2. Special Focus Interagency Research Programs

In 1990 the Interagency Committee agreed on the following policy:

> The IARPC agrees that a more comprehensive approach to funding of research and baseline programs is required to ensure a long-term, viable research and development presence in the Arctic. This presence will ensure support of the national needs, which include renewable and nonrenewable resource development, environmental protection, and partnerships with the private sector and residents of the Arctic. It will complement other national and international scientific programs, such as Global Change. To this end the IARPC agencies agree to develop, starting in 1992, an integrated interagency program sufficient for meeting national needs.

Subsequently the IARPC agencies examined Arctic research from an interagency perspective. For this biennial revision of the plan, agencies agreed that the following three programs are ready for immediate attention as multiagency focused efforts:

- Study of Environmental Arctic Change (SEARCH)
- Bering Sea Research
- Arctic Health Research.

These coordinated, multiagency programs are being designed to:

- Focus research activities in concert with national policy;
- Build on individual agency efforts in reconnaissance, monitoring, process studies, and modeling;
- Facilitate research and logistics coordination through regionally focused programs;
- Take maximum advantage of remote sensing and new technologies;
- Strengthen interagency data and information management;
- Draw on the strengths of the academic, industrial, and government research communities in planning and implementing programs;
- Support and enhance programs to acquire long-term measurements of key parameters and environments; and
- Enhance international research collaboration.

The U.S. has a substantial economic, strategic, and environmental stake in the Arctic. Domestic energy reserves and the explosive growth in Bering Sea fisheries harvests are two examples of our dependence on Arctic resources. Sound management decisions for sustainable development of Arctic resources hinge on enhanced understanding of the environment, leading to better forecasts. In addition, there is a strong international commitment to collaborate.

Benefits to the Nation from Arctic research include improvements in:

- Knowledge of fishery resources and controlling dynamics;
- Models and data for assessing past climates and global change and their effects;
- International cooperation in a strategic region;
- Forecasts of weather, ice, and ocean conditions;
- Protection of the Arctic environment;
- Understanding of the causes, effects, and limits of air and water pollution; and
- Protection and understanding of cultures and cultural resources.

2.1 The Study of Environmental Arctic Change (SEARCH)

The Arctic Ocean and the surrounding lands and seas are seemingly remote areas for most of us, yet ongoing changes in this area may have profound impacts not only on the people and economies of the region, but also on residents throughout the Northern Hemisphere and beyond. Native subsistence hunters and others with a keen sense of observation have noted substantive changes in the physical environment and in the behavior of wildlife.

"Last spring we only got six walrus because of the weather and ice moving out too quick. I talked to elders about the weather. A long time ago it used to be real nice for weeks and even sometimes for months. Now we only have a day or two of good weather. And a lot of times it is real windy now. They don't know what is causing that either. And the hunters that I talked with about the ice conditions say it is getting a lot thinner. It is going out too quick. Maybe it is because of the weather. Maybe it is because of that global warming."

Herman Toolie, Savoonga, St Lawrence Island, 2000

"My people hunted beaver in Hay Slough for over 100 years, and in one house we had 32 beaver. Because a lot of our lakes don't freeze as deep. We are having more warmer winters than usual on a consecutive basis. What's happening is that because the winters are warmer, the lakes don't freeze all the way down and more of the young beavers survive. We now have more beaver than ever in this slough because of warm winters that give the beaver the most favorable conditions to survive. The beaver then proceed to dam and tier off the sloughs so resident species of fish, which again provides the Indians with a very viable source of food, cannot reach their spawning ground to provide the next generation of food for the Indians of the Interior."

Paul Erhart, Fairbanks, 2000

Scientists are documenting concurrent large-scale changes in the Arctic,* of which these local fluctuations are a reflection. There is strong observational evidence consistent with thinning of the Arctic ice pack and a decrease over time of the maximum extent of the sea ice cover. The state of the Arctic atmosphere has changed over the past few decades, changing temperature and wind patterns and causing ice to circulate differently in the Arctic Ocean. Warm Atlantic water has intruded unusually far into the eastern Arctic Ocean. Surface air temperatures throughout much of the Arctic are increasing, especially in winter and spring, leading to thawing of permafrost and earlier ice melting. Stratospheric ozone over the Arctic is diminishing in the spring, leading to elevated UV levels reaching the surface.

These physical changes are leading to changes in the biosphere. Canadian studies demonstrated that polar bears are malnourished because of a shortened hunting season caused by earlier retreat of shorefast ice. Walrus are finding fewer sturdy ice floes to serve as haulout areas. The tree line is advancing, consistent with the milder winters. Beavers are flourishing in the milder climate, causing increased damming of rivers that reduces the return of salmon to spawning grounds.

In the Arctic itself, these physical and biological changes have social and cultural consequences for the Native communities and lifestyle and economic consequences for all Arctic residents. Because these changes in the Arctic environment make it difficult to predict what tomorrow may bring, the entire complex of changes has been given the name "Onami," which is derived from the Yup'ik word for "tomorrow."

The dramatic environmental changes seen in the Arctic over the past few decades will almost certainly create daunting environmental and socioeconomic challenges (or, perhaps, new economic or social opportunities?) in the Arctic region itself, but can these changes affect a much larger portion of the earth? For the most part, the observed changes relate to the physical environment and are thought to be linked to climate variability or change. Whether the processes at work are entirely natural or are being caused or strengthened by human activities, impacts to a much larger area can occur in at least two major ways: via the atmosphere and via the oceans.

Evidence is mounting that the state of the Arctic atmosphere, as characterized by the Arctic Oscillation index,† strongly influences seasonal weather patterns over the U.S. The Arctic Oscillation was only recently described, and our understanding of its influence on weather and climate is at an early stage. In a preliminary finding the National Weather Service has stated that for the eastern third of the U.S., "the AO is the single most important factor in wintertime seasonal temperature variability." They also stated that at this time it is the most difficult factor to forecast seasonally with skill.

While connections through the atmosphere can influence weather and climate outside the Arctic on seasonal and interannual scales, connections through the oceans operate over time scales of up

* The areal extent of the "Arctic" for the Study of Environmental Arctic Change includes not only all areas north of the Arctic Circle, but also the entire Bering Sea, the Labrador Sea, the far North Atlantic, the entire permafrost zone on land, and watersheds that drain into the Arctic Ocean.

† The Arctic Oscillation index is defined as the first empirical orthogonal function of the Northern Hemisphere winter sea level pressure field. The AO can be thought of as the difference between the weighted average of sea level pressure over the entire midlatitude belt centered near 45°N and the weighted average of sea level over the entire Arctic basin. The AO has been in a strong positive state for the past decade.

to several decades. The global thermohaline circulation (THC), in concert with the Gulf Stream, carries a significant amount of heat north and east across the North Atlantic to northern Europe and Scandinavia. Processes in the North Atlantic and Arctic strongly influence the rate at which the THC transports water. It is theoretically possible that increases in the flux of fresh water from the Arctic can decrease the rate of the THC and cause a significant cooling effect in Northern Europe and Scandinavia and perhaps even trigger an increase in glaciation over much of the Northern Hemisphere. There is evidence that such changes have occurred in the past, perhaps even over short time scales of about 10 years. The National Academy of Sciences has begun a study of “abrupt climate change” that will consider the scientific evidence regarding the causes and probabilities of such events.

The U.S. agencies that conduct or sponsor scientific activities in the Arctic have agreed that greater attention must be given to Arctic environmental processes and their potential impacts on the biosphere, including human social and economic well being. Many of these agencies have joined together to support the Study of Environmental Arctic Change (SEARCH). The SEARCH program will consist of research, monitoring, and analysis activities to track and quantify environmental changes in the Arctic, distinguish causative factors, assess environmental and socioeconomic impacts, provide an analysis of the changes that may be expected in the future, and provide outreach to policy makers and the public.

2.1.1 Evidence for Climate Variability and Change in the Arctic

The earth’s climate is not constant. There are climate cycles that vary over seasonal to centennial scales, and sudden climate changes can be induced by rare events (such as meteor impacts or volcanism). Now there is a new worry—that human activities may cause climate change. The primary cause of this worry is the undeniable build-up of carbon dioxide in the atmosphere as a result of a century of accelerating combustion of fossil fuels. Most worrisome is the recognition that the use of fossil fuels will continue to increase for decades to come, resulting in concentrations of carbon dioxide in the atmosphere that may exceed the pre-industrial level by four times or more. Already, there is solid evidence of significant increase of surface temperatures on a global basis and of increased storage of heat in the global oceans.

In the Arctic the increase in surface temperature has been quite dramatic over the past 30 years, leading to changes in a number of environmental parameters sensitive to temperature. The temperature changes seen in the Arctic are consistent with the output of global climate models forced with increasing concentrations of atmospheric carbon dioxide. Many studies have been reported over the past decade that argue that the Arctic may be a sensitive indicator of global change. Models show that under a representative global warming scenario, temperature increases will be amplified in the Arctic, and the upper Arctic Ocean salinity will decrease because of enhanced precipitation at high latitudes. Archaeological studies have shown that human cultures have been drastically affected by such terrestrial and ocean-based changes. For example, studies have demonstrated a dramatic expansion of Vikings across the North Atlantic and their settlement of Iceland and Greenland during a warm climatic period, followed by their subsequent extinction from Greenland during the early part of the Little Ice Age. Similar human impacts have been documented in the archaeological records for virtually every area of the circumpolar region and are especially well known in Labrador and the eastern North American Arctic.

Recent Changes

Even though science cannot at present provide irrefutable arguments regarding the cause(s) of the recent observed global and Arctic warming, studies have proven that these changes are unprecedented over at least the last 400 years, although the Arctic has experienced more significant changes during the past 8000 years. The rapid changes that have occurred in the last decades provide the motivation for SEARCH, and it is useful to review a few of these key findings.

In the ocean the warming influence of Atlantic water appears to have started in the late 1980s and has persisted through the 1990s. Data collected during several cruises in 1993–1995 indicate that the boundary between the eastern and western halocline types has shifted from over the Lomonosov Ridge to roughly parallel to the Alpha and Mendeleyev Ridges. In terms of longitudinal coverage, this means that the area occupied by the eastern, Atlantic water types is nearly 20% greater than previously observed. This distribution has persisted well into 1999, although the Atlantic water temperature appears to have ceased to increase in 1998.

The observed shift in ocean frontal positions is associated with changes in ice drift and atmospheric pressure patterns. The ice drift and pressure fields for the 1990s are shifted counterclockwise 40°–60° from the 1979–1992 pattern, just as the upper ocean circulation pattern derived from the hydrographic data is shifted relative to climatology. This change is consistent with the findings that the annual mean sea level atmospheric pressure over the central Arctic basin is decreasing and has been below the 1970–1995 mean in every year since 1988. This change in atmospheric pressure is part of the recent large change in atmospheric circulation of the Northern Hemisphere as captured by the AO index.

There have been changes in terrestrial variables as well. Increased air temperature has been attended by reductions in spring snow cover since the mid-1980s. Arctic glaciers have exhibited negative mass balances, paralleling a global tendency. Other studies point to increased plant growth, northward advances of the tree line, increased fire frequency, and thawing and warming of permafrost.

Long-Term Trends

There is evidence for multi-decadal and longer trends in several key Arctic variables. There has been pronounced warming over northern Eurasian and North American land areas since the early 1970s, particularly during winter and spring, partly compensated for by cooling over northeastern North America. Temperatures have also increased over the Arctic Ocean in spring and summer. These changes are in general agreement with those depicted in model anthropogenic change experiments. Reconstructions based on proxy sources indicate that late-20th-century Arctic temperatures are the highest in at least the past 400 years. Statistical analysis of this time series against records of known forcing mechanisms suggests that the recent warming has an anthropogenic component. Available observations point to long-term and recently augmented reductions in sea ice cover.

These physical changes coincide with a shift in the Arctic budget for biogenic carbon. Recent data suggest that past carbon accumulation in Arctic tundra has changed to a pattern of net loss, with growing season releases of up to 150 g m^{-2} yr^{-1}. The Arctic has been an overall significant sink for carbon over historic and recent geologic time scales, resulting in large stores of soil carbon of perhaps 300 gigatons. Present conditions appear to represent significant deviations from historic and Holocene carbon fluxes and indicate the potential for a positive feedback on global change through losses of CO_2 to the atmosphere of up to 0.7 Gt C yr^{-1} (about 12% of the total emission from fossil fuel use). These soil emissions augment the anthropogenic impact.

Links between the Arctic and the Global System

The Arctic is one of two primary sinks for solar energy, which enters the earth climate system most strongly in the equatorial regions; the other sink is the Antarctic. The observed changes impact the efficiency with which the Arctic can act as a heat sink. First, the Arctic Ocean's stratification and ice cover provide a control on the surface heat and mass budgets of the north polar region and thereby on the global heat sink. If the distribution of Arctic sea ice were to continue its present decrease, the altered surface fluxes would affect both the atmosphere and the ocean and would likely have significant consequences for regional and global climate.

Second, the export of low-salinity waters, whether liquid or in the form of desalinated sea ice, has the potential to influence the overturning cell of the global ocean through control of convection in the subpolar gyres. For example, recent suggestions that North Atlantic and Eurasian climate variability may be predictable on decadal time scales rest in part on the variability of such upstream forcing in the Greenland Sea.

Third, sea ice, nutrient availability, and water density condition Arctic marine life. Changes in these factors may impact marine ecosystems and biogeochemical cycling of essential nutrients and dissolved organic matter. Changes in the terrestrial hydrologic cycle may alter soil moisture, impacting plant communities and their grazers. If Arctic soils have shifted from a sink to a source of carbon dioxide and methane as indicated earlier, this would be a strong connection between Arctic processes and global climate.

Finally, the atmospheric circulation of the Northern Hemisphere has been changing as part of a pole-centered pattern, termed the Arctic Oscillation (AO). Recent modeling studies suggest that the AO is a fundamental mode of atmospheric change that has impact well beyond the Arctic. Other studies suggest that the positive trend seen in recent decades may be symptomatic of anthropogenic climate change.

2.1.2 The Human Dimension

There is a strong human dimension to the environmental changes of recent years. These have direct effects on the residents of the Arctic because many of them live so close to the environment. Moreover, the changes seem to be having farther-reaching effects that touch society in sub-Arctic and even temperate regions through fisheries and transportation. For example, Canadian grain is being shipped through Churchill, on Hudson Bay, for the first time because of decreased ice cover in the Canadian Arctic.

Local and Regional Effects

The environmental changes discussed above affect the residents of the Arctic that subsist wholly or in part on Arctic flora or fauna. Indeed, the hunters and fishers of the north have made many of the observations of environmental change. They have recounted recent declines in abundance of a variety of fish species as well as marine mammals and seabirds. They have reported changes in the terrestrial environment, such as drying of lakes and wetlands, drying of summer vegetation, and thawing of discontinuous permafrost. Indigenous people are uniquely prepared to note the increased variability and decreased predictability of the physical environment. Examples of their reports of sea ice conditions, storm patterns, sea level, weather changes, snow, rain, and water temperatures and their effects on plant and animal food sources show remarkable connections to the changes cited in the scientific literature.

Changes in the physical and biotic environment have impacts beyond the local village and community scales. Changes in the duration and extent of pack ice cover influence the abundance of polar bears and seals; changes in seawater temperature in Baffin Bay have a profound impact on the West Greenland and Baffin cod and halibut fisheries; and changes in temperature and snow cover influence the population sizes of caribou, muskox, and small fur-bearers that northern residents depend on for food, clothing, and income. The presence or absence of polynias and open ice leads influences the availability of sea mammals to hunters, and the amount of stormy weather can determine whether hunters can reach their prey even when game is present. Modern Arctic residents confirm these and many other climatic and environmental changes that influence the distribution of Arctic resources important to humans in the north.

Large-Scale Effects

There is growing concern that the Arctic is a final destination for airborne contamination from the rest of the Northern Hemisphere. This is a major concern of the indigenous population. Further, the recent changes in the Arctic environment seem to have a connection with changes in the fisheries of the North Atlantic, the Bering Sea, the Barents Sea, and the Yukon River. These have resulted in regional economic change and a redistribution of income in many areas.

It is a mistake to think of the Arctic Ocean as being pristine. The recent report of the Arctic Monitoring and Assessment Program makes this abundantly clear. One reason is the atmospheric transport of semivolatile organic pollutants (DDT, PCBs, etc.) and mercury that enter the atmosphere in lower latitude regions and condense in the Arctic. Through this mechanism, we find concentrations of pollutants such as PCBs in Arctic fauna. In addition, there is local atmospheric pollution. The largest Arctic rivers drain some heavily industrialized zones, including portions of the former Soviet Union that were used heavily for the production and processing of radionuclides. Finally, there has been direct dumping of pollutants into the Arctic Ocean and toxic chemicals left behind after closure of former defense sites. It is difficult to predict what the future holds for the transport of pollutants into the Arctic, except to say that it is likely to change and that for some pollutants such as organochlorines and mercury there is legitimate concern. There is also concern that, just as the rising AO enhanced the northward heat flux, it may also be responsible for an increase in the northward flux of contaminants. These concerns have given rise to a lack of confidence in the safety of Native foods.

Over the past decade, large-scale ecological changes have impacted fishery-dependent societies around the world. Fishing pressure has been one driver for these changes, but often the changes have coincided with climatic variations as well. Economically critical groundfish populations, for example, exhibited steep declines or collapses off Norway, the Faeroe Islands, Iceland, West Greenland, Newfoundland, and New England during the late 1980s or early 1990s. The collapse of Newfoundland's northern cod fishery in 1991-92 occurred in conjunction with unusual ice conditions and a broadening of the cold intermediate layer of the Labrador Current during a Northwest Atlantic cooling phase of the NAO. Norway's cod fishery was partially recovering from its own crises (1989) during the same years, assisted by a Northeast Atlantic warming phase. West Greenland's cod fishery first developed as the warm Irminger Current extended northwards around 1920 but later declined and eventually collapsed (1992) as fishing increased and waters cooled.

Climate and ocean circulation variations directly affect commercial fish populations (particularly their reproduction, larvae, and food webs) through variables such as water temperature, salinity anomalies, vertical mixing, and currents. Moreover, fishing itself can increase the vulnerability of target populations to climatic change by altering age structure (for example, removing most of the robust and high-fertility older individuals) and densities among predatory fish populations and reducing the populations of food fish. Human adaptive efforts, in response to these ecological changes, include technological intensification, shifts to alternative species, economic diversification, government subsidies, and out-migration. Fishery-dependent communities throughout the northern Atlantic have experienced population losses during the past decade.

In the North Pacific a physical regime shift took place in the mid-1970s with an intensification of the Aleutian low-pressure system. Among the many changes associated with that shift were increased Alaskan salmon catches and a change from shrimp to groundfish dominance in the Gulf of Alaska. Similarities have been observed among the effects on fisheries of ecological changes in the Bering Sea, along the Newfoundland coast, and in the Barents Sea. The groundfish stocks associated with these areas have historically contributed to relatively stable fisheries over fairly long periods of time until recently. The cod and pollock fisheries seem to be drawing down mature age classes at rates that exceed recruitment in most years. Periodically, however, a good year provides exceptional juvenile survival, which builds the fishable stocks back up several years later as the young fish mature. We are uncertain of the ecosystem changes that are causing this. Both the Barents Sea fishery and the Canadian Atlantic fisheries saw a rapid increase in the industrial fishery in the 1950s and 1960s, combined with boundary disputes that frustrated fishery managers. It seems that when the natural fluctuations in productivity of the marine ecosystem are large, “normal fishing pressure” can be enough to deplete stocks beyond recovery in just a few years if oceanographic changes cause the good years to become less frequent. These fisheries, which are among the world’s largest, may be extremely vulnerable to climate change.

An example of the potential interaction of climate and fisheries management is the recent collapse of some western Alaska salmon stocks and the curtailment of groundfish operations in the Bering Sea because of declines in the western populations of the Steller sea lion and northern fur seal. These are significant current management issues. The basic science problem with resource management is that fisheries agencies with responsibility over stocks important for human harvest are driven toward solving narrowly focused, short-term problems. For productive fisheries management, we need to understand how the whole system works, from climate influences to ocean circulation to ecosystem productivity to specific species that are important to humans.

These recent changes in sea ice conditions and weather have impacted local transportation. The changes may be most far reaching for their effect on the Northern Sea Route (NSR) along the Russian Arctic coast. The NSR has been a primary concern of Russian polar scientists for many years. Much of their research was done with the aim of improving predictions of shipping conditions along their Arctic Ocean coast. Now several nations, notably Japan and Russia (there are Alaskan interests as well), are examining the new potential of the NSR for trade. If the Arctic change affects navigability, this may change shipping patterns between Asia and northern Europe, altering the world economic significance of the Arctic Ocean. Impacts are likely, as well, on the use of the Northwest Passage through the Canadian Archipelago and on shipping into the Alaskan and Canadian North Slope. As noted above, light ice conditions in Hudson Bay now allow the use of Churchill as a shipping port.

2.1.3 Science Hypotheses

A complex suite of related atmospheric, oceanic, and terrestrial changes have dominated the Arctic in the last several decades. Because they have made it harder for those who live in the north to predict what the future may bring, this complex of recent changes has been termed “Onami,” derived from the Yup’ik for “tomorrow.” Onami is characterized among other things by:

- A decline in central Arctic sea level atmospheric pressure;
- Increased surface air temperatures in Northern Europe, the Russian Arctic, and western North America, with cooling over eastern North America and Greenland;
- Alterations in terrestrial precipitation and changes in vegetation;
- Cyclonic ocean circulation and rising coastal sea level;
- Increased temperature of Atlantic waters in the Arctic;

- Decreased sea ice cover; and
- Decreased Beaufort Sea surface salinity.

Learning the full scope of Onami will be an ongoing goal of SEARCH. However, a working definition based on present knowledge is useful. For this we define Onami as the recent and ongoing, decadal (3–50 year), pan-Arctic complex of intertwined changes in the Arctic system. These changes encompass the physical processes listed above, as well as resultant changes in ecosystems and living resources and consequent impacts to the human population. Four key working hypotheses have been developed to help guide SEARCH.

The first hypothesis is that Onami is related to the Arctic Oscillation. Associations between the AO and changes in many environmental parameters, such as air temperature and ocean circulation, have been documented. A key goal of SEARCH is to test this hypothesis by quantitatively assessing the interactions among the atmosphere, ocean, and land. It will tell us much about how Onami is tied to the global atmospheric system.

A second hypothesis is that Onami may be a component of anthropogenic climate change. The AO is a fundamental mode of atmospheric variability, and the increasing dominance of its positive mode may be tied to the anthropogenic component of climate change. Thus, Onami may be tied to climate change through the AO as well as through other large-scale patterns of atmospheric variability. Testing this hypothesis bears directly on the goal of understanding how Onami fits into the larger picture of global climate change.

A third hypothesis is that feedbacks among the ocean, land, ice, and atmosphere are critical to Onami. These feedbacks could determine whether the Onami, and therefore the Arctic, play critical roles in global climate change. For example, a decrease in sea ice and snow cover forced by higher temperatures could lead to further warming because of the reduction in albedo (the well-known ice–albedo feedback). This could in turn alter patterns of atmospheric circulation, further impacting Onami and snow and sea ice. A second example is albedo and sensible heat flux feedback through reductions or expansion in sea ice extent in marginal seas. The Barents, East Siberian, and Labrador Seas are especially sensitive to such change.

The final hypothesis is that the physical changes of Onami have large impacts on the Arctic ecosystems and society. This is true whether Onami is tied to either natural or anthropogenic climate change or is the result of other factors, including human activity. The key issues growing from this idea are that we must describe (and ultimately attempt to predict) the ecosystem and societal impacts of Onami, and we must distinguish between the changes associated with the large-scale physical Onami phenomenon and the changes caused by other human activity. Archaeological and paleoenvironmental studies can assist such investigations by presenting data sets from before periods of modern human impacts.

2.1.4 Objectives

The overarching goal of SEARCH is to understand Onami. This requires that we address the following objectives:

- Determining if Onami has happened before;
- Determining if Onami is continuing; and
- Understanding the forcing mechanisms and feedbacks that control Onami.

From this understanding the SEARCH Program will derive the ability to:

- Assess the predictability of Onami and, to the extent possible, develop a capability to predict the course of Onami;
- Assess and predict the impact of Onami on ecosystems and society; and
- Provide information of societal relevance in a timely way.

These objectives must be approached differently when dealing with different components of the Arctic system. For example, Onami relationships are perhaps most readily apparent in atmospheric and oceanographic data, such that research to understand processes and feedbacks can proceed without delay. Initial assessment is still needed in the biological realm, and in the human dimension the separation of effects of environmental change from those of society's actions remains a challenge.

2.1.5 SEARCH Organization and Interagency and International Coordination

SEARCH was conceived initially as a physical oceanography program, because recent changes in the Arctic environment were most readily apparent in the ocean and sea ice. It has rapidly become clear, however, that recent Arctic changes go well beyond the marine environment into the terrestrial environment and the atmosphere. Consequently SEARCH has been broadened into a thematic program extending across many scientific disciplines. It has become apparent that SEARCH must include a long-term observation program, an international dimension, and a remote-sensing component. Because of this breadth, SEARCH requires support by multiple U.S. agencies, as well as international collaboration. Organizational efforts have been directed, to date, at developing an interagency effort for SEARCH and for making SEARCH part of the World Climate Research Program's International Program on Climate Variability and Predictability (CLIVAR).

IARPC and the Interagency Working Group for SEARCH

In the previous edition of the U.S. Arctic Research Plan (*Arctic Research of the United States,* Fall/Winter 1999), Arctic Environmental Change was one of the proposed research initiatives. In March 2000 the full IARPC met and, after a discussion of the SEARCH goals, formally established the Interagency Working Group for SEARCH and directed that it prepare an Interagency Research Plan for SEARCH. An initial interagency implementation plan was prepared in June 2000 to cover FY 01 activities related to SEARCH. In April 2001 the working group was given direction by the full IARPC to prepare similar implementation plans for FY 02 and FY 03.

SEARCH Organization in the Scientific Community

The SEARCH program will obtain scientific guidance through a Science Steering Committee (SSC) supported through a Project Office structure. The membership of the SSC consists primarily of scientists from U.S. academic institutions but includes representatives from government and international organizations. The present SEARCH SSC was formed to write the initial Science Plan. A new committee will be formed for the implementation phase of SEARCH and will have the responsibility for interpretation and implementation of the Science Plan in the principal investigator community.

Data archival will be a major task for SEARCH because of the heavy emphasis on long-term observations. Here, various data archival facilities with experience editing, storing, and displaying the wide variety of data types might be used, but their data must be centrally available. It should be possible with the use of the World Wide Web to create a distributed data bank that appears to the user as a centralized site. A similar paradigm should work to some extent for information dissemination.

National and International Coordination of SEARCH

The organizers of the SEARCH Program are taking steps to ensure proper coordination with Arctic science activities conducted by other groups and countries. The World Climate Research Program (WCRP) is the primary international activity for global climate research. It is the parent of two activities of relevance to SEARCH: CLIVAR and CLIC.

The Climate Variability and Predictability (CLIVAR) program is a major driver for U.S. research on climate. "Panels" represent the main efforts within the U.S. CLIVAR program. There are three CLIVAR panels: the Atlantic Panel, the Pacific Panel, and the Pan-American Panel. The panels are equally represented on the CLIVAR Science Steering Committee (SSC), which is also responsible for providing oversight of the panels. An interagency team representing NSF, NOAA, DOE, and NASA set up the SSC. These panels enable the program to provide a critical mass of resources, ensure coordination and communication between climate research activities (both within the U.S. and internationally), ensure a proper program balance by identifying and filling crucial gaps in the program, and strengthen the multiagency support for high-priority climate research in the U.S. In November 1999, SEARCH was proposed to the U.S. CLIVAR Scientific Steering Committee as a component of the U.S. CLIVAR program. The CLIVAR SSC response was positive, and SEARCH is now recognized as a component of CLIVAR.

The SEARCH SSC has been encouraged to establish close ties with other international programs, such as the Climate and Cryosphere (CLIC) program. Like CLIVAR, such programs operate under the WCRP and have received significant support in Europe. Other interactions are developing with the Norway–U.K. joint climate program, activities supported by the European Union, and activities supported by the Japanese Frontier program in the Arctic.

2.1.6 Recommendations for the Future

The SEARCH SSC needs to ensure that its science plan is comprehensive and has been generally accepted by the scientific community. Further, the SSC should develop a set of science-based priorities within each subset of the science plan. SEARCH must move forward in all areas and not be limited to only the "most comfortable" areas, while leaving the complex issues for an undefined future time.

2.2 Integrated Assessment for a Sustainable Bering Sea

The Bering Sea, located between the Aleutian Archipelago and Bering Strait, is a marginal sea that connects the North Pacific and Arctic Oceans. It is the world's third-largest semi-enclosed sea and includes a wide eastern shelf encompassing about half its total area.

The Bering Sea region supports one of the world's richest assemblages of seabirds and marine mammals and large stocks of commercially valuable fish and shellfish. Its multiple habitats are ideal as homes to a rich variety of biological resources, including the world's most extensive eelgrass beds; at least 450 species of fish, crustaceans, and mollusks; 50 species of seabirds; and 25 species of marine mammals.

This rich, abundant, and ecologically diverse system has attracted and supported aboriginal cultures for millennia. Today, Bering Sea resources continue to support the economic survival, subsistence, and cultural foundation for a majority of the 227 federally recognized tribes of Alaska. In addition, the U.S. Bering Sea fishery contributes over half of the nation's fishery production, with an annual product value estimated at $2.2 billion. Walleye pollock comprise much of the fish landings, Bristol Bay supports the world's largest sockeye salmon fishery, and snow crab landings represent the largest crustacean fishery in the U.S. In addition to supporting commercial fisheries, the Bering Sea also supports 80% of the U.S. seabird population, comprising 36 million birds. Many unique and endemic species breed in the Bering Sea. The importance of the region is reflected in a variety of recent agreements, adopted by the U.S., other nations, and international organizations, designed to protect Bering Sea marine mammals, birds, and fish resources.

During the 1970s, 1980s, and 1990s, rapid changes in the physical and biological characteristics of the Bering Sea raised significant concern among resource managers, Native communities, commercial interests, and conservationists, among many others. While change is a natural characteristic of all ecosystems, and animal and plant communities are adapted to natural environmental rhythms, some natural changes or anthropogenic pressures can be too great or too sudden for biota to adjust, resulting in die-offs within species and shifts in community composition. Observed changes in the fish and mammal populations of the Bering Sea region suggest that current environmental and human pressures are too great. For example, over the last 20 plus years, Bering Sea Steller sea lion populations declined 50–80% and are now listed as "endangered." Northern fur seals are listed as "depleted" under the Marine Mammal Protection Act. Bering Sea populations of common murres, thick-billed murres, and red and black-legged kittiwakes declined up to 90%. In 1999 the collapse of the salmon fishery in Bristol Bay led the State of Alaska to consider the region an economic disaster area. Natural and anthropogenic forces are likely combining to cause rapid changes in the physical environment and biological communities of the Bering Sea region. Although considered among the most productive of high-latitude seas in the world today, the Bering Sea is at risk.

Significant changes occurring in the oceanographic and atmospheric Arctic environment, targeted under SEARCH (Study of Environmental Arctic Change, see Section 2.1), are powerful influences in the Bering Sea region. As in other Arctic regions, the Bering Sea is likely responding to these forces of change. The Bering Sea integrated assessment will benefit from work completed under SEARCH. At the same time, work completed as part of the Bering Sea integrated assessment will contribute to SEARCH, serving as a case study sub-ecosystem.

2.2.1 Arctic Research Commission Charge

The Arctic Research Commission, in its 2001 Report to Congress, targeted integrated research and assessment of the Bering Sea as a key research priority. The Commission observed that concern about the Bering Sea has engendered large and intense research synthesis and planning efforts with significant research and financial investment. These efforts share a commitment by scientists from diverse disciplines and organizations to come together to define the most important research needs and share research results. The quality of past and current research is unquestioned. However, while significant research efforts have produced important results, our understanding of how and why those changes are occurring remains elusive. Based on meetings it held during 1999, the Commission concluded:

- There is insufficient integration among key Bering Sea research programs.

- Current research does not enable managers to predict ecological responses to management decisions implemented within the Bering Sea region.

As the Commission noted, for example, connections must be made between research efforts on different populations of the same species to allow for comparisons. Basic oceanographic data collection and analyses should be integrated with studies of population effects in species at higher trophic levels, such as marine mammals, birds, and fish. Further, scientists must process data in such a way that predictions about changes in the Bering Sea ecosystem can be made, particularly on the population dynamics of higher trophic organisms.

The Commission found that data analysis is now *post hoc*, and management decisions are primarily based on historical records of system behavior rather than on predictions about ecological responses to new management decisions. Managers need the type of scientific information that will allow them to prevent negative effects and avoid crisis management. While there are ecological, social, and financial risks associated with making incorrect predictions, predictions with carefully stated confidence limits are essential for effective resource management and protection of the Bering Sea.

2.2.2 Building an Iterative Bering Sea Research Strategy

While continued research is critical to better elucidate the mechanisms and processes of change in the Bering Sea as well as the Arctic, ensuring that all essential scientific questions are well directed and investigated to answer key management concerns is a challenge. To meet the needs for an integrated assessment in the Bering Sea, Federal partners are implementing a strategic plan to clarify and connect scientific questions to management needs, as well as identify key goals. Since natural ecosystems, science, and management are all dynamic systems, an iterative process will be established to ensure linkages among needed management decisions, research, and ongoing system changes.

Components of Strategic Integrated Research

The Bering Sea Research Strategy will include four key components, each of which influences the others in an iterative framework. They include:

- Common Vision and Goals: Based on dialogue among interested parties of the Bering Sea, key concerns, common interests, and desired outcomes from management actions will be defined. In this process, diverse interests establish agreement on key ecological and human values of concern to provide the necessary framework around which to structure integrated assessments.
- Conceptual Synthesis: Existing data will be integrated to identify potential relationships among forcing functions, ecosystems changes, sources of stress, and ecological endpoints of concern identified in the goals. The process is interactive, iterative, and interdisciplinary, transforming diverse data into a set of conceptual models and predictive testable hypotheses about the influences of multiple natural and human stressors on ecological and human systems. The purpose is to learn more from existing data, generate multiple working hypotheses about likely causal relationships, and define essential research needs.
- Research Plan: Based on the conceptual synthesis and resulting conceptual models, a research plan will be developed that identifies key questions, information gaps, and conceptual links. A superimposed guiding framework for integrating research and interpreting results can then be used to generate an integrated interagency research plan among Federal agencies and other research organizations that capitalizes on existing research efforts and encourages strategic new research.
- Research Implementation: New research will be initiated to evaluate predictive relationships among natural and human influences on key values of concern. The research will investigate processes, trends, and effects, as well as monitor the impacts of management decisions. Information will be fed back into goal setting, synthesis, and planning for re-evaluation of goals, refinement of conceptual models, and development of updated research plans.

Goal development, conceptual synthesis, research planning, and implementation each provide feedback to all other components. As a result the strategy is inherently iterative, involving an interplay among research findings and environmental observations, desired management outcomes, goal setting, and new insights that lead to new research.

Chapter Organization

To provide background about the Bering Sea, Section 2.2.3 describes some of the basic characteristics of the region and the forces influencing it. Section 2.2.4 provides an outline of recommended research, giving priorities for current research needs. To build a more comprehensive integrated research strategy in the future, Section 2.2.5 describes the process planned to establish unified goals, conceptual syntheses, and research planning to achieve strategic research of integrated assessments.

2.2.3 The Bering Sea Region

The larger Bering Sea region includes the waters and coastal regions of the Bering Sea situated between Alaska and Russia. The southern extent includes currents from the North Pacific flowing through the Aleutian Chain and waters flowing north through the Bering Strait to the Chukchi Sea and Arctic Ocean. A large terrestrial component is part of the region that includes watersheds in Alaska and Russia discharging into the Bering Sea, such as the Yukon and Kuskokwim watersheds covering the majority of Alaska.

Characteristics

In the early 1980s, scientists working under the Processes and Resources of the Bering Sea Shelf (PROBES) project defined specific hydrographic regimes for the southeastern Bering Sea: the coastal or inner shelf domain, the middle shelf domain, the outer shelf domain, the continental slope, and the transitional areas or fronts between them. Each of these domains represents a different marine habitat.

Time series data collected in Bering Strait on salinity and temperature confirm that Alaskan coastal waters are relatively warm, have low salinity, and flow through the eastern channel of the strait. Bering Shelf water is of higher salinity. The eastern Bering Sea consists of an oceanic and shelf regime. Within the broad (>500 km) shelf regime, three distinct domains exist, characterized by contrasts in water column structure, currents, and biota. The balance between mixing (tidal and wind) and buoyancy flux (freshwater discharge, ice melt, and solar radiation) generates the domains. A system of three hydrological zones exists over the western shelf that is somewhat analogous to the system of hydrological zones on the eastern shelf. The coastal, transition, and oceanic zones are easily distinguished by their temperature–salinity characteristics and vertical structure. As with the eastern shelf, atmospheric processes that regulate the heat balance and result in the formation of ice are primary features of the environment that dictate oceanographic conditions of the western shelf. Ice typically covers the entire western shelf in winter.

North of approximately 62°N, changes in topography, tidal energy, and river discharge from the Yukon modify boundaries between domains. South of St. Lawrence Island, three water masses exist across the shelf: Alaskan Coastal, Bering Shelf, and Anadyr. North of St. Lawrence, all three water masses are present and can be identified as they flow northward through Bering Strait. Over the western shelf, the dominant circulation feature is the Anadyr Current, a coastal flow extending from the Gulf of Anadyr westward past Cape Navarin.

The status of living marine resources in the Bering Sea ecosystem is largely confined to commercially important fish and invertebrates and birds and mammals readily observed from land or air. Data on forage fishes are largely confined to the Pacific herring, which is dominated by the Togiak stock. Knowledge of invertebrates is largely restricted to crabs. Eastern Bering Sea salmon abundance was generally high during the 1980s and 1990s, although specific runs, such as chinook and chum in western Alaska, have been poor. Several marine mammal and seabird populations have undergone major changes in abundance. Patterns of change for marine birds has varied among species, locations, and decades over the past 20–30 years. Changes in many bird and mammal populations are most likely related to prey abundance and availability. Changes in oceanographic conditions can affect the geographic distribution and availability of species. One of the more important anthropogenic influences on the Bering Sea ecosystem is commercial fishing.

Forces of Change

Observations and historical analyses supported by NOAA and NSF over the last six years show that the Bering Sea ecosystem is influenced by hemispheric processes that many believe explain recent biotic declines. Observed changes in biota have also been linked with a long history of natural resource exploitation that has spanned two centuries but that has increased dramatically within the last few decades. There is rising evidence of increased loading of pollutants being transported to and sequestered in Arctic oceanic, atmospheric, and terrestrial environments and biota. Alterations of the ocean floor from industrial fishing and changes in terrestrial habitats caused by development activities have also occurred and cannot be excluded as factors in these declines. The natural changes and human influences are likely altering the biocomplexity of the Bering Sea in ways not yet understood. Quantifying the relative importance of natural and human-induced variations in explaining upper-trophic-level ecosystem change is a key management issue for the Bering Sea. The cause of biotic fluctuations, while still unknown, is likely a reflection of natural, climate-related, and other human-induced pressures.

Oceanographic and Atmospheric Influences

The Bering Sea responds to two dominant climate patterns in the region: the Pacific Decadal Oscillation (PDO) and the Arctic Oscillation (AO). The PDO has a 40- to 50-year cycle with principal impact on the southern Bering Sea. This was reflected in lower sea surface temperatures in the North Pacific from 1925 to 1947 and from 1977 to 1998, with reverse conditions occurring in 1899–1924 and 1948–1976. The Arctic Oscillation is associated with the spin-up of the polar vortex and has influence from the sea surface to the stratosphere and from the Arctic to mid-latitudes.

The highly varying sea ice cover of the Bering Sea has a profound influence on the physical and biological ocean environment. Sea ice in its most extensive years arrives in January and remains to May, coincident with negative values of the PDO (for example, in the early 1970s there was extensive winter ice cover before the 1977 shift in the PDO and, to some extent, the AO). The late 1970s and 1980 were warmer years with reduced ice cover. In the 1990s winter ice has again become more common after a 1989 shift in the AO, although not to the extent observed in the early 1970s. A key Arctic change that impacts the Bering Sea and Alaska is a shift toward higher temperatures in April.

Resource Extraction

The Bering Sea ecosystem has been impacted by significant human activity. Many believe that the ecosystem has been damaged as a result of these impacts. These beliefs are based on (1) significant increases in levels of human activity, especially commercial fishing, since the 1960s, and (2) unexpected and unexplained changes in important components of the ecosystem (for example, some pinnipeds and seabirds). The removal of biomass from the Bering Sea has been very large (for example, more that a million tons of pollock per year plus large landings of salmon, crab, and other commercial species). Biomass removal of this magnitude will likely cause both direct and indirect effects on many other species within the ecosystem, including predators, competitors, and prey, as well as change in the proportions of various species within the ecosystem.

Extraction of arsenic, lead, zinc, and oil within the Bering Sea region may also be contributing to the loadings of contaminants now increasingly found within Bering Sea resources. Local sources could be combining with long-range transport of contaminants to play an important role in the health and distribution of biological resources as well as humans living in the region.

Contaminants

In 1998 the Arctic Monitoring and Assessment Program (AMAP), under the Arctic Council, published *The AMAP Assessment Report: Arctic Pollution Issues*. The principal conclusions in this report were that in comparison with most other areas of the world, the Arctic remains a relatively clean environment. However, characteristics of the Arctic environment place Arctic ecosystems at risk:

- The Arctic is a focus for major atmospheric, riverine, and marine pathways, resulting in long-range transport of contaminants to and within the Arctic, where it enters the food web and biomagnifies.
- Low temperatures, extreme seasonal variations in light, and lack of nutrients are some of the physical and chemical characteristics that cause environmental stress to organisms, limit productivity of Arctic ecosystems, and make them potentially more vulnerable to environmental contaminants.
- Several groups of people in the Arctic are highly exposed to environmental contaminants. Persistent contaminants, derived from long-range transport and local sources, accumulate in animals that are used as traditional foods.
- The combination of long-range transport processes, climatic conditions, and physical, chemical and biological properties results in the accumulation of some contaminants in traditional subsistence foods at levels higher than found outside of the Arctic.

Habitat Alteration

Habitat is critical to all living organisms, whether fish, invertebrates, mammals, birds, or primary producers. Habitat characteristics influence survival, growth, and reproduction. Habitat encompasses the physical, chemical, and biological environment within which an organism lives. At different life stages, habitat requirements may differ significantly for a particular species at birth or spawning, during early life stages, and as an adult. Thus, to understanding the habitat requirements for a particular species requires a significant understanding of its life history characteristics. Unfortunately our understanding of the life history and habitat requirements for most species depending on Bering Sea ecosystems is limited at best, making it a significant challenge to understand the ramifications of activities causing habitat alteration within watersheds, wetlands, coastal regions, and the domains of the Bering Sea.

2.2.4 Bering Sea Research Plan

Interagency integrated Bering Sea research will be implemented in stages. Ongoing research programs will continue to gather important information and may benefit from the research recommendations provided below, which outline research topics of particular importance. Concurrent with ongoing research, interagency efforts to develop an integrated research strategy will begin and run concurrently. Both efforts will revolve around four questions central to ensuring future integration:

- What array of factors (stressors or forcing functions) are influencing change in the Bering Sea, over what time scales and spatial characteristics?
- How are these factors (anthropogenic and natural) interacting to effect change on priority components and processes of Bering Sea ecosystems?
- What feedback mechanisms are operating within the Bering Sea systems that will impact the course of change?
- What and where is change most likely to occur within Bering Sea ecosystems, given alternative scenarios of natural forces and human influences?

The relative importance of natural cycles and human factors in explaining variability in abundance in the Bering Sea is a key management issue. In addition to perturbations created by human activities, environmental factors are seldom stable and are subject to large-scale fluctuations. It is clear that the production of new organic matter, which provides the basis for exploitable fish populations and all other higher-trophic-level animals, is greatly affected by both human actions and environmental factors. Questions remain, however, concerning the ecosystem dynamics of the vast Bering Sea shelf that supports this high productivity. An integrated assessment for the Bering Sea must include questions that investigate the interplay of human and natural processes.

Research Recommendations

To promote integrated interpretations of data, studies in general should be collaborative and multi-disciplinary and should include standard physical and chemical measures as well as a suite of biological measures. Biological measures recommended include primary production, zooplankton biomass and production, zooplankton grazing, grazing by larval and juvenile fishes and the abundance of forage species, and the diets of marine birds and mammals. Specific ongoing research activities recommended include the following:

1. Maintain long-term time series data collection important for integrating and indicating ecosystem change in the eastern Bering Sea. These include:

- Four biophysical moorings maintained by the National Oceanic and Atmospheric Administration (NOAA) to collect vital information on winds, sea ice, water column structure, currents, nutrients, and chlorophyll concentrations across the eastern shelf.
- National Marine Fisheries Service (NMFS) data on northern fur seal pup production and diet samples in the Pribilof Islands and Bogoslof Island.
- NMFS surveys of Steller sea lions in the Aleutian Islands and Bering Sea.
- U.S. Fish and Wildlife Service (UFWS) surveys of seabird population dynamics and diet samples from colonies around the Bering Sea and Pribilof Islands.

2. Conduct comprehensive research on the connections between climate change and ecosystem function to evaluate and predict the effects of climate change on the structure and function of biotic communities in the eastern Bering Sea, asking questions such as:

- What is the influence of the timing and magnitude of spring primary production on the characteristics and ecological relationships within the biotic community? How has summertime warming of waters over the shelf during the past three decades impacted or created a northward shift in ecosystem properties required for successful pollock production?

- How have changes in the timing of the spring bloom altered the transfer of energy from phytoplankton to zooplankton, and what are the implications for the food web?
- What similarities and differences in physical properties exist between the southeastern and northeastern Bering Sea now, and how has the southeastern Bering Sea changed since the region was evaluated under PROBES?
- How does wind stress and heating of the upper mixed layer during summer influence summertime primary production? How does this summertime production influence zooplankton biomass and lipid content (food value) in the upper water column? How does zooplankton abundance and quality affect the condition of small forage fish in late summer and the survival of juvenile fish during the following winter?

3. Conduct studies to evaluate the effect of spring and summertime cross-shelf flux in determining ecosystem function and trophic transfer of energy to apex predators. A key question to ask is:

- What is the influence of the interannual variation of on-shelf flow of nutrient- and zooplankton-rich slope water on new production and zooplankton populations on the outer shelf?

4. Evaluate how decreased cross-shelf flux may lead to decreased production in zooplankton for planktivorous birds, and in small fishes for piscivorous birds and mammals. Hypotheses to evaluate include:

- On-shelf transport of slope water advects oceanic copepods onto the shelf and supplies nutrients that enhance new production, which alters production and supports the zooplankton on which forage fish feed.
- Increases in forage fish would in turn influence seabird and fur seal foraging success on the Pribilof Islands by virtue of variability in the magnitude and pathways of on-shelf flow, with enhanced reproductive success associated with moderate to strong on-shelf flow and lower success during weak on-shelf flow. This enhanced reproductive success may result from bottom-up processes caused by the introduction of nutrient- and zooplankton-rich slope waters.
- On-shelf flow and tides create areas of convergence at the shelf edge, where birds feed on small fish attracted to concentrations of neuston.

In addition, based on research recommendations made by the Bering Sea research community, the following four categories of research are recommended.

Monitoring

- Maintain and enhance time series from moored biophysical buoys and discrete shipboard samples across the southeast Bering Sea, Bering Strait, Aleutian North Slope current, and Unimak Pass. This includes weather, temperature, salinity, primary production, and zooplankton sampling.
- Strengthen existing surveys of groundfish, crabs, birds, and mammals and add information on benthos, forage fish, and predator species.
- Archive, in a geographically registered format, all available remote sensing for sea ice, SST, and ocean color in near-real-time.

Retrospective Analyses

- Characterize the space/time structure of climate forcing.
- Establish baseline conditions, including variability, of key physical and biological indicators.
- Survey archaeological middens and sediment cores to look at species abundance and change.
- Evaluate the relative impacts of anthropogenic versus natural factors on patterns of biological change.
- Produce a unified database for the Bering Sea.

Modeling

- Use downscaling techniques to relate the results from global general circulation models to changes forcing the Bering Sea.
- Implement high-resolution physical/biological models that include zooplankton dynamics and individual-based models for nodal and commercially valuable species.
- Conduct statistical and explicit model building to investigate changes in trophic-level structure in response to physical changes.
- Model the effects of alternate natural resource management strategies.

Process Studies

- Examine mechanisms of nutrient replenishment onto the continental shelves.
- Determine the role of the physical environment on the critical life stages of key species.

- Evaluate the cause of changes in trophic interactions.
- Use telemetry to define marine mammal and apex predator feeding areas.
- Evaluate experimental management strategies, including fish removals, on local prey abundance and distribution.

2.2.5 Strategic Research for Integrated Assessments

While continued research is critical to better elucidate the mechanisms and processes of change in the Bering Sea as well as the Arctic, ensuring that the essential scientific questions are well directed and investigated to answer key management concerns is a challenge. To meet the needs for an integrated assessment in the Bering Sea, Federal partners are developing a strategic plan to clarify and connect scientific questions to management needs as well as identify key goals.

Since natural ecosystems, science, and management are all dynamic systems, an iterative process will be established to ensure linkages among decisions that need to be made, new knowledge that will be obtained, and ongoing changes that will influence outcomes. The importance of this process was reflected in 1996 when the Polar Research Board of the National Research Council published a study on the Bering Sea ecosystem, which included a set of recommendations emphasizing the vital link between science and management including:

- Adopting a broad ecosystem perspective for scientific research and resource management;
- Adopting an adaptive management approach for Bering Sea resources;
- Evaluating how well management and research institutions are able to address emerging problems;
- Providing appropriate management solutions; and
- Developing research programs to help policy makers solve short- and long-term ecological problems.

Building an Iterative Bering Sea Research Strategy

The Bering Sea Research Strategy will include four key elements. Each element will be linked to the others through clearly defined feedback loops within an iterative framework. They include the following:

- Unifying vision and goals: Through dialogue among parties interested in the Bering Sea, identify key concerns, common interests, and desired outcomes of management actions and agree on key ecological and human values of concern. This will provide the necessary framework around which to structure integrated assessments and help ensure scientific advances and adaptive and predictive management.
- Conceptual synthesis: Assess and integrate available information within an interactive, iterative, interdisciplinary process to transform current data into a set of conceptual models characterizing predictive testable hypotheses about the influences of multiple natural and human stressors on ecological and human systems. For best success, the process will generate multiple working hypotheses about potential causal relationships.
- Research planning: Based on the conceptual synthesis, define the essential research needs and a research plan designed to produce integrated research and assessments. The expected outcome is a proposed research program among Federal agencies and others that capitalizes on existing research efforts and defines new research within a structured framework for integrating research activity and interpreting results.
- Research implementation: Initiate new research designed to test potential causal relationships among natural and human influences impacting key values of concern. New findings would be used to refine the conceptual links established during conceptual syntheses to derive new knowledge about processes, effects, trends, and relationships, as well as to assess the influence of management decisions on ecosystem change.

Each of these elements is iterative. Successful implementation results in feedback among elements to create an interplay between research findings and environmental observations, desired management outcomes, goal setting, and new insights that lead to new cutting edge research.

Implementation of the Strategy

In April 2001 the Interagency Arctic Research Policy Committee authorized the establishment of an Interagency Working Group (IWG) for the Bering Sea. The IWG was charged to develop a coordinated approach to implementing an integrated assessment for a sustainable Bering Sea. Over the next year the IWG will organize and develop a plan for implementing an assessment.

Questions managers and scientists answer during early dialogues.

Managers answer

- What are the ecological and human values of concern and what outcomes are desired?
- What are the management goals and decisions needed and how will an integrated assessment help?
- At what scale must it be addressed?
- What are the policy considerations?
- What precedents have been set through previous decisions?
- What is the context of this assessment?
- What resources are available?
- What level of uncertainty is acceptable?

Scientists define

- What are the spatial and temporal boundaries of the problem?
- What information is already available, compared to what is needed?
- What practicalities constrain data collection?
- Can decisions be based on assessments of a small area evaluated in depth or a large-scale assessment at lesser detail?
- What are the critical ecological endpoints and key ecosystem and receptor characteristics?
- What are the likelihood and duration of system recovery?
- What is the nature of the problem now, compared to the past and the future?
- What are the current state of knowledge, the available data, and the type of analyses?
- What are the constraints?

Defining a Vision and Goals

Federal efforts to establish a vision began with dialogue among interested parties in the Bering Sea region between 1998 and 2000. Interviews were conducted with Federal and state officials, and commercial and environmental interests, among others. The results from these interviews generated several common themes:

- Current management regimes and institutional structures need to be enhanced to achieve a coordinated ecosystem-wide approach to management.
- A common vision and agreement on a desired future condition for the Bering Sea is needed. The vision should be as specific as possible to guide managers.
- A common understanding of the threats to the Bering Sea ecosystem is essential. Given insufficient science, there must be agreement on scientific priorities to answer fundamental questions about what is happening in the ecosystem.

As follow-up to these findings, the U.S. Environmental Protection Agency (EPA) is serving as a catalyst for organizing a Bering Sea Summit to be held in Anchorage in April 2002 through implementation of the Bering Sea Regional Geographic Initiative (RGI). EPA is serving as a lead Federal organizer based on EPA's broad mandate (protect human health and safeguard the natural environment), the absence of specific resource management responsibilities in the Bering Sea (a "disinterested" Federal partner), and substantial experience with community-based environmental protection and predictive risk assessment. EPA is working in partnership with Federal and state agencies, tribes, and environmental and industry groups, among others, to convene the Summit, which is being designed to foster dialogue among the diverse organizations, management agencies, and communities in the Bering Sea region. The expected outcome is a multi-party strategic vision for protecting, investigating, and utilizing Bering Sea resources in a sustainable way. A principal goal for the Summit is to develop an implementation strategy with local, regional, national, and international components.

Conceptual Synthesis and Research Planning

A Federal effort for promoting conceptual synthesis and research planning for a Bering Sea integrated assessment will be developed based in part on the results of the Bering Sea Summit 2002 and efforts by a newly formed Federal Bering Sea Interagency Working Group, a partnership among Federal agencies and other interagency management organizations including efforts under SEARCH. National efforts will be linked to international activities, including work by the Arctic Council and the United Nations Environmental Programme (UNEP) Global International Waters Assessment.

Strategy development will progress concurrently with ongoing research efforts. The outcome over the next several years will be the completion of goal setting, conceptual synthesis, and a first-stage integrated assessment and research plan.

Early conceptual synthesis will be based on available information on all aspects of the system of concern (for example, ecosystem characteristics, natural and anthropogenic forces influencing the ecosystem, exposure to potential stressors, and observed changes). This initial synthesis will provide the basis for developing preliminary conceptual models, which generally lead scientists to seek other types of data and information not previously recognized as needed. The conceptual models include written descriptions and visual representations of predicted relationships among ecological values and factors potentially influencing them. They are valuable as learning and communication tools, are easily modified in response to new information, highlight what is known and not known, and provide a framework for prediction.

A research plan will be generated from a careful evaluation of conceptual synthesis. Planning normally results in a delineation of an integrated assessment design, data needs, and measures and methods for conducting analyses for an integrated assessment. This is directly linked to conceptual models and includes the rationale for selecting priorities.

Strategy development, integrated assessments, and research planning and implementation will remain an iterative process that can be used, modified, and used again as new understanding and new questions emerge for the Bering Sea.

2.3 Arctic Health

Arctic health research encompasses two major subdivisions: environmental health and public health. The former includes the topics of environmental contaminants, the effects of climate change (Arctic Climate Impact Assessment), and radioactive nuclides. The latter includes infectious diseases, occupational injuries, chronic diseases, behavior, delivery of health care, capacity building, and the elimination of health disparities between the Alaska Native and non-Native populations.

2.3.1 Environmental Health

The occurrence of artificial radionuclides and pesticides in the environment and biota has been documented for over 30 years and has since remained a matter of scientific and public concern. This concern was heightened considerably in 1990s, first by an increased awareness of the unexpectedly high levels of contamination in the Arctic that led to the adoption of the Arctic Environmental Protection Strategy in 1991 by the eight Arctic countries, including the U.S. Soon thereafter, in 1992, there was a major disclosure of widespread dumping of nuclear reactors and wastes into the Arctic and northwest Pacific Ocean by the former Soviet Union. Later in the same year, it was reported that 15,000 pounds of soil contaminated with radioactive material, including fallout material collected from an atom bomb test in Nevada, was buried 30 years ago near Cape Thompson, Alaska.

In recent years it has become increasingly clear that many contaminants found in the Arctic, particularly certain pesticides and industrial chemicals, originate in areas far removed from the Arctic but that those chemicals tend to persist and accumulate in the Arctic environment and food chains, including human residents. Because of their reliance on local fauna for subsistence and preserving their cultural heritage, Alaska Natives have become increasingly apprehensive about the quality of their traditional food resources and the health of Arctic ecosystems. The paucity of scientific data on the nature and severity of environmental contamination on human health and renewable biological resources has prompted the Interagency Arctic Research Policy Committee (IARPC) to begin planning for a focused, interagency research program emphasizing health concerns in the U.S. Arctic, including its environmental aspects.

Radionuclides in the Environment and Subsistence Foods

Global fallout from atmospheric testing of thermonuclear devices is the principal environmental source of artificial radionuclides in the U.S. Arctic. Even though the ground deposition of fallout radionuclides is quite pervasive, its distribution is greatly influenced by patterns of mean annual precipitation. Thus, portions of southeastern Alaska (which is not part of the U.S. Arctic) are estimated to have orders-of-magnitude higher activity of the radionuclide cesium-137 than, for example, the North Slope of Alaska. However, proportionately high consumption of caribou, freshwater fish, berries, bowhead whales, and other subsistence foods in the U.S. Arctic is often considered an important means of radionuclide exposure to humans.

The National Oceanic and Atmospheric Administration (NOAA) in collaboration with the Los Alamos National Laboratory (LANL) have measured activities of anthropogenic and naturally occurring radionuclides in coastal sediments and a number of faunal species that are used for subsistence in the U.S. Arctic. The study, supported in part by the Office of Naval Research (ONR), showed that typical yearly consumption of caribou meat by an adult resident of Barrow added a very small amount (0.0045 mSv) to the average effective dose equivalent of ionizing radiation. This value should be viewed in relation to the average radiation dose to humans from natural sources (3.0 mSv)*, such as exposure to radon and cosmic radiation, and other anthropogenic sources (0.6 mSv), such as consumer goods, medical x-rays, and air travel. Subsistence foods derived from marine food chains accounted for a much smaller, and perhaps negligible, dose.

It is generally concluded that human health and ecological risks from projected releases from nuclear waste dump sites in the Arctic are likely to be inconsequential. However, a summary of ONR-funded studies has noted the need to consider other known sources and potential transport pathways for radionuclides in the Arctic. For example, major Siberian rivers may potentially contribute significant amounts of radionuclides from nuclear power plants and weapons factories in Russia, amounts that could pose as much or greater risks than the materials dumped directly into the Arctic Ocean.

Contaminants in Species of Subsistence, Commercial, and Aesthetic Value

The presence of persistent organic contaminants in Arctic wildlife has been documented for more than 30 years. For example, specimens of gyrfalcons collected from the Seward Peninsula in 1970 had highly variable levels of DDE (a metabolite of DDT that is most often related to adverse biological effects in the field) and PCBs in their tissues, but in some cases the levels exceeded 200 ppm. The peregrine falcon in the Amchitka region was considered a highly vulnerable species as early as 1970, when DDE residue in members of that population were associated with thinning of eggshells. Since then, relatively high levels of these and other contaminants, such as hexachlorocyclohexane (HCH), have been reported in liver and fatty tissues of many species of fish and wildlife, including marine mammals. Some marine mammals, such as the Pacific walrus, have relatively high concentrations of potentially toxic metals in their tissues.

Both NOAA and the U.S. Fish and Wildlife Service (FWS) have ongoing programs to determine the contaminant levels and their biological effects in protected and threatened species under the Marine Mammals Protection Act and the Endangered Species Act. Nearly all marine mammal tissue collected for contaminant analyses in these programs were from animals harvested by Alaska Natives, often in consultation with statewide Native organizations and cooperatives, such as the Alaska Eskimo Walrus Commission. This results in a broad geographic distribution of samples and cooperative efforts with subsistence hunters. Examples of contaminant-related studies on selected Arctic faunal species are noted below.

The polar bear biomonitoring program of the FWS 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. Levels of PCBs in adult male polar bears from Alaska analyzed to date are relatively low compared to the high levels found in polar bears in eastern Hudson Bay, Canada, and Norway. Average levels of HCH in Alaskan bears are among the highest reported in the Arctic. Little is known, however, about the potential impacts that these relatively high HCH levels may have on the health of polar bears, human consumers, and the Arctic ecosystem. To date, samples have been obtained from approximately 28 bears. Sampling for this project will continue through FY 02, when a final report will be prepared. Polar bears have been identified as a sentinel species under the Arctic Monitoring and Assessment Program (AMAP) 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.

Tissue samples have also been collected for long-term storage by the Alaskan Marine Mammal Tissue Archival Project (AMMTAP) for use in

* Sievert (Sv) is a measure of absorbed radiation dose per unit mass, often expressed as millisievert (mSv). A 1-mSv yearly dose is often equated to an increased risk of cancer in one person out of 20,000, and a dose of 0.01 mSv is generally considered negligible in terms of potential risk to individuals.

future analyses as analytical techniques improve and for assisting in the development of spatial and temporal trends of contaminant levels in the Arctic. AMMTAP is a cooperative interagency program supported by the U.S. Geological Survey (USGS), NOAA, and the National Institute of Standards and Technology (NIST). 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 have been used for inter-laboratory comparisons, as well as for physiological studies on contaminant accumulation and effects on polar bears.

The FWS studies of organochlorine pesticides and industrial chemicals, hydrocarbons, and heavy metals in walrus tissues over the past two decades have shown only extremely low levels of organic contaminants in walrus blubber collected from coastal and offshore sites in the Bering Sea. However, these studies have documented high levels of cadmium in the kidney and liver tissues of walrus in the Bering and Chukchi Seas. In several instances, cadmium concentrations in kidney tissues were higher than the level thought to interfere with organ function in some mammals. 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). Histopathological examination of samples from 170 animals collected from Gambell and Diomede indicated that the metals present in the kidneys and livers did not appear to cause injury to the tissues. Data on heavy metal contamination in the walrus tissues are being synthesized for publication. Although data are few and from disparate sources, high levels of cadmium in bowhead whale kidney tissues have also been reported.

Concentrations of persistent organic pollutants (POPs) in blubber, and heavy metals in liver and kidney, have been determined for two stocks of Alaskan Arctic beluga whales (Beaufort Sea and Eastern Chukchi Sea stocks) from the Bering Sea population and for beluga whales from the sub-Arctic Cook Inlet population. Generally the sub-Arctic Cook Inlet animals appear to be substantially different from the two Alaskan Arctic stocks, having lower concentrations of POPs and metals (except for copper). The two Alaskan Arctic stocks have concentrations of POPs that are similar to levels reported for beluga populations across the North American Arctic; however, certain metal concentrations are substantially different. Hepatic total mercury concentrations are higher and cadmium concentrations are lower in these Alaskan belugas than what has been reported for belugas farther east in the Canadian Arctic.

In recent years, FWS has made organochlorine and heavy metals measurements in livers and kidneys from 66 sea otters that were collected in coastal waters throughout Alaska. Preliminary results have identified several otters with low levels of PCBs, beta-BHC, pp-DDE, and dieldrin. Given a rather sparse sampling coverage, the source of these contaminants is unclear, and the physiological effects of contaminants on sea otters can only be speculated.

Mercury is a naturally occurring element that is present in rocks and ores. It is also released into the atmosphere by degassing of the earth's crust and oceans in large amounts; an approximately equal amount is released by way of human activities, such as burning of household and industrial wastes and waste discharge from certain industries. Its presence in food chains, particularly large predator fish such as sharks, swordfish, and large species of tuna, has been well documented. In recent years, the presence of mercury in coastal and freshwater fish has become a matter of great concern, prompting many states to issue fish consumption advisories. Although extensive data are available on mercury concentration in fish tissues in the Arctic, data from the U.S. Arctic are scant. Few data have recently been obtained on total mercury and methylmercury in the muscle and liver tissues and eggs of Pacific salmon species from the Yukon, Kuskokwim, Nugashak, and Kvichak Rivers. The higher concentration of mercury in chinook salmon could be because of its longer life span in ocean waters and its higher trophic level. Analysis of these data continues. It is not clear whether mercury in natal streams and lakes is further recycled by freshwater fauna or whether there is further bioaccumulation through freshwater and terrestrial food chains.

Comparisons of hepatic total mercury concentrations in beluga whales across the North American Arctic indicate that the highest concentrations may be found in the Beaufort Sea and Chukchi Sea stocks of the Alaska Bering Sea population (averaging around 50 mg/kg ww); these levels are within the range reported for the St. Lawrence Estuary population. Although levels of total mercury in the Cook Inlet animals have been found to be much lower (averaging 5 mg/kg ww) than concentrations in the other Alaskan belugas, the hepatic concentrations of methyl mercury are similar among all three Alaskan groups (0.3–2 mg/kg ww).

FWS has determined concentrations of organochlorine pesticides, including toxaphene, in burbot collected from three National Wildlife Refuges in interior Alaska and the Tanana River near Fairbanks, Alaska. In general, there were greater contaminant concentrations from sites below Fairbanks and within the Yukon Flats Refuge than at Tetlin and Kanuti refuges. There were greater concentrations of DDT and its metabolites at Fairbanks, probably reflecting the historical use of that pesticide within the city of Fairbanks and at nearby military bases. Concentrations of DDT and metabolites from Fairbanks were up to two orders of magnitude greater than in burbot from five studies in Canada. The range of PCB concentrations were similar to those from four of six Canadian studies and were generally less than laboratory-derived effects values. Toxaphene concentrations were generally low. Because this was an initial assessment and sample sizes were low, further studies would illuminate whether the concentrations found at Fairbanks and Yukon Flats are of concern to fish and wildlife resources. This report will be finalized in FY 01.

Personnel from the Alaska Maritime NWR collected bald eagle carcasses from Adak Island between 1994 and 1998. Tissues were collected for contaminants analysis, and data from the 1994–1996 samples were reported in a technical report entitled "Contaminant residues in bald eagles (*Heliaeetus leucocephalus*) from Adak Island, Alaska" (WAES-TR-97-02). Additional funding in FY 99 allowed for analysis of the remaining samples collected after 1996. Data from all birds have been combined, compared, and drafted into a manuscript, which will be submitted to a peer-reviewed scientific journal in FY 01.

The number of red-throated loons breeding in Alaska declined 53% from 1977 to 1993. Aerial population surveys in Alaska have produced rigorous trend data for red-throated loons, but despite this, only fragmentary knowledge exists about the natural history of this species. In 1998, FWS identified red-throated loons as a "species at risk" in Alaska and identified four specific data needs: demographic parameters, distribution among wintering areas and links to breeding areas, subsistence bycatch in fishing nets, and exposure to contaminants. This work will continue during FY 01.

The Agency for Toxic Substances and Disease Registry (ATSDR) has initiated the Alaska Native Subsistence and Dietary Contaminants Program to study contaminants in the environment, subsistence resources, and people in Alaska Native populations. Working with other Federal, tribal, state, and local governments, ATSDR will focus on research and public health activities necessary to empower Alaska subsistence diet users to make informed dietary decisions while incorporating traditional and western scientific information. The primary goals and activities for this program are to:

- Identify Alaska Native traditional subsistence diets and characterize human exposure to dietary contaminants;
- Characterize and analyze human health risks and nutritional benefits of the Alaska Native subsistence lifestyle;
- Evaluate human health effects in the Alaska Native population that may be associated with contaminants found to be part of the subsistence lifestyle;
- In partnership with the affected Alaska Native communities, provide communication and education to assist in culturally appropriate decisions on risks and benefits of the diet; and
- Develop and implement interventions that are culturally appropriate and based on the defined needs of the Alaska Native population.

Ecosystems at Risk

The U.S. Arctic ecosystems are quite varied in their complexity and biological productivity. In the marine environment, they include some the world's most productive, for example, the southeastern Bering Sea and Chirikov Basin ecosystems, which support important commercial fisheries and an extraordinary feeding habitat for wildlife. In contrast, oceanic waters of the Canadian Basin have low biological productivity, although they may contain faunal assemblages that are unique, consisting of species of both the Atlantic and Pacific Oceans, or species that have survived through the ages (certain sponges and bryozoans). On land the U.S. Arctic is dominated by wet and alpine tundra, both of which are critical to thousands of migratory birds, caribou, and other species. The spruce–poplar forests are extensive and highly productive, but they occupy a relatively small portion of the U.S. Arctic lands.

Irrespective of their location, all Arctic ecosystems are highly cyclic (because of large seasonal changes in light levels, nutrient input, and temperature) and have low species diversity. On an annual or decadal cycle, they are also affected by weather and climatic changes, such as those caused by the presence, intensity, and movement of the Aleutian Low Pressure System in the northern North Pacific Ocean. In the marine environment, the location of the ice edge, as well as continental shelf-slope exchange of materials, is also critically important to both the onset and sustenance of primary productivity and ultimately to food chains culminating in fish and wildlife species, many of which have considerable commercial, subsistence, and aesthetic value.

The structure and dynamics of the U.S. Arctic ecosystems have been studied for nearly 30 years with primary funding support from a number of Federal agencies, such as DOD/ONR, NSF, DOC/NOAA, DOI/MMS and others. Programs such as the Outer Continental Shelf Environmental Assessment Program, 1975–1992, provided a strong foundation for multidisciplinary scientific studies of coastal and continental shelf waters around Alaska. Many concurrent and follow-up studies, such as PROBES, ISHTAR, and SHEBA funded by the National Science Foundation and the Fisheries–Oceanography Cooperative Investigations (FOCI) funded by NOAA, have greatly advanced the scientific database and understanding of Arctic ecosystems. New studies and programs, as well as budget initiatives, will continue to shed new light on ecosystem dynamics, particularly in relation to climatic changes, shelf-slope exchange of energy and materials, and factors controlling the deposition and environmental fate of contaminants.

Both NOAA and the Minerals Management Service (MMS), U.S. Department of the Interior are continuing congressionally mandated studies of the Arctic environment and resources, notably those relating to fisheries and wildlife. In the case of MMS, the primary purpose is assessment of impacts from oil and gas activities along the North Slope of Alaska. The USGS will be conducting studies over the next five years (2001–2005) to examine the impacts of climatic change and atmospheric transport of contaminants in the Yukon River basin. The studies will be designed to characterize water quality parameters, identify contaminant sources, and assess the effects of contaminants on regional biota and ecosystems.

There are sixteen National Wildlife Refuges in Alaska, encompassing approximately 92,000,000 acres. 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, training grounds, and historic battlefields. After these operations ceased, sites were often abandoned. At other sites, hazardous materials were spilled with no subsequent cleanup. The total number of formerly used defense sites (FUDS) in Alaska is 648. Most of them have undergone preliminary assessment for the nature of contamination and clean-up needs. A number of sites are currently scheduled for remediation by the U.S. Army Corps of Engineers, the Department of the Navy, or the Department of the Air Force. The FWS has also conducted numerous studies on contamination in refuges within the Arctic, establishing baseline conditions or investigating impacts on trust species. These investigations are needed to determine significant changes through time; the need will continue as new issues are identified.

EPA has been evaluating the Polar Sunrise Effect on atmospheric mercury in Barrow, Alaska, since 1999. Research has confirmed that mercury is depleted in the atmosphere during the month following Arctic sunrise. Preliminary results support the hypothesis that mercury is transformed from elemental mercury in the atmosphere to reactive gaseous mercury. Mercury may then become bioavailable in the terrestrial and aquatic environments following Arctic sunrise coincident with onset of the breeding season of Arctic wildlife.

2.3.2 Public Health

Infectious Diseases

The CDC's National Center for Infectious Diseases, Arctic Investigations Program (NCID/AIP), together with Health Canada's Laboratory Centres for Disease Control, Bureau of Infectious Diseases, has initiated an International Circumpolar Surveillance (ICS) system linking existing public health laboratories and facilities in the Arctic to address emerging infectious disease problems. This initiative follows U.S. government interagency recommendations established by the Committee on International Science Engineering and Technology (CISET) and the CDC's Global Health Strategy. In 2002–2006 ICS participant countries will include the U.S., Canada, Greenland/Denmark, Iceland, Norway, and Sweden with planned linkage with public health laboratories in the Barents Sea regions of the Russian Federation. The current focus of ICS is on population-based surveillance of invasive bacterial diseases caused by *Streptococcus pneumoniae, Haemophilus influenzae, Neissera meningitidis*, Group A & B *Streptococcus* in aboriginal and non-aboriginal peoples residing in Arctic regions. Outcomes will include descriptions of diseases rates, epidemiologic factors, bacterial agent characteristics including antimicrobial susceptibility profiles, and collaborative approaches for prevention and control. Extending the ICS to include other infectious disease problems of Arctic countries is planned. Tuberculosis, particularly multi-drug-resistant tuberculosis, is once again becoming a threat to human health in many Arctic communities. Tuberculosis is expected to be included in the ICS in 2002–2006. NCID/AIP will continue research focusing on the prevention and control of infectious disease problems in the U.S. Arctic. These include viral infections caused by respiratory syncytial virus; hepatitis A, B, and C; and diseases caused by bacteria now commonly resistant to antibiotics (*Streptococcus pneumoniae, Staphylococcus aureus,* and *Helicobacter pylori*). Together with the Alaska Native Tribal Health Consortium, NCID/AIP will conduct projects to evaluate the immunogenicity of a new 7-valent pneumococcal conjugate vaccine in Alaska Native children and study the effectiveness of the current 23-valent pneumococcal vaccine in Alaska Native elders. *Helicobacter pylori* infection is commonly associated with gastric ulcers. Recent studies conducted by CDC's National Center for Chronic Disease Prevention and Health Promotion's Division of Nutrition and Physical Activity, the Yukon Kuskokwim Delta Health Corporation, the State of Alaska Division of Public Health, and NCID/AIP have shown an association between *Helicobacter pylori* infection and iron deficiency anemia in Alaska Natives. Additional studies are needed to assess the validity of this association, as well as the development and evaluation of effective prevention and control strategies.

Occupational Injuries

The CDC's National Institute for Occupational Safety and Health, Division of Safety Research Alaska Field Station (NIOSH/DSR/AFS), in collaboration with the Indian Health Service, the State of Alaska, the Alaska Native Tribal Health Consortium, and the Alaska Native Health Board, will continue studies on the epidemiology, risk factors, and prevention strategies for occupational injuries in Alaskan communities. The NIOSH/DSR/AFS will continue to coordinate the development of an integrated surveillance system for disease and injury in the Arctic, linking the existing NCID/AIP-initiated International Circumpolar Surveillance (ICS) system for infectious diseases with nascent systems for injuries and birth defects, eventually monitoring chronic diseases and malignancies, behavioral risk factors, and a broader spectrum of injury events. It will provide a more seamless picture of the current health status and trends by partnering with the Alaska Division of Public Health, the Alaska Native Medical Center, and the Alaska Native Health Board's Epidemiology Center.

The NIOSH/DSR Alaska Field Station is mounting two other initiatives in Arctic research. Surveillance for work-related injuries has identified the commercial fishing industry as contributing high numbers of fatal and severe non-fatal injuries. A new project will address the problems of vessel stability in the fishing fleet, the hazards posed by machinery and fishing equipment, and the physical design and layout of fishing vessels and will develop feasible interventions to prevent injuries among fishermen. Vessel stability and the deck environment surrounding the deployment and retrieval systems of fishing equipment (including the use of cranes, winches, lines, nets, crab pots, and crab pot launchers) will be examined from a mechanical and safety engineering perspective. Through effective industry focus groups and application and promotion of new technological innovations and interventions, the number of fatal and non-fatal injuries in this industry should decrease.

Alaska experienced an overall downward trend in occupational fatalities since 1990 (from 78 in 1990 to 42 in 1999, a decrease of 46%), but occupational aviation fatalities continue to be a problem. In response the U.S. Congress supported a Federal initiative to reduce aviation-related injuries and fatalities and to promote aviation safety in cooperation with the air transportation industry in Alaska. The initiative is a three-year partnership of four Federal agencies: the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), the National Weather Service (NWS), and the National Institute for Occupational Safety and Health (NIOSH). The goal is to reduce the number of aircraft crashes and injuries in Alaska by at least 50% by the end of 2009.

Chronic Diseases

The CDC's National Center for Environmental Health, Division of Environmental Hazards and Health Effects (NCEH/EHH), will continue studies on the relationship between exposure to environmental organochlorines and development of breast cancer in Alaska Native women. This will be assessed by collecting biological samples from women undergoing breast biopsy or surgery at the Alaska Native Medical Center and analyzing these samples for endocrine-disrupting chemicals (for example, DDE, PCB, and PBB). Interviews are being conducted to identify potentially confounding risk factors for breast cancer (such as parity and family history) and to collect dietary information.

The Alaska Native Tumor Registry (ANTR) was initiated in 1974 in collaboration with the National Cancer Institute (NCI), NIH, and the Centers for Disease Control and Prevention (CDC). From the outset of registry efforts, the procedures and policies followed were those of the NCI Surveillance, Epidemiology and End Results (SEER) Program. The registry takes an active role in management and follow-up care of cancer patients. 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.

ANTR completed the "Alaska Native Cancer Survival Report," and several scientific articles have been published based on ANTR data. The registry will provide an update of cancer incidence for Alaska Natives statewide and by service unit. Discussions are underway with the Army Corp of Engineers and the Air Force to study contaminants at military sites and cancer patterns. Research studies in progress include:

- Serum PCB levels in breast cancer patients and controls;
- Prospective study of breast cancer and organochlorines in serum and fat tissue in the breast;
- *Helicobacter pylori* and cancer and other diseases of the stomach;
- Prevalence of colorectal cancer genes in (formalin fixed) tissue among colorectal cancer patients;
- Familial aggregation of nasopharyngeal cancer; and
- Biomarkers expressed in tumor tissue of Alaska Native breast cancer patients.

The Genetics of Coronary Artery Disease in Alaska Natives (GOCADAN) Study is a five-year project that is focusing on a family study of 1200 individuals comprising 40 families of adults and children over the age of 18, primarily from two villages near Nome, Alaska. This project is a partnership with Norton Sound Health Corporation, a subcontractor to the Indian Health Service, to study the etiology of heart disease in Alaska Natives using the protocol and many investigators from the Strong Heart Study, an NHLBI-funded 12-year study of cardiovascular disease in American Indians. The study will also include a cardiology center at Cornell Medical School, a genetics center at Southwest Foundation for Biomedical Research, a coagulation laboratory at the University of Vermont, a central laboratory at Medlantic Research Institute, and investigators located at the University of Alaska. Examinations began in October 2000. A ten-centiMorgan genetic scan will be used to identify significant linkages between markers and risk factors and disease.

Three projects are being reviewed or have been approved for funding during the coming year. The Age, Gene/Environment Susceptibility (AGES) study is funded from 2001 to 2008 by the National Institute on Aging. NIA is seeking additional funding to expand this study to an existing cohort of approximately 12,000 members to identify genetic and other new risk factors for selected diseases and conditions including atherosclerosis and stroke and to characterize phenotypes for these diseases and conditions, in relation to genetic susceptibility, gene function, and genetic/environmental contributions to disease. Improvement in the measurement of quantitative traits as phenotypes will result from the use of prior longitudinal data and more recent non-invasive imaging techniques. These include calcium scoring of the coronary arteries by computerized tomography (CT) and hippocampal volume by magnetic resonance imaging (MRI).

The second proposed project is an intervention study entitled Stroke Prevention in Alaska. The intervention will focus on dietary counseling of Alaska Natives to modify and reduce fat intake, improve weight control, and increase physical activity. The study will include 600 adults over the age of 24 from four Alaska villages, including two Siberian Yup'ik villages, one central Yup'ik village, and one Inupiaq village. Protocols for data collection will follow those for the Strong Heart Study. Data collection will include dietary assessments, cardiovascular disease risk factors, and ultrasound carotid artery measures, as well as extensive laboratory measures and lifestyle surveys.

The third proposed project is focused on Alaska villages below the Arctic Circle. It will expand, facilitate, and stimulate biomedical research, including multiple components focused on disease surveillance; survey systems for genetic, environmental, and behavioral risk factors; high-throughput genotyping; and cultural/behavioral research.

National Eye Institute (NEI) staff are engaged in discussions with investigators in the Department of Ophthalmology of the Alaska Native Medical Center regarding a proposed epidemiological study of refractive error in Alaskan children, adopting a protocol used successfully in China, Nepal, and Chile under WHO/NEI sponsorship. The Bethel area of Alaska is under consideration. With the increasing significance of refractive error as a public health problem in children, a study in a Native American population would be of high potential interest.

Alcoholism is a long-term, progressive disease that can lead to compromised workplace performance; disrupted families; long-term health complications including cirrhosis, heart disease, and cognitive impairment; and injuries and death from accidents or violence. Research into the causes, prevention, and treatment of alcoholism, including approaches that can serve the far northern environment in particular, is central to reducing the consequences of excessive alcohol use. Research supported by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) in Alaska is aimed at the nature of alcoholism in this population, approaches to treatment, and the impact of public policy on drinking. The research addresses features particular to the Alaskan environment, including the sparse population in a remote landscape with a significant Native American population.

One study is the first comprehensive clinical description of Native Alaskans in treatment for alcohol dependence using a standardized assessment protocol, identical to that used in NIAAA's multi-center Collaborative Study of the Genetics of Alcoholism (COGA), making comparison across different ethnic groups possible. In particular, identification of possible ethnic and cultural differences is likely to have implications for improved treatment outcomes for Native Alaskans.

NIAAA-supported investigators also recently looked at local policy changes in Barrow, Alaska, and their effects on alcohol consumption. During a 33-month period, referenda passed by the citizens at first imposed, then withdrew, and finally re-imposed a total ban on alcohol sales. Research findings indicated significant decreases in emergency room visits (including those for assaults) when alcohol was banned, increases to levels of the pre-ban period when the ban was lifted, and significant declines again when the ban was re-imposed by Barrow voters. The contrasts between periods when the policy was in force and periods when it was suspended makes this a revealing study of the effects of public policy on drinking.

Looking ahead, NIAAA and the National Institute of Child Health and Human Development are preparing to collaborate in studying the role of prenatal alcohol exposure in sudden infant death syndrome (SIDS). Recent findings suggest a strong relationship between alcohol use during pregnancy and SIDS, adding to the established risks of fetal alcohol syndrome and alcohol-related neurodevelopmental disorder. The high incidence of both alcohol problems and SIDS in Alaska lends itself to such research.

Another study is designed to understand how Alaska Natives maintain or achieve sobriety, such as factors that protect individuals from alcohol dependence and facilitate recovery. Spirituality is thought to be a critical element in the recovery process, and investigators will explore its role in promoting resiliency to abusive drinking behaviors.

The National Institute on Aging (NIA) continues to fund the Native Elder Research Center, located within the Division of American Indian and Alaska Native Programs of the Department of Psychiatry, School of Medicine, and University of Colorado Health Sciences Center in Denver. The Center coordinates a research career development program targeted at American Indian (AI) and Alaska Native (AN) investigators, focusing on aging, health, and culture. The Center augments ongoing partnerships with AI/AN communities to ensure 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.

The Alaska Native maternal and newborn blood monitoring program will measure persistent organic pollutants, heavy metals, and micronutrients in the blood of women entering prenatal care and in the umbilical cord blood of their newborn infants.

The program was developed at the request of Alaska Native communities to provide data on human tissue levels of contaminants that are transported to the Arctic from lower latitudes, entering the food chain of subsistence species, and being ingested by rural Alaska Natives pursuing their traditional diet.

The data will be utilized for several purposes:

- It will be used to provide trend data on human tissue levels over time.
- It will allow, over time, for examination of health outcome data, to see whether correlations with contaminant levels exist.
- Combined with a subsistence dietary history in each woman and micronutrient levels, the data will be examined for correlation of subsistence food intake with micronutrient levels and examined for positive health outcomes in women and infants.
- Communities will be able to perform their own risk-benefit assessment and formulate community-specific strategies to reduce exposure and maintain the traditional diet.
- The data will be shared with state and Federal agencies with responsibilities for contaminant risk assessment, and reduction of pollutant release.
- The data will be shared with the other Arctic countries as part of the AMAP protocol.

At present the monitoring program covers approximately 75 villages along the Arctic Ocean and Bering Sea, as well as the Yukon and Kuskokwim Rivers. The monitoring program is funded by the EPA, the Alaska Native Tribal Health Consortium, the CDC National Center for Environmental Health, and the State of Alaska.

Behavioral Aspects

Supported by a grant from the National Science Foundation, a researcher at the Food and Drug Administration is investigating cognitive performance related to extended residence in Antarctica and seasonal mood alterations. The project has two specific objectives. The first is to determine whether long-term exposure to low temperatures and/or dim light, both characteristic of polar winters in high-latitude environments, are associated with significant changes in cognitive performance and emotional well-being. The second objective is to determine whether decrements to mood and cognitive performance can be effectively prevented or minimized through the administration of pharmacological interventions and/or phototherapy.

The National Institute of Mental Health, NIH, is expanding its portfolio of research on the prevention of suicide in response to the recent Surgeon General's report on suicide. Included in these efforts are attempts to reach out to traditionally underserved populations such as Alaska Natives.

The National Institute on Drug Abuse, NIH, supports evaluation of the benefits of needle exchange programs (NEPs) and/or pharmacy distribution of syringes by intervening with injection drug users to reduce hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV); this research has been underway at the University of Alaska Anchorage (UAA) since 1996. Data being monitored include results of urine testing for amphetamines, cocaine metabolites, and morphine, as well as serological testing for HBV, HCV, and HIV. An objective is to refer drug injectors recruited into the study for a free HBV vaccination series, with success in enrolling over half of the active drug users participating. The subject population includes Alaska Natives, whites, African Americans, and Hispanics. NIDA anticipates that such efforts will continue in the future, with the possibility of cooperation with other countries (Canada and Russia) holding Arctic territory adjacent to Alaska.

A First Independent Research Support and Transition (FIRST) Award (1997–2001) at the University of Alaska Anchorage (UAA) is identifying subgroups of women and their risk behaviors and potential for diseases relative to use of drugs and condoms. The 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-using and sexual behaviors (particularly among Alaska Native women) that put them at risk for sexually transmitted and other blood-borne infectious diseases. Plans include expansion into full-fledged research aimed at expanding knowledge of drug use, sexual risk, and infectious disease risk of Alaska Native women.

In May 2000, NIDA staff co-organized the Eighth International Conference on AIDS, Cancer, and Related Problems in St. Petersburg, Russia, and co-chaired sessions devoted to drug abuse and AIDS epidemiology and prevention/intervention, with participants from Siberia, the Russian Far East, and the Arctic. A large symposium is planned for May 2001 in St. Petersburg.

Delivery of Health Care

The National Institute of Mental Health, NIH, currently supports a number of telemedicine grants that are testing the delivery of mental health interventions through this technology. The NIDA-supported extramural research initiatives at the UAA have benefited from UAA's Telemedicine Project that helps to bridge the geographic expanse of Alaska in a series of "research at a distance" projects using desktop video teleconferencing technology. 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. It is anticipated that these efforts will be expanded to include countries with Arctic territory adjoining that of the U.S. (Canada and Russia).

Capacity Building/Health Disparities

The National Institute of Neurological Diseases and Stroke is funding a Specialized Neuroscience Research Program at the University of Alaska Fairbanks (UAF) that establishes an Alaskan Basic Neuroscience Program (ABNP) to expand, facilitate, and stimulate neuroscience research, to facilitate the collaborative research, and to stimulate the active participation of Alaska Native students. The ABNP will carry out interdisciplinary research to study mechanisms of neuroprotective adaptations via four specific aims: 1) develop an administrative core directly under the Provost that will provide the most effective environment, 2) develop a research program around the theme of neuroprotective adaptations and increase collaborations with other neuroscientists, 3) develop an emphasis on neuroscience graduate education, and 4) upgrade an existing tissue culture/imaging facility to state-of-the-art standards. The proposed research focuses on neuroprotective adaptations associated with hibernation and signal transduction in the control of cell death, neuronal regeneration, circadian rhythms, and thermoregulation.

The National Library of Medicine (NLM), NIH, has in the last two years created several Web-based information services that serve the public directly. MEDLINEplus and ClinicalTrials.gov are two notable resources that together are receiving more than 50 million page hits per year. NLM is prominently featuring outreach to minority and underserved communities so they may make maximum use of these services. For the Native American communities in Alaska and the Pacific Northwest, these activities are centered at the Regional Medical Library in Seattle at the University of Washington. "Tribal Connections in the Pacific Northwest" (www.tribalconnections.org) connects American Indian/Alaska Native communities to health resources on the Internet, including MEDLINEplus. This highly successful program is connecting hospitals, clinics, libraries, and remote villages via the Internet and thus reducing the isolation from quality health information and health care of this vulnerable population. Related to the Tribal Connections program is a series of telemedicine projects in rural Alaska that collectively is serving as a testbed strategy for cost containment and for raising the quality of health care for a minority population that is scattered across a vast area.

The National Cancer Institute (NCI), NIH, through its Surveillance Research Program, Division of Cancer Control and Population Sciences, supports the Network for Cancer Control Research among American Indian and Alaska Native Populations. Established in 1990, this network of researchers working among American Indians and Alaska Natives developed a National Strategic Plan for Cancer Prevention and Control Research in FY 92. The NCI shares support for Network meetings with the Mayo Comprehensive Cancer Center, Rochester, MN. With additional NCI support, the Network has convened three national conferences to discuss research and training and to disseminate results.

In 1997, NCI assisted the Network and Mayo in establishing the Native CIRCLE, a clearinghouse for information and resources developed through research (http://www.mayo.edu/nativecircle). Many useful, culturally sensitive materials, including school curricula, videos, pamphlets, and survey instruments, are catalogued and made available to researchers and communities for application in areas of smoking prevention, cancer screening, and dietary change.

Ongoing efforts for the Network include collaborative efforts with the Indian Health Service and the Centers for Disease Control and Prevention, expansion of cancer surveillance among American Indian populations, and pursuit of new studies in patterns of care and cancer survivorship. Members successfully competed to become one of NCI's new Special Population Networks. This large, five-year project will address comprehensive tribal cancer control using partnerships between populations, tribes, multiple cancer centers, the NCI, and the American Cancer Society and will also develop, assess, and implement cancer education among community members.

The NCI supports the Native American Student Research Program, a cancer control research training program for American Indian and Alaska Native graduate and post-doctoral students. Spanning six years, the program has provided training to 53 trainees of diverse Native groups, including Alaska Natives. A substantial proportion of the trainees have been awarded NCI funds (17 of 43 eligible, or 40%) to carry out community-based cancer control activities among Native groups. The training program has been awarded another five-year grant. The projects require implementation of a research plan within an established timetable and a report utilizing analytical skills.

The Office of Intramural Research, Office of the Director, NIH, is pursuing an initiative called the Arctic Health Disparities Research Dissemination Network (AHDRDN), envisioned as a central point of recognizance for U.S. human health efforts, including research, surveillance, education and training, communications, and outreach activities, particularly aimed at the Native populations. A starting point for the Network is the new Arctic Health Information web site, currently under development by the Specialized Information Services Division of the National Library of Medicine, NIH. The AHDRDN could be proposed to the Arctic Council as a new project under its Sustainable Development Working Group (SDWG).

The U.S. Department of State will continue to promote international cooperation on health issues in the Arctic Council. The Arctic Council is an intergovernmental forum for the eight Arctic nations and six indigenous organizations representing Arctic communities concerned with environmental protection and sustainable development. The U.S. raised the profile of Arctic health issues during its 1998–2000 Chairmanship of the Arctic Council. The U.S. initiated projects on telemedicine and infectious disease, featured presentations by U.S. experts at Council meetings, and hosted the May 2000 International Conference on Arctic Development, Pollution and Biomarkers of Human Health. The U.S. also contributed to the Council's Human Health Effects Program in the Arctic Monitoring and Assessment Program (AMAP) and helped fund a new assessment of contaminants in the food supply of Russian indigenous communities in the Arctic.

At the Second Ministerial Meeting of the Arctic Council in Barrow, Alaska, in October 2000, Ministers welcomed and approved the report on Telemedicine in the Arctic prepared by the Institute for Circumpolar Health Studies and the proposal by the CDC's Arctic Investigations Program to develop an International Circumpolar Surveillance System (ICS) for infectious diseases.

The Arctic Investigations Program worked closely with Canada and Denmark/Greenland in setting up the ICS for *Streptococcus pneumoniae*. As a follow-on initiative, the Office for the Advancement of Telehealth at the U.S. Health Resources and Services Administration (HRSA) will work with Sweden and Norway to organize an international workshop to develop elements of a common methodology for evaluating the varied telehealth programs in the Arctic.

The Department of State will facilitate U.S. participation as appropriate in all the health activities of the Arctic Council. Canada's program on Children and Youth, for example, will focus on data collection and analysis of health indicators by developing pilot projects in the four broad areas of health (socio-economic-cultural, health services, psychosocial well-being, and biophysical health). The U.S. has supported the Russian Indigenous Peoples of the North (RAIPON) proposal to monitor and assess the levels of contaminants in the indigenous food eaten by residents of the Russian Arctic. RAIPON has funding from the Global Environment Facility (GEF) for this research project.