highway problems in the Arctic. These projects have been conducted primarily in collaboration with the various state highway agencies, espe-

cially Alaska and the states with more severe winter conditions. Together with the state highway agencies, the FHWA sponsors, collaborates with, and monitors work done under the auspices of the National Academies of Science and Engineering through the Transportation Research Board, National Cooperative Highway Research Program (NCHRP). Some of this work includes funding for and collaboration with other agencies such as the U.S. Geological Survey and the U.S. Army Corps of Engineers, as well as university and private consultant contractors.

	Funding (thousands)	
	FY 98	FY 99
Stream Crossings/Hydrological	100	100
Pavement Problems	800	800
Soils/Subbases (Permafrost)	200	100
Weather Monitoring/Storm Forecasting	500	500
Air/Water Quality Impacts	1,250	1,400
Snow Control/Pavement Treatment	300	1,300
Total	3,150	7,350

Department of State

The Department of State continues to be involved in multilateral and bilateral activities related to environmental protection and scientific research in the Arctic.

U.S. policy in the Arctic has focused primarily on environmental protection since the late 1980s. In 1991 the U.S., along with Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, and Sweden, became signatories to the Arctic Environmental Protection Strategy (AEPS), a high-level forum designed to identify priorities for regional cooperation with regard to environmental protection in the Arctic. Organizations representing the Arctic indigenous communities were admitted as Permanent Participants to the AEPS. On September 19, 1996, the eight Arctic countries signed the Declaration on the Establishment of the Arctic Council, creating the Arctic Council and expanding its mandate to deal with issues of sustainable development. The Council comprises four environmental subsidiary groups: the Arctic Monitoring and Assessment Program (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Emergency Prevention Preparedness and Response (EPPR), and Protection of the Arctic Marine Environment (PAME). A fifth subsidiary group, the Sustainable Development Working Group (SDWG), was established at the Arctic Council's first ministerial meeting in Iqaluit, Canada, in September 1998.

On September 19, 1998, the U.S. became chair of the Arctic Council for a two-year period. The State Department's Office of Oceans Affairs represents the U.S. on the Council and houses the Council's Secretariat during the U.S. chairmanship. As chair the U.S. has taken the lead in several important Council initiatives in environmental protection and sustainable development. One such initiative in the environmental area that deals directly with Arctic research is the Arctic Climate Impact Assessment (ACIA). NOAA and NSF are backing this comprehensive effort to paint a clearer picture of some of the effects that climate change is having on the Arctic environment. The ACIA has attracted the interest of all Arctic Council member states. The Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP) is another Council initiative that should be ready for

	Funding (thousands)	
	FY 98	FY 99
MAB: Arctic Directorate	20	20
Total	20	20

formal approval at the U.S.-hosted ministerial meeting in Barrow, Alaska, in October 2000. This program is designed to "clean up" some of the pollution threats in the Arctic identified by Council members through research during the first phase of the AMAP. The U.S. joined other Arctic nations in supporting the Russian Federation's efforts to develop a National Plan of Action to address land-based sources of marine pollution.

In the area of sustainable development, the U.S. is focusing on human health in the Arctic. The State Department and the State of Alaska are coordinating Council members' activities in the area of telemedicine. The State Department is also supporting a new sustainable development project on emerging infectious diseases in the Arctic led by the Centers for Disease Control, Anchorage, Alaska. The U.S. EPA's support of a cord blood study to identify and monitor the level of contaminants that indigenous people in northern Alaska are absorbing in traditional foods and by general exposure to the environment will soon yield its initial results. The Alaska Native Tribal Health Consortium, based in Anchorage, Alaska, is conducting the U.S. study as part of a larger Arctic-wide study.

As host of the Arctic Council through October 2000, the U.S. Department of State welcomes suggestions from individuals and agencies with an interest in participating in the work of the Council or contributing to the knowledge base and/or data that inform the Council's five working groups. Interested individuals are encouraged to visit the Arctic Council Web site (<http://arctic.council.usgs.gov/>). The Web site lists current and future activities of the Council, as well as the names and addresses of individuals and secretariats related to specific aspects of the Council's work.

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Back Cover

Tuluq Site excavations, a paleoindian site along Wrench Creek in Noatak National Preserve, northwest Alaska.

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