United States Arctic Research Commission

Report on Goals and Objectives for Arctic Research

2001

IN MEMORIAM

Photography Chris Arend

This document is dedicated to the memory of Elmer E. Rasmuson, charter member of the United States Arctic Research Commission, who died on December 1, 2000. A devoted Alaskan, banker, philanthropist and one uniquely sensitive to the ecology of the North, Elmer was deeply committed to sustainable development in Alaska well before the concept and term became wide spread. Appointed to the Commission at its founding in 1985, he worked to set proper, pragmatic objectives for the Commission and for Arctic research. His wise counsel and his cheerful, enthusiastic and insightful presence will be sorely missed.

A MESSAGE FROM THE CHAIR

The Arctic Research and Policy Act of 1984 (as amended) directs the United States Arctic Research Commission to publish its Report on Goals and Objectives for Arctic Research every two years to guide the Interagency Arctic Research Policy Committee, and thus, the member Federal Agencies as they prepare their revision of the National Arctic Research Plan. This report for the year 2001 reflects the best judgement of the Commission based upon information gathered at our formal meetings, from the Commission's Group of Advisors, through reading and from our daily interactions with those involved in Arctic research - US and foreign researchers, research administrators, Alaskan natives and others living and working in the North.

The Commission has studied the research programs of both the United States and other nations with Arctic interests. We have attempted to synthesize them into a focused set of goals that meet what we understand are federal, state, local and native needs. At the same time we have tried to be sensitive to the dynamics of the Arctic which affect the international as well as the national landscape of politics, economics, sociology and the environment. Because this is a far reaching and diverse effort, completed on its own schedule, these goals and objectives may not exactly coincide with the research priorities articulated in the President's budget which must sometimes respond to requirements outside the Commission's purview.

In recent years our country's focus on Arctic research has increased significantly. This, in turn, has resulted in numerous advancements that will enable additional research and greatly increase our understanding of the least studied and most poorly understood area on Earth in the years ahead. Examples of these are:

- The highly successful data collection efforts of the SHEBA Program.
- The stunning revelations gained from the SCICEX Program.
- The implementation of the Arctic Research Logistics Program at NSF as a vital adjunct to more cost-effective research.
- Continuous upgrades at the Toolik Lake and Barrow Environmental Observatory research facilities.
- The establishment of NOAA's Arctic Research Initiative.
- The implementation of the International Arctic Research Center at the University of Alaska.
- The establishment of a year-round environmental observatory at the summit of the Greenland icecap and a general increase of active international cooperation in Arctic research.
- The establishment of several new bilateral and multilateral cooperative research arrangements.
- The entry into service of the new US Coast Guard research icebreaker *Healy*, WAGB 20.

But as we advance in our ability to conduct research and we realize the accomplishments thus derived, we find there are more unanswered questions. In response, we are compelled to study the Arctic perhaps more so now than ever. Specifically:

- The Arctic Ocean is undergoing rapid change. Is it the result of man-induced global climate change or part of a natural decadal cycle? Can we expect to exploit these changes in the Arctic Ocean for commercial purposes? What is the potential impact on world climate of this change?
- The permafrost which underlays roughly 80% of the State of Alaska is decreasing. What engineering will mitigate the degradation of the State's infrastructure? Will the change foster new commercial opprotunities?
- The Bering Sea fishery provides 50% of the table fish for our nation and is in obvious decline. Why? Can it be reversed? What are the social and economic impacts?
- As climate changes so do the habitats and ranges of animals and plants. What is happening to the terrestrial ecology of the Arctic as the climate changes? What will be the effects on human activities such as subsistence hunting, forestry and agriculture?

These sample questions beg for research at all levels - from basic through applied engineering. Though the Arctic is remote and complex, the fact that nine out of ten people on Earth live on the continents that are in the Arctic demands that we continue our studies. The goals and objectives recommended in this report show the way toward new and needed accomplishments in Arctic research.

George B. Newton, Jr.
Chair

MEMBERS OF THE
ARCTIC RESEARCH COMMISSION

Chairman
Mr. George B. Newton, Jr.
Management Support Technology Inc.
9990 Lee Highway, Suite 300
Fairfax, VA 22030

Dr. Jacqueline M. Grebmeier
Department of Ecology and
Evolutionary Biology
University of Tennessee
Knoxville, TN 37996

Mr. Jim O. Llewellyn, Esq.
BellSouth Corporation
1155 Peachtree Street, N.E., Ste. 1800
Atlanta, GA 30309

Mr. John R. Roderick
1620 Hidden Lane
Anchorage, AK 99501

Mr. Richard K. Glenn
Energy Management Department
North Slope Borough, Bldg 42 NARL
P.O. Box 1120
Barrow, AK 99723

Dr. John E. Hobbie
The Ecosystem Center
Marine Biological Laboratory
7 MBL Street
Woods Hole, MA 02543

Mr. Walter B. Parker
Parker Associates
3724 Campbell Airstrip Road
Anchorage, AK 99504

Ex-Officio
Dr. Rita Colwell
National Science Foundation
Arlington, VA 22230

Staff

Executive Director
Dr. Garrett W. Brass
Arlington, VA

Administrative Officer
Ms. Kay Brown
4350 N. Fairfax Drive, Suite 630
Arlington, VA 22203

Staff Officer
Mr. Lyle D. Perrigo
707 A Street
Anchorage, AK 99501

ARCTIC RESEARCH AND POLICY ACT OF 1984 AMENDED 1990

Finding, among other facts, that "Arctic research expands knowledge which can enhance the lives of Arctic residents, increase opportunities for international cooperation, and facilitate the formulation of national policy for the Arctic," the United States Congress passed the Arctic Research and Policy Act in July 1984 (Public Law 98-373), and amended it in October 1990 (Public Law 101-609).

The main purposes of the Act are:

To establish national policy, goals and priorities to provide a federal program plan for basic and applied scientific and engineering research in the Arctic;

To establish an Arctic Research Commission to promote Arctic research and to recommend Arctic Research policy and priorities;

To establish an Interagency Arctic Research Policy Committee to develop with the Commission a national Arctic Research policy and to prepare a five-year plan to implement that policy;

To designate the National Science Foundation as the lead agency responsible for implementing Arctic Research policy.

The Act assigns specific duties to the Commission and the Interagency Committee, and specifies procedures for the development of the five-year Arctic Research Plan and its periodic revision. The Commission reports to the President and to the Congress and consists of seven voting members appointed by the US President. By law, four are from academic or research institutions, two from private industry undertaking Arctic resource development, and one from among indigenous residents of the Arctic. The Director of the National Science Foundation serves as a nonvoting *ex-officio* member.

U.S. Arctic Research Commission
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INTRODUCTION

The Arctic remains one of the least explored, studied and understood places on Earth. The perpetual ice cover over much of the Arctic Ocean, the rigorous climate on land and sea and the resulting difficulties, not only in carrying on research but in simple survival, all lead to the current state of relative ignorance about Arctic processes and problems.

Political changes in Russia have surpassed in depth and speed all previous forecasts, and the end of the "Cold War" has converted the Arctic from a region of confrontation into a circumpolar region of cooperation. This new opportunity has also brought to light new dangers in the Arctic, particularly along the shores of the Arctic Ocean. The Arctic Ocean receives about 10% of all the river runoff in the world but contains only 5% of the area and 1.5% of the volume of the world ocean. Much of the river drainage of the former Soviet Union flows into the Arctic Ocean over the vast Russian continental shelf (25% of the area of the world's continental shelves). The results of decades of industrial development, military activities, natural resource development and nuclear power operations have left a substantial, largely uncontrolled and generally unassessed legacy of contaminants in close communication with the Arctic Ocean with the potential to be transported into the Arctic domain with very little warning or opportunity for remediation. Once again, the rigors of working in the Arctic Region make the necessary studies of this potentially serious situation substantially more difficult than their temperate or tropical equivalents.

The native people of the North have lived for long ages in harmony with the Arctic but new intrusions by human activity both in and outside the Arctic have brought problems to the North - problems which make it imperative that research into the unique Arctic environment be carried out to close the gaps in our understanding and to provide effective information and guidance for decision makers, particularly in the national government.

The founding, in 1990, of the International Arctic Science Committee, agreement in 1991 on an Arctic Environmental Protection Strategy, establishment of a Northern Forum of regional government leaders in 1991, the Establishment of the Arctic Council in 1996, and the establishment of the Alaska Native Science Commission in 1997 have brought new emphasis to the importance of a vigorous research effort in the Arctic. The promulgation of a national policy for the Arctic by the President of the United States in 1994, which highlights our national commitment to environmental protection in the Arctic, demonstrates our growing national awareness of the importance of Arctic Research and focuses our nation's Arctic research interests and resources.

The ultimate challenge for Arctic research is to help lead the country on a course in which opposing trends are reconciled, showing that Arctic resources can be extracted with minimum adverse impact on the environment; that profit-motivated industrial operations are compatible with environmentally conscious communities; that indigenous lifestyles can be preserved without relinquishing the benefits of modern society and that improved transportation systems are being built with minimum disturbance to the indigenous community and to wildlife. The Arctic

Research Commission was established to recommend policies and priorities to ensure that the basic understanding of how the Arctic system works as a component of our planet can be gained while at the same time solving the practical problems posed by environmental hazards and the needs of Arctic residents.

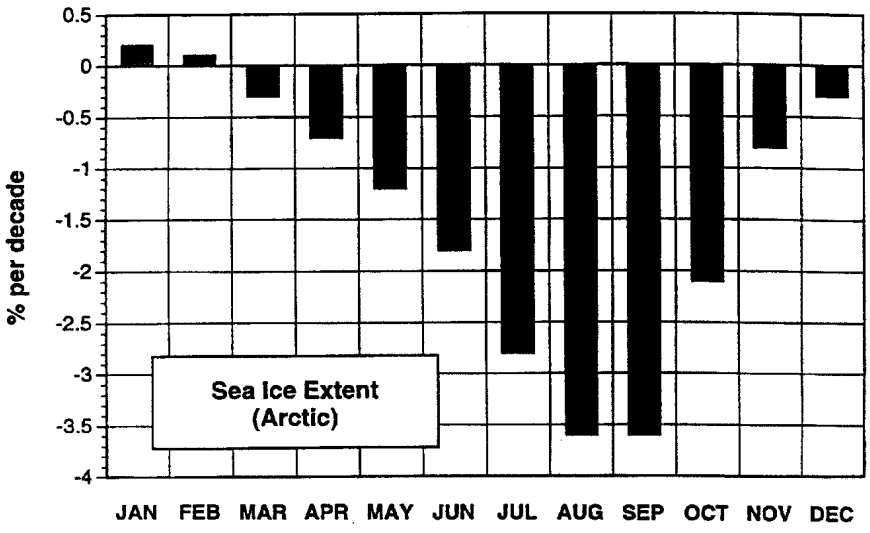
The Arctic Research Commission is charged with the task of assembling and synthesizing the nation's needs for research in the Arctic. This report presents the Commission's view of the future for research in the Arctic.

MAJOR RESEARCH PRIORITIES

This edition of the Arctic Research Commission's Report on Goals and Priorities for Arctic Research focuses on three Major Interagency Projects: Climate Change, The Bering Sea and Arctic Health. Although the division between basic and applied research is often arbitrary and acknowledging that there must be a continuous flow of ideas and priorities between basic and applied research, the Arctic Research Commission has collected a number of more applied research topics, requirements and recommendations in the section on Applied Research.

STUDIES OF THE ARCTIC REGION AND GLOBAL CHANGE

Global change, particularly climate change, is expected to have its most pronounced effects in the Arctic. A significant amount of data has already been gathered on such phenomena as the thinning of Arctic Ocean sea ice (Rothrock *et al*., 1999) and reductions in its extent (see Fig. 1), the reduction of the thickness of the distal parts of the Greenland ice cap (Krabill *et al*., 2000) and changes in the circulation of the Arctic Ocean (Morison *et al*., 1998). These and other data strongly suggest that rapid and important changes are occurring in the Arctic environment. The albedo of snow-covered sea ice is the highest of any natural surface and the albedo of open sea water is the lowest. Thus, changes is sea ice cover caused by climate change have a profound effect on the energy balance of the region. Reductions in sea ice cover will affect the productivity and probably the community structure of the marine flora and fauna of the Arctic seas reaching up to the highest trophic levels such as birds, seals, sea lions, walrus, whales and polar bears.



Figu re 1. Rates of change in the extent of Arctic sea ice during the period 1979 to 1995 in percent per decade. (From Serreze ***et al.,*** 2000)

Model studies indicate that temperature changes induced by increases in atmospheric carbon dioxide will be several times greater in the Arctic than elsewhere on the planet. Such changes will

modify the hydrologic regime of the Arctic including changes in precipitation, river runoff, permafrost and the mass balance of glaciers. The impacts on Arctic soils and their plant and animal communities may be profound and studies already underway indicate an increase in the rate of carbon release to the atmosphere as methane and carbon dioxide, two gases with major impacts on the radiative balance of the atmosphere. If the Arctic has a positive feedback on climate warming the results will be to amplify warming everywhere on the planet.

The Earth is a fragile planet and, because it is our home, we may not conduct experiments on it which might have serious consequences for its habitability. Our only approach to understanding the complex phenomena of climate change is to learn as much as we can about the processes causing and responding to these changes, to apply our growing computational capabilities to model studies and especially to study diligently the record of climate change in the past. Recent insights derived from the study of the climate record in the Greenland ice cap have shown that our previous ideas of slow steady change at the end of the last ice age were wrong and that climate change can occur in rapid transitions from one climate state to another. Other studies of fossil climate record in lake sediments have been used to test the predictions of numerical models for climate during the most recent ice age and have shown them to require further refinement. Without the ability to experiment on the planetary systems which sustain us we must rely on the record of the experiments that nature has conducted in the past to test and refine our understanding and our ability to predict the future. The cause of these phenomena and the question of their relationship to potential permanent changes in the climate of the Arctic region is of vital importance both to residents of the Arctic and as early indicators of change for the rest of the planet.

But, it is also clear that environmental change is always with us. There are few recent changes in climate that compare with the difference between summer and winter regimes in the Arctic. Because of these stupendous changes in temperature, precipitation, wind, light and other annually varying environmental properties subtle changes on longer time scales are not easy to detect. Processes such as the North Atlantic Oscillation which appear to have episodic time scales of the order of a decade have been causing climate changes for many centuries. Other changes with similar time scales indicate that the circulation patterns in the surface waters of the Arctic Ocean change regimes on similar time scales. It is essential that we understand the current changes in the Arctic environment and that we seek to separate those which represent oscillations about a stable state from those which indicate that the Arctic may be undergoing significant, long-term changes in its climate regime. To do so requires a broad based attack on the question which seeks to understand the particular mechanisms of environmental change. The Arctic is an apt place for this study as changes in environment are magnified by the extremes of the natural cycle. The common observable boundaries in the Arctic (such as the edge of the polar ice pack, the marginal permafrost zone and the tree line) are particularly sensitive to these changes. The movements of these boundaries are not only sensitive indicators of environmental change but also have major effects of the lives of Arctic residents, particularly on native people endeavoring to continue their subsistence lifestyle in the face of major cultural and material stresses.

Environmental change has important consequences for human activity in the Arctic. As climate changes the means by which life goes on in the Arctic will also change. In particular, the physical

infrastructure will sense these changes. Roads, bridges, buildings and other aspects of civil infrastructure will react to changes in the environment. These changes will affect human activities in many ways including local energy consumption, housing design and construction, transportation, water and waste water management and subsistence activities. These in turn will lead to changes in the social milieu which depends on interactions between people living in the Arctic and on the stresses imposed on their lives by the Arctic environment.

At its meeting in March, 2000 the Interagency Arctic Research Policy Committee (IARPC) agreed to organize an interagency program of research on the Study of Environmental Arctic Rapid Change (SEARCH). The emphasis of the SEARCH project is on those changes occurring rapidly enough to be evident today in climate and oceanographic data -- changes which are affecting Arctic ecosystems and the modes of living of Arctic residents now.

The SEARCH program has drawn on many agencies and on a broad spectrum of Arctic researchers in constructing its program. Early efforts for Fiscal Year 2001 have begun using budget requests submitted during calendar year 2000. These activities have, of necessity, significant gaps in the program which could not be addressed using established funding levels. The Commission expects that subsequent years will lead to a unified approach and that the Office of Management and Budget will consider the SEARCH program in a unified manner recognizing the interdependence of the research programs of each of the agencies. Similarly, the Congress must consider budget requests for the SEARCH program in the light of the effects of budget decisions for each of the agencies individually on the efforts of the program as a whole. While we expect this will be difficult, we believe that an integrated rather than a piecemeal approach is essential for success.

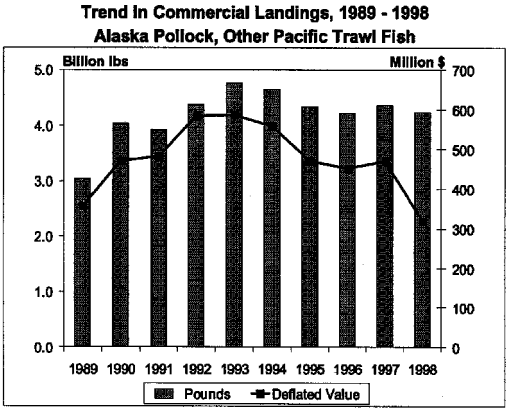
The Arctic Research Commission strongly supports the Interagency SEARCH program and encourages it to grow into a fully developed program with a common research agenda and an integrated budget approach.

Included within the SEARCH program is the US effort in the Arctic Climate Impact Assessment (ACIA), a study sponsored jointly by the International Arctic Science Committee and the Arctic Council. This study will attempt to collate the current state of knowledge about the climate of the Arctic and its changes and use this knowledge to predict the impacts of climate change in and beyond the Arctic region. In particular, ACIA will illuminate the environmental challenges to be faced by Arctic residents and the time scale and severity of the impacts of climate change on individuals and communities. ACIA will serve to alert policy makers to the magnitude of the changes occurring now and in the future and to encourage early action to prevent, ameliorate or accommodate to these changes. In addition, ACIA will produce a “road map” of the gaps in our knowledge about Arctic climate and guide the future of climate change research in the region.

The Arctic Research Commission supports the Arctic Climate Impact Assessment and urges its swift completion in order to support policy decision on accommodating climate change effects in the Arctic region.

STUDIES OF THE BERING SEA REGION

...the most effective environmental regulations and policies will be based on adequate scientific understanding of the interactions of organisms and their environments. This understanding must be predictive; that is, it must allow the development of scenarios of the effects of various choices for management. (Hobbie, John E., 2000)



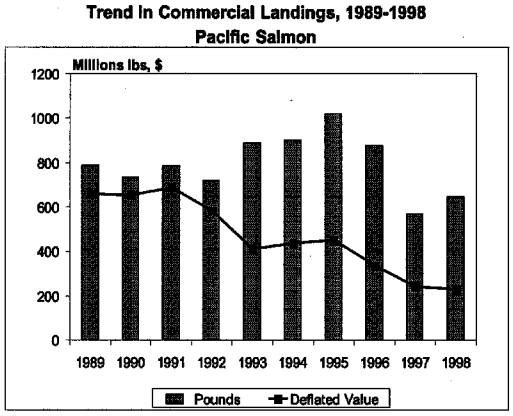


Figure 2. Trends in commercial landings of species important in the Bering Sea and the Aleutians.

In 1998 Alaska led all states in the amount of fish and shellfish landed with 4.9 billion pounds. Louisiana with 1.1 billion pounds was its nearest competitor. Alaska also led all states in the value of landings with $951.2 million followed again by Louisiana at $291.9 million. Much of Alaska's fish come from the Bering Sea and Dutch Harbor-Unalaska is the leading US port in terms of value. In addition to its commercial value, the Bering Sea is home to an array of animal life including sea birds, whales, walrus, seals and sea lions unprecedented in the rest of the nation. The inhabitants of the Bering Sea region include Inuit, Aleut and Yupik people who have lived by and from the Bering Sea for many ages.

The health of the Bering Sea ecosystem is of vital importance to the nation, to the State of Alaska and to the residents of the region. Changes in the ecology of the Bering Sea have major impacts not only on fisheries but on the everyday lives of thousands of people who rely on it for their sustenance. Human activity has had its impact in the region but it is not the sole, nor perhaps the most important cause of many of these changes. Changes in climate, in ocean circulation, in weather patterns and the behavior of sea ice in fall and spring are all major actors on the Bering Sea stage. The Arctic Research Commission is concerned that our knowledge of the Bering Sea is not sufficient for the important decisions which must be made for the safe and effective management of the resources of the region.

In 1996, the Polar Research Board of the National Research Council published a study of the Bering Sea Ecosystem (NRC, 1996). This study noted the complex interaction of the various parts of the Bering Sea ecosystem and the potential for unexpected effects in the structure of the biological community resulting from human actions as well as the unknown connections between these and natural environmental change. Their recommendations for research were:

- Adopt a broader ecosystem perspective for both scientific research and management of Bering Sea resources.
- Adopt an adaptive or experimental approach to management actions concerning the Bering Sea ecosystem.
- Conduct research on the structure of the Bering Sea ecosystem, including the nature and causes of the dynamics of pollock populations in the northeastern Pacific and Bering Sea over the past 50 years.
- Conduct research on how well the management and institutions of the Bering Sea are structured to address problems and provide appropriate management solutions.

Under the heading of "Management and Institutional Recommendations" the report recommended:

- Develop a research program to increase understanding of the Bering Sea ecosystem (keeping international issues and cooperation in mind), to fulfill the research needs identified by the committee to help future policy makers solve both short-term management and longer-term ecological problems.

While these recommendations constitute an important guide for action, they fail to make specific recommendations for agencies and organizations. They do not indicate in these direct recommendations which agencies or institutions should carry them out.

In the 1997 version of the US Arctic Research Plan, a new initiative was introduced entitled, "Beringian Systems Studies" (USARP-97, p. 11-18). This initiative was directed toward the following Goals and Objectives:

- Assess the magnitude of changes in the Beringian system as a consequence of global change;
- Assess and predict the consequences of these changes on the physical, biological and socioeconomic systems in the region and determine the cumulative impacts of these changes on the region including assessment of past impacts;

- Promote studies addressing the modern socioeconomic conditions of Beringia's rural residents and in particular problems of environmental quality, education and human health;
- Increase baseline documentation and synthesis on Beringian paleoenvironments and landscape history and distributions of marine and terrestrial flora and fauns for use in global change modeling;
- Develop baseline documentation of cultural, biological and linguistic variation in historical and modern times, and inventory and assess the status of these resources;
- Develop integrated syntheses of human-environmental interactions with regional and global perspectives;
- Establish baseline documentation on contaminants and their pathways in Beringian food chains and their environmental, health and economic impacts;
- Develop modeling capabilities and relate the results of regional Beringian studies to larger global patterns of climatic and environmental change; and
- Develop coordination and infrastructure by enhancing regional research centers, by promoting the spread of scientific knowledge and by encouraging cooperative and international research and education programs that include representation of northern residents and communities.

While these recommendations are applauded by the Commission, we see substantial gaps in this current state of affairs with regard to Bering Sea studies. The Commission met in Anchorage in December 1999 and conducted a forum on Bering Sea research with participation from many of the principal participants (see ARC Annual Report for CY 1999). Two lessons were drawn from this and other activities of the Commission. First, there appeared to be a notable lack of integration in the approaches of the various programs. This was particularly notable in the lack of integration between basic oceanographic data collection and analysis and studies of population effects at higher trophic levels such a marine mammals, birds and fish. Indeed there seemed to be little connection between the efforts of researchers studying particular populations and the work of others on other populations. This lack of integration has been likened to the parable of the blind men describing the elephant. Each project appeared to see the Bering Sea system from its own limited perspective but did not adequately integrate the observations of others.

The second lesson drawn from our study of Bering Sea research was the absence of emphasis on the ability to predict changes in the Bering Sea system, particularly in the population dynamics of the higher trophic levels. The analysis of data appeared to be almost entirely *post hoc.* Management decisions were based on records of past behavior in the system but the ability of the system to see ahead, to produce scenarios reflecting changes and to act to preempt negative effects before they occurred and to avoid crisis management were not in evidence. Scientists are always reluctant to engage in prediction. There are many pitfalls in predicting natural systems not the least of which is the high potential costs of incorrect predictions. Nevertheless, careful and concise predictions with carefully stated confidence limits are essential for the effective management of our interaction with the Bering Sea ecosystem. In order to build predictive capacity two approaches are useful. The first is to conduct predictions testable by historical data, *i.e.*, use the data from the past to predict more recent years and compare the predictions to

the actual data. This approach allows continual refinement of the predictive system and can indicate the limits of reliability of predictions of the future. The second approach is to study intensively the processes linking the various phenomena occurring in the system. This approach requires abundant detailed study and provides guidance to modeling and predicting the behavior of the system by characterizing the essential links in need of further study. The use of these two approaches in tandem, empirical modeling guiding detailed study and detailed study improving the empirical models by emphasizing the data most useful for predictions is the most effective means for predicting complex systems. While such systems are common in various aspects of science, they appear to have been avoided by the programs studying the Bering Sea. They need to be applied, improved and implemented.

All in all, there appears to be no comprehensive plan for the study of the Bering Sea. One of the reasons for this lack is the absence of a vision of what a comprehensive plan should contain. It would be extremely helpful if a description of an integrated study of the Bering Sea could be produced which indicated the essential elements and their connections to the improvement of the ability to predict changes in the system, particularly at the most sensitive parts of the system such a endangered or threatened and economically important species.

The Commission recommends that a study be conducted by the National Research Council's Polar Research Board and Ocean Studies Board to recommend an integrated research plan for the Bering Sea system.

The planning and construction of the SEARCH program discussed above has built a model for interagency cooperation in the study of important Arctic research questions. The Arctic Research Commission believes that the study of the Bering Sea requires an equivalent interagency program, based on the results of the NRC study recommended above, which can produce predictions of the important changes in the Bering Sea based upon an integrated application of the research tools of all the relevant agencies acting in concert. While the study of change in the Bering Sea is currently an element of the SEARCH program, the Commission believes that the importance of the Bering Sea system to the resident populations, to other users of Bering Sea resources and to the nation's economy justifies a stand-alone interagency program which can command the attention of all contributing agencies and lead to assurances that critical parts of the study do not fail for lack of visibility during the budget process.

The Commission recommends that IARPC organize an interagency program for the study of the Bering Sea and encourages its implementation.

In order to fully understand the Bering Sea, studies must be carried out on the western side of the basin which will require the active participation of Russian scientists. Such a program exists in the Department of the Interior. This program, known as Berpac, has conducted sporadic cruises in recent years in various parts of the Bering and Chukchi Seas with Russian collaborators and often using Russian research vessels. This program offers an outstanding opportunity for increasing our understanding of the Western Bering Sea.

The Arctic Research Commission recommends an immediate expansion of the Berpac program to include annual research cruises and appropriate support for related research both within the Department of Interior and by extramural funding paths.

Of all the Bering Sea fish species, the several pacific salmon species hold a unique position as they are collectively unrivaled both for their commercial value and as a subsistence resource to US Arctic coastal and upriver communities. The Bristol Bay salmon fishery is the largest salmon fishery in US waters. Dramatic fluctuations in salmon returns are poorly understood, yet affect the lives of all residents of Western and Interior Alaska. These fluctuations and the classification of some populations as "stocks of concern" have raised awareness of the complexities of the management of an anadromous fish stock where populations may be mixed together in some regions but separated and subjected to different conditions at other parts of their life cycle. Preliminary results indicate that the identification of particular stocks within mixed populations may be possible using mitochondrial DNA analysis. This technique should be studied and, if effective, rapidly developed for the identification of fish from over- harvested stocks for more effective management and restoration.

The Commission recommends an accelerated program of research on problems in the Bering Sea region with an emphasis on the distribution of Pacific Salmon.

HEALTH OF ARCTIC RESIDENTS

The United States assumed the Chair of the Arctic Council at the conclusion of its first ministerial meeting in the fall of 1998 and surrendered it in the fall of 2000. During this era of US leadership substantial progress has been made in bringing the results of US research in the Arctic to bear on important problems identified by the Arctic Council. The Arctic Monitoring and Assessment Program (AMAP) continues its work on environmental health concerns in the Arctic.

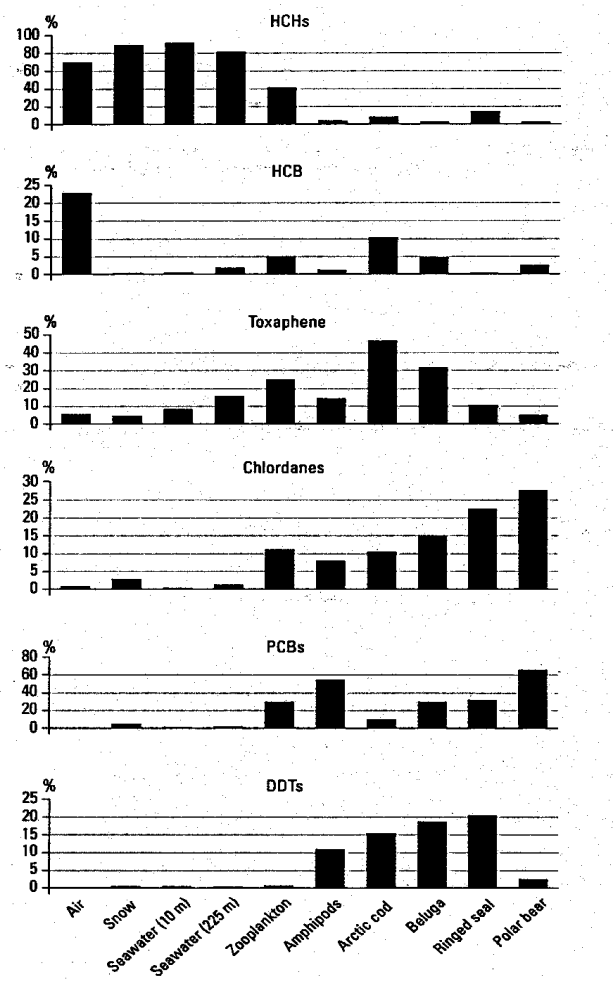


Figure 3. Distribution of organochlorine contaminants in the Arctic. HCH=Hexachlorohexanes, HCB=Hexachlorobenzene.

The questions surrounding environmental health effects in the Arctic are many and varied. Potential sources of effects on human health include radionuclides, heavy metals and Persistent Organic Pollutants (see Fig. 3). Residents of the Arctic are concerned that contaminants are transported to the region from sources farther south and that they are entering the food chain causing effects on both wildlife and humans, especially on those engaged in subsistence hunting

and fishing. Research is needed to identify the abundances of these contaminants throughout the environment and in humans, especially the young. Arctic residents need guidance on coping with these problems and it is the responsibility of the research community to supply them with the information they need to live safe and healthy lives. Substantial research progress is being made through programs such as NOAA's Arctic Initiative, research on PCBs and mercury by the EPA and NSF's new Contaminants Program but much remains to be accomplished.

While environmental health concerns play an important role in AMAP deliberations, they do not (at least not yet) constitute the major causes of morbidity and mortality in the US Arctic. Infectious diseases, chronic diseases such a diabetes, cancer, heart attack and stroke as well as behavioral problems such a alcoholism, drug use and suicide are the most frequent causes of ill health and death in Arctic populations. These must also be studied with an eye toward relieving the Arctic population of as much of this sad burden as possible. Such a program falls predominantly within the purview of the National Institutes of Health and the Indian Health Service. Collaboration with health officials in the State of Alaska is essential as is coordination with local organizations and native groups. The Arctic Council will also focus on sustainable development in the Arctic, a focus which will include studies of health concerns in the North.

The health of Arctic residents depends on many factors. It is clear that life in the Arctic, particularly in small communities, is affected by the complexities of the provision of the essential infrastructures of community life. The Arctic environment requires an approach to housing, water, waste-water, energy and transportation systems far more difficult than those of temperate regions. Perhaps the best indication of the severity of these problems was stated by John Seibert, formerly the Executive Director of the Alaska Science and Technology Foundation.

> "At this time, the level of service for potable water and sanitary waste disposal in the 239 village communities in rural Alaska is highly variable. Systems range from modern, pressurized potable water and gravity sewerage in 31 villages (approximately 13% of the villages), to the most rudimentary honey bucket systems that are found in 103 villages (43%).
>
> Of the remaining villages, 104 are served by septic tank or leach field systems (approximately 44%), and one village, Galena, operates a truck-haul system for both potable water delivery and wastewater disposal.
>
> Conditions in villages that operate honey bucket haul systems vary from efficiently operated, well-managed systems to indiscriminate dumping of honey bucket wastes within the community. Under the worst conditions, the potential for disease is unacceptably high and can be traced to this dumping and spillage of honey bucket wastes. In addition, village aesthetics and quality of living are significantly degraded by the absence of adequate sanitation."

Clearly these problems must be addressed by the application of the best technologies and practices available. At the same time, the relative obscurity of these problems in the larger context of US engineering research must be overcome. Partners are available in willing to attack these problems. The Commission has opened discussions with the American Society of Civil Engineers on how they can assist in developing new initiatives in Arctic infrastructure. The Denali Commission was established in 1998 to attack the problems of rural infrastructure in Alaska. The Arctic Council's Program on Sustainable Development is considering a new program on Arctic Infrastructure. These initiatives should be used to bring the considerable talents and

abilities of the US engineering community to bear of those systems directly affecting health in the Arctic.

At the IARPC Staff Retreat in May, 2000, it was agreed that IARPC would consider the planning of an interagency program of studies on Arctic health. Lead agencies would be somewhat different from those most involved in the SEARCH and Bering Sea programs. The National Institutes of Health, the Centers for Disease Control, the Public Health Service, and the Indian Health Service will be the most prominent participants with applied engineering research and environmental measurements programs in other agencies contributing as noted above.

The Arctic Research Commission recommends that IARPC commence planning for a third focused, interagency program to coordinate and emphasize research on health concerns in the Arctic.

The Arctic Research Commission takes special note that the National Institute of Occupational Safety and Health has established a research unit in Anchorage, Alaska to examine occupational injuries. Substantial progress has resulted from this program especially in reducing injuries and fatalities in such dangerous occupations as fishing and helicopter lumbering. This unsung program has already saved many lives and stands to realize further advances in safety and protection of workers in the most dangerous occupations.

The Commission supports the continuation and expansion of this program.

APPLIED RESEARCH

RESEARCH ON CIVIL INFRASTRUCTURE AND CLIMATE CHANGE

Understanding climate change in the Arctic is an important goal as the SEARCH Program has recognized. It is at least as important, however, to begin the task of finding ways to cope with the effects of climate change, particularly on Arctic infrastructure. The effects of infrastructure problems on human life in the Arctic are particularly noted below in the section on Arctic Health. These difficulties are compounded by climate change. The destabilization of structures by changes in permafrost, changes in coastal communities caused by changing in sea level and in the frequency and strength of storm induced wave action, changes in weather patterns requiring changes in aircraft operation and many others require a strong commitment to engineering research in the Arctic. The Commission is encouraged by arrangements between the US Army's Cold Regions Research and Engineering Laboratory (CRREL) and the University of Alaska to bring the nation's most able engineering talent to bear on these problems. CRREL is recognized around the world as a national treasure of expertise in Arctic engineering.

The Commission recommends continuing support for the US Army Cold Regions Research and Engineering Laboratory and encourages their connection to infrastructure research in Alaska.

APPLIED RESEARCH IN FISHERIES

The exploitation of the resources of the Bering Sea region are conducted in a rigorous climatic regime under difficult and often dangerous conditions. The technologies employed in these activities are in need of research to improve the success of resource extraction activities, to reduce the environmental impacts of these activities and to provide for the safety and welfare of workers and residents in the region. Research on effective fishing techniques, on the development of new products, on the improvement of current products, on the use of harvesting byproducts and the reduction of effluents are all vital to sustaining the fishing industry in the Bering Sea region. Research on the development of ports, factories, navigation and Search and Rescue facilities are similarly needed with an additional emphasis on the impacts of all of these activities on socio-economic activities in the region.

The Commission recommends an accelerated program of applied research on problems in the Bering Sea region with an emphasis on the fishing industry.

NATURAL RESOURCES

The US Arctic is a vital source of renewable and non-renewable resources. Over 66% of the land in the State of Alaska is managed by federal agencies. The extraction of these resources requires high levels of technological innovation. At the same time, the environmentally sound use of these resources require industry to limit the environmental damage cause by resource utilization on to be prepared for the restoration of site after their resources have been exhausted.

Federal agencies play an important role in identifying options and promoting the development of innovative technologies for resource exploration; extraction of oil, gas, and minerals; long distance energy transmission; fisheries; and marine transportation, usually as regulators and sometimes as owners of the resources in question. An integrated approach to the study of all those issues involving Arctic resources is required.
The Commission's highest priority is to develop an oil spill prevention and response capability, including innovative containment and cleanup operations in ice-infested waters and on permafrost terrain. Three types of research are needed: a) applied work to perfect *in situ* burning techniques in ice covered seas, b) more basic and applied research to identify and develop alternatives to combustion on land, and c) policy analysis and associated information transfer activities related to the testing and acceptance of new pollution abatement processes.

The development of oil resources in the Arctic, particularly the US and Canadian Arctic, are proceeding currently. Offshore drilling and production activities have occurred in both US and Canadian offshore waters. In addition, the possibilities for marine transport of Arctic oil are growing. The Commission has been informed of Canadian interest in shipping oil from their Arctic region by sea from the MacKenzie delta region to ports in the Pacific.

The Arctic Research Commission has been briefed on the special research needs for the response to oil spills in ice covered waters. In particular, the Commission has consulted with Alaska Clean Seas and Environment Canada on their research efforts and the gaps in our knowledge of oil in sea ice. Alaska Clean Seas has, for example, reported that there is no vessel capable of an adequate response to an oil spill in ice covered waters in the US Arctic. The only ships capable of responding to such an event are US Coast Guard icebreakers *Healy*, *Polar Sea* and *Polar Star* and these ships are generally either operating in the Antarctic or stationed in Seattle unless performing specific tasks in the Arctic. Alaska Clean Seas also indicated that it was likely that burning was the method of choice for the disposal of oil in ice They also stated that the use of emulsion breaking chemicals was generally prohibited as they are considered flammable. Since this restriction is in conflict with their use (to promote burning) there appears to be a need to revise this prohibition. In April of 2000 an International Oil and Ice Symposium was held in Anchorage and Prudhoe Bay, Alaska. The Commission expects to publish the proceedings of this workshop as a special report containing an agenda for research on oil in ice. The Commission recommended a comprehensive attack by agencies participating in the interagency oil spill response program on these problems in its 1997 and 1999 Reports, but no action has been forthcoming.

The Arctic Research Commission recommends that Federal agencies immediately commence a comprehensive program of research on oil in ice and suggests that the Oil Spill Research Institute (OSRI) should take the lead in organizing this program.

RESEARCH ON VALUE ADDED PRODUCTS

The development of value added products derived from the extraction of non-petroleum

resources also requires an accelerated research approach. We have already discussed applied research in fisheries. Similar advances are needed in such other industries as timber and mineral use. New and improved products, produced in the North not only increase the value of the resource but also retain more of the economic benefits of the resource industries in the region where new economic activity is vitally needed.

RESEARCH ON TECHNOLOGIES FOR REMOTE COMMUNITIES

The technologies developed to cope with the problems of living in the Arctic are often valuable for other communities with a similar distribution of rural residents. The use of such technologies as distance education and telemedicine are not by any means restricted to the Arctic nor are water, waste-water and energy technologies developed for small, remote communities. Rural regions throughout the rest of the world can profitably employ these techniques and developers may find much broader markets for these products than expected from a purely Arctic perspective. In order to achieve expanded developments, research must continue to supply the new technologies for continued growth.

The Arctic Research Commission recommends an expansion of the research base for the development of value-added products.

RESEARCH ON COMMUNICATIONS TECHNOLOGIES AND THEIR APPLICATIONS

The Arctic includes some of the most remote settlements in the modern world. Communication technology provides the potential to bring the delivery of services to these remote settlements. In particular, distance education and telemedicine are valuable providers of services to remote settlements that can not otherwise be supported. Distance education can bring the educational resources of the world to the most distant villages. Telemedicine has the potential to provide expert medical care to patients who are unable to go to a medical facility to consult with a physician and can support local medical personnel by supplementing and supporting their efforts in medical care. The Commission is pleased to see the expanded efforts in these two vital fields which are currently underway.

The Arctic Research Commission supports the current efforts in distance education and telemedicine and supports further efforts to improve the provision of these services.

EDUCATION

The Commission's priorities for education can be divided into three parts: (1) General scientific and technological literacy; (2) Education of professional researchers; and (3) Education of Arctic residents, particularly native peoples, about scientific advances in understanding the Arctic. The Arctic Research Commission lacks a direct mandate for action in general education but notes the role of the NSF Directorate for Education and Human Resources in this vital task. The Commission also notes the efforts of the Arctic Research Consortium of the United States (ARCUS) in education.

GENERAL SCIENTIFIC AND TECHNOLOGICAL LITERACY

Better education of the citizenry, particularly in science and technology, is a continuing national priority. In this modern, technologically complex world the education of the nation is essential if democracy is going to cope with the increasingly technical nature of public debate on such matters as environmental protection, ozone depletion, nuclear waste disposal and many more. The Arctic is a particularly important topic for educational activities as it is considered by many to be both remote and exotic. For example, a very large proportion of the population is unaware that an ocean exists at the top of the world. The relationship of events and processes in the Arctic to the well being of the nation is very poorly understood.

The Commission supports efforts by Arctic researchers to make their results available to interested citizens.

The Commission is pleased to note the new Teachers Experiencing the Arctic (TEA) program at the National Science Foundation. This program takes teachers to the Arctic for research experiences during their summer recess. The result is teachers with a new understanding of the modes of research, the importance of the Arctic and an excitement which can only result from actually participating in the research endeavor. This enthusiasm is then transmitted to all the student influenced by these teachers over the ensuing years with the result that research in the Arctic will be understood and appreciated by a growing number of citizens.

The Commission approves of the TEA program and urges its continuation and expansion.

EDUCATION OF PROFESSIONAL RESEARCHERS

In the past the Commission has noted the slow growth in the number of young scientists and engineers with Arctic expertise in our nation. In recent years the rapid growth in the Arctic research account at the National Science Foundation has afforded many new opportunities for graduate education in the Arctic as have more recent developments at NOAA.

The Commission is pleased that the cadre of new Arctic researchers currently in training is growing and encourages the NSF and NOAA to continue the good work they are accomplishing.

EDUCATION OF AND BY ARCTIC RESIDENTS

The US Arctic, in the State of Alaska, is characterized by small, remote communities. The provision of adequate educational opportunities is difficult and the financial base for the support of education is usually small, and smallest in the most remote communities. The support of education in these communities is a serious problem. The National Science Foundation is providing support for rural education if Alaska through its Rural Systemic Initiative. This effort combined with advances in the technology of distance education have the potential for dramatic improvements if the provision of education an hence the potential for economic improvements in Alaska's rural communities and the upward mobility of their youth.

The Commission supports the NSF's Rural Systemic Initiative in Alaska.

The education of Arctic residents, particularly native people, about scientific advances in understanding the Arctic is vital to the continued success of Arctic research. Citizens of the Arctic, particularly the native people, experience the research endeavor more directly than most. Indeed, they are often subjects of the research effort and, if not, their fragile support systems for food, water, shelter, health, energy and transportation are often the subject of study. It is incumbent upon Arctic researchers to return to these communities in order to inform and involve the Arctic citizenry in the benefits of our increasing knowledge.

The Commission notes with pleasure that the NSF has agreed to fund the ARCUS visiting lecturer program which will bring distinguished Arctic researchers into the Arctic to discuss their research with local residents.

At the same time it is essential that the scientific community absorb the vital and hard-won knowledge that only many years and even generations of residence in the Arctic can produce. The absorption of traditional knowledge into the scientific endeavor serves to sharpen the focus of the research effort and to bring into the research system the observations and experience of the native community.

RESEARCH INFRASTRUCTURE

Arctic research responsive to national needs requires responsible management and adequate support services. Because of the extremely high cost of support systems in the Arctic environment, coordination of logistic services and cooperation in their use are essential in achieving maximum cost effectiveness.

LOGISTIC SUPPORT

In order to form a consensus on the logistic needs of the research community, the Commission, with additional financial support from the National Science Foundation, engaged the Arctic Research Consortium of the United States (ARCUS) to consult with the community of Arctic researchers and construct a report indicating the scientific needs and the logistics systems and facilities needed to support these science needs now and in the future. This report entitled *Logistics Recommendations for an Improved U.S. Arctic Research Capability* (Schlosser *et al.*, 1998) was published in 1998. As part of an ongoing review of Arctic logistics needs, ARCUS is now engaged in updating this report. The Commission looks forward to the revised Logistics Report. There are many recommendations for logistics improvements in the 1998 report with varying degrees of urgency in their implementation. All agencies should consider these recommendations and collaborate in supporting logistics improvements for Arctic Research.

The Commission is pleased to note the continuing efforts by the National Science Foundation to upgrade and improve research facilities in the Arctic. Their collaboration with the Barrow Arctic Science Consortium in improving facilities and services at Barrow and the establishment of the Barrow Environmental Observatory are laudable efforts which the Commissions hopes will continue to grow and prosper. The conclusion of a cooperative agreement with the University of Alaska for support and expansion of the research facilities at Toolik Lake is similarly a positive step in the support of the basic infrastructure of research in the region. The establishment of a year-round research facility at the summit of the Greenland ice cap in the facilities constructed for the Greenland Ice Sampling Program is especially noteworthy. This is the first US Arctic facility which approaches the level of difficulty readily assumed for Antarctic research. Winter access is difficult to impossible and the environment is extreme. The Commission commends the National Science Foundation for their efforts in establishing Summit as a permanent research facility. It is, however, notable that the National Science Foundation is called upon to shoulder the entire burden of these facilities without financial aid or participation from other agencies of the Federal Government.

The Commission has encouraged cooperative use of US military logistic capabilities to support civilian research in the Arctic. Following the successful Arctic science cruise of the Navy's nuclear submarine USS *Pargo* in the summer of 1994 the National Science Foundation, the US Geological Survey, the National Oceanic and Atmospheric Administration, the Office of Naval Research, the Director, Submarine Warfare Division in the Office of the Chief of Naval Operations, and the Commanders of the Atlantic and Pacific Submarine Forces signed an historic, multi-agency Memorandum of Agreement (MOA) for continuing use of submarines of

opportunity for scientific studies of the Arctic Ocean.

The Program resulting from this initial test cruise and the MOA was called the Science Ice Exercise (SCICEX) Program and resulted in extended research cruises in 1995, '96, '97, '98 and '99. Unfortunately, changes in the number and configuration of the US Navy's submarine fleet have ended the opportunity for annual "dedicated" cruises aboard Navy nuclear submarines in the Arctic.

The Arctic Research Commission has initiated the study of new ways to approach the Arctic Ocean with the capabilities which can replace those lost with the end of the "dedicated" cruises. Other cruise opportunities referred to by the Navy and the research community as "opportunity" and "accommodation" cruises may, from time to time, become available on US submarines (For details see *Arctic Science from Submarines - A Report Based on the SCICEX 2000 Workshop,* Rothrock *et al*., 1999). The Commission has opened discussions with the Royal Navy on the use of their nuclear submarines and has begun exploring the availability and capabilities of Swedish and German submarine with "Air Independent Power" systems which carry both fuel and oxidizer for extended operations while submerged. With the advent of *Healy* requirements for deep sampling and surfaced operations from a submerged platform have subsided. It became clear in the latter days of the SCICEX dedicated cruises that submerged operations were the most appropriate use of the submarine's capabilities. This has lead to discussions of the capabilities of unmanned or autonomous vehicles for survey research in the Arctic. Discussions continue on all of these fronts as well as continuing discussions with the Navy about the possibilities for another "dedicated" cruise to the Arctic.

The NSF is now supporting an Internet site for logistics information called the Arctic Logistics Information Access Service (ALIAS, http://www.nsf.gov/od/opp/arctic/ logistic/ start.htm/). This web site is expanding rapidly and is becoming an important reference for researchers seeking Arctic logistics information.

The NSF's Arctic Science Section has made great strides in coordination with the US Coast Guard on the utilization of Coast Guard icebreakers and the design and construction of science facilities aboard *Healy*, the Coast Guard's new icebreaking research vessel currently preparing for her first science missions. NSF has engaged the University Oceanographic Laboratory System (UNOLS) to operate the Arctic Icebreaker Coordinating Committee (AICC) to build a communications and cooperation bridge between the US academic oceanography community and the Coast Guard's design, construction and operating teams. The AICC has worked diligently with the Coast Guard and the Commission is confident that *Healy* will operate as an effective and efficient research vessel in the Arctic as she commences research support operations in the year 2001.

The Arctic Research Commission is pleased that the National Science Foundation is commencing regular support for research aboard *Healy* in the coming year. Other Federal Agencies including NOAA, MMS, FWS and others have research needs which require icebreaking research vessels such as ecosystem research in the Bering Sea in

winter. The Commission recommends that these agencies become involved in *Healy* scheduling and operations.

ENGINEERING RESEARCH

The Commission has not made any special recommendations for logistics support for engineering research. Nevertheless, these needs are present and are not necessarily appropriate for the logistics facilities available for basic research. Studies on such topics as road and airstrip construction, housing technology, corrosion under Arctic conditions, construction techniques in cold climates, coating technology and permafrost engineering require special facilities which were not addressed in the Commission's report. As the time approaches for a revision of this report the Commission intends to seek input from the engineering research community

DATA AND INFORMATION

In 1997 the Commission identified and negotiated the declassification of Arctic bathymetry data collected by US Navy submarines between the inception of nuclear submarine operations in the Arctic and 1982. This data was released for public use in early 1998. The Navy is now engaged in the declassification of bathymetry and ice profile data up to 1988. The Commission is pleased that these data are now accessible to the research community and believes that, along with unclassified data gathered by the SCICEX program, this will permit new insights into many branches of marine and earth science in the Arctic.

The Commission supports the continued declassification of bathymetric, ice and other oceanographic data collected in the Arctic Ocean as appropriate.

INTERNATIONAL COORDINATION

The Government of Japan has expressed an interest in the Arctic region which has led them to a cooperative project with the University of Alaska entitled the International Arctic Research Center (IARC). The first part of this collaboration has been the construction of a very substantial new building on the University of Alaska Fairbanks campus. In Fiscal Year 1999 the IARC received new funding from the United States government in the amount of $5 million which is expected to continue for several more years. In the summer of calendar year 2000 a cooperative agreement was signed between NSF and IARC for support of the Center using these funds. IARC is now fully established and supported and will proceed to make notable advances in Arctic research.

International cooperation is an integral component of many scientific endeavors in the Arctic, linked to, and often inseparable from, the normal process of research planning and execution. The Commission is charged with advising the President and Congress on Arctic Research policy and priorities, and with recommending the means for developing international scientific cooperation.

Scientific cooperation among the circumpolar nations, as well as among other countries with scientific activities in northern latitudes, is accelerating. Quite generally, the increasing number of international bilateral and multilateral agreements for Arctic research (now about 450) signals the rising importance and breadth of both governmental and non-governmental international collaboration.

The US and Denmark have had a long and successful logistical cooperation in support of research in Greenland. The support of ski equipped C-130 Hercules aircraft of the New York Air National Guard has been a mainstay of research in Greenland. The National Science Foundation has recently negotiated a new research agreement with Greenland/Denmark for continuing research activities in Greenland. In September 1998, the International Arctic Science Committee (IASC) held an informal meeting of "Arctic Operators" in Tromsø, Norway. At this meeting, logistics providers in the Arctic agreed to work on the means for sharing information on logistics opportunities in the Arctic. FARO has since met in Tromsø in 1999 and in Cambridge, UK in 2000. The Executive Director of the Commission is one of the US representatives to FARO.

The Arctic Research Commission has been engaged in a discussion of logistics opportunities with the Canadian government through talks between the Commission and the Canadian Polar Continental Shelf Project. An agreement has been reached to support annual meetings between Canadian and US logistics providers. The first of these meetings was held in April in Cambridge, UK. Opportunities for collaborative research using Canadian facilities presents a timely and cost effective means to expand both the efforts of US researchers in the Arctic and their Canadian colleagues.

Research in collaboration with our Russian colleagues is growing and the Commission encourages this process. Difficulties in conducting Arctic research in collaboration with colleagues at major institutions in European Russia are surmountable by diligent efforts on both sides. Obstacles to

research in the Russian Far Eastern Region are, however, much more severe. The Commission has received a considerable amount of information on these difficulties and considers them a serious threat to research collaboration which is, in fact, in the interests of both nations. Communications with political entities in the Russian Far East are difficult and some means to alleviate these problems would make an important contribution to progress and research and in understanding the challenges of living in the Arctic. Collaboration with Russian colleagues represents an opportunity for the International Arctic Research Center.

The Commission recommends that the International Arctic Research Center investigate opportunities to support joint US-Russian research collaboration in the region.

RECOMMENDATIONS FOR AGENCIES

1. The Interagency Arctic Research Policy Committee (IARPC). The Commission is pleased to note the initiative by IARPC to organize and support the SEARCH Program and to be prepared to commence planning on similar initiatives on the Bering Sea and Arctic Health. The response of IARPC to the Commission's recommendations is heartening and the Commission wishes to commend the participating agencies and their staffs for their commitment. The Commission expects continued progress and cooperation in bringing the Bering Sea and Arctic Health initiatives forward.

2. The National Science Foundation (NSF). The NSF has made great strides in their support for Arctic Research. Funding has grown as has the enthusiasm with which Arctic research is considered inside the Foundation. The Commission hopes for continued cooperation and growth.

3. The Department of Defense (DOD). A number of activities fall under the Department of Defense. Chief among these is the SCICEX Program of the Department of the Navy. The 109th Airlift Wing of the New York Air National Guard provides LC- 130 support for both Arctic and Antarctic research operations. In addition, DOD is conducting a program entitled Arctic Military Environmental Cooperation (AMEC) jointly with the Norwegian and Russian ministries of defense. The Commission encourages the Department of Defense to continue to provide support for Arctic Research and environmental studies and to communicate with the Commission on any new programs

A. Department of the Navy. The level of interest in Arctic research at the Office of Naval Research is fairly low. Recent developments, however, suggest that changes in the climate of the Arctic may result in new roles and missions for the Navy in the Arctic. The Commission believes that these changes in the Arctic environment require an increase in research levels in the Arctic in order to maintain the national capability in the region. The knowledge base created and maintained by research in the region may be of vital national interest in the future, particularly as access to the Arctic Ocean improves; a fact made likely through the observed thinning and retreat of Arctic sea ice. Rapid changes in the region suggest that research efforts based on Navy needs should be substantially increased.

With this in mind, the Commission commends the efforts of the Navy in carrying out the SCICEX dedicated cruises. The Commission notes the substantial effort made by the Navy to support this program in the face of shrinking resources and facilities. These expeditions into the Arctic Ocean aboard operational fast attack nuclear submarines show an extraordinary interest in the support of science by the Navy. The retirement of the last of the Sturgeon Class submarines and the difficulties in finding resources for future dedicated cruises are of great concern to the Commission. The Commission recommends that the Navy continue to explore with the scientific community the means to continue this invaluable access to the Arctic Ocean.
The SCICEX Program began in 1998 to collect swath bathymetric data in the Arctic for the first time from a submarine. This instrument known as the Seafloor Characterization And Mapping Pods (SCAMP) has been made possible by the enthusiastic support of the National Science

Foundation's Office of Polar Programs. This data collected by SCAMP will be of great value for students of the region from many disciplines. The regions surveyed in 1998 and 1999 will comprise only a moderate fraction of the area of the deep water portion of the Arctic Ocean. The means to continue gathering swath bathymetry with the SCAMP system should be developed for the future. Navy nuclear submarines are the preferred platform for these investigations and the Commission continues to explore these possibilities but other opportunities may also be developed. Under the new Memorandum of Agreement between the participating agencies the SCICEX Program will continue with "opportunity cruises" using occasional time slots provided during other Navy Arctic visits. While these opportunity cruises will not allow for scientist "rider" or the installation of specialized equipment, they will offer the opportunity to observe many characteristics of the Arctic environment. The Commission wishes to express our gratitude for the opportunities past and future provided by the Navy for study of the Arctic Ocean from Navy nuclear submarines.

A corollary issue is the declassification of archived bathymetry data collected on previous operations. These data are a valuable resource for the research community. A continuing program should be established to bring these data out from the classified realm respecting the security concerns which may surround the collection of this data. The construction of the new US-Russian Arctic Ocean Atlas CD shows that these difficulties may be overcome.

As a further indication of the utility of Navy nuclear submarines for research in the Arctic Ocean the Commission also notes the cooperation of the Navy in attempting to carry out a test of the submarine as a receiving ship for seismic refraction measurements. This test, when completed, will indicate the suitability of the submarine for such experiments and the Commission encourages further investigation of this concept. The Commission also notes the cooperation of the Navy in the declassification of bathymetric and ice profile data collected by Navy nuclear submarines in the Arctic. The value of this data is indicated by the importance attached to the bathymetric data by the international community in connection with the update of the GEBCO chart of Arctic Ocean bathymetry. Navy data will at least double the data base available for this update.

B. Department of the Army. The Army Cold Regions Research and Engineering Laboratory (CRREL) in Hanover is a national treasure. In the current climate of budget stringency the pressure on Army labs is growing. The Commission wishes to be on record in support of the vital national resource that exists at CRREL. Serious reductions at CRREL might be helpful in the short term but a detriment to the national welfare over the long term. The Commission encourages continued support for CRREL.

The Commission has recently discussed with CRREL the importance of understanding the effects of global climate change on the permafrost regime. The Commission looks forward to CRREL's plans for further study of climate change and permafrost, supports the concept and encourages support for these studies by all of the IARPC agencies. These changes are especially relevant to questions of civil infrastructure, an area of particular expertise at CRREL. The Commission is pleased that an agreement has been concluded between CRREL and the

University of Alaska to bring the experience and talent of CRREL researchers to bear on the infrastructure needs of the State of Alaska through this collaboration.

4. The National Oceanographic and Atmospheric Administration (NOAA). NOAA has been the leading US agency for Arctic Monitoring and Assessment Program (AMAP). In this role, NOAA has supplied both staff efforts and funding to the AMAP. These efforts have been largely conducted on a goodwill basis without organized programs or a satisfactory funding base. NOAA deserves great credit for these efforts and the Commission commends and supports their efforts. NOAA has conducted an Arctic Initiative beginning in 1996 at a funding level of approximately one million dollars. The Commission supports this initiative and recommends that it continue in the coming fiscal year with expanded funding.

NOAA will play an important role in a new program of Ocean Exploration. The Commission hopes that the Arctic Ocean will continue to be noted as part of the world ocean with a special place as an important source region for deep convection in the world ocean and as a region where air-sea interactions influence both the world's climate and ocean circulation. The Commission strongly encourages NOAA to include intensive studies of the Arctic Ocean in its World Ocean Exploration plans.

NOAA operates a suite of National Data Centers including the National Snow and Ice Data Center, the National Oceanographic Data Center, the National Geophysical Data Center and the National Climate Data Center. These data centers are charged with the responsibility for data rescue in the Former Soviet Union. The Commission recommends that the national data centers communicate the nature of their data rescue activities to the Commission and expand them as necessary to collect data vital to our understanding of the Arctic, especially the dispersal of contaminants in the region.

5. The Environmental Protection Agency (EPA).

The native residents of the Arctic live in a close relationship their environment (roughly 50% of their annual caloric intake comes from native plant and animal species). The stresses of village life (almost 50% of Alaskan villages use the "honey bucket" system for human waste disposal) and their vast and ancient store of traditional knowledge of the Arctic environment make their continued well being a matter of great concern. At the same time, the Arctic native community is probably more closely coupled to their environment and to new stresses introduced by human activity and natural variations than any other community in the United States. This suggests that, although their numbers are small relative to the rest of the nation, they are in the front lines of environmental susceptibility. For this region, the Commission commends the recent activities of the EPA, especially the Alaska office, in involving Alaska natives in agency activities. The results of the AMAP study indicate that there is still much to learn about contaminant stressors in the Arctic. The interagency program on Arctic Health recommended above will require serious efforts by EPA if questions concerning environmental health are to adequately attacked. The Commission notes that the Alaska governor's office has mounted a new initiative on

contaminants and that EPA is a participant. As the Arctic Health Program goes forward, the Arctic Research Commission will look to EPA to play a major role.

There are important efforts in the Arctic sponsored by the EPA's Office of International Programs. EPA's Office of International Activities (OIA) has supported the study of contaminants in umbilical cord blood samples from Arctic residents and projects to assess and reduce sources of Mercury and PCBs. The Commission commends EPA-OIA for their efforts and urges support for there activation and expansion.

6. The Department of State. The Department of State is responsible for the negotiation and operation of our international agreements in the Arctic. The Department seeks input from the IARPC agencies and others through the Arctic Policy Working Group which meets monthly with the Polar Affairs Section at State. Matters concerning US participation in the Arctic Council are the principal topics for discussion at these meetings. The United States has recently finished a two year term as Chair of the Arctic Council. Hard work by the State Department and close cooperation, particularly with the *ad hoc* working group organized in the State of Alaska has resulted in a successful two years. The Commission commends the State Department's efforts.

7. The US Coast Guard. The US Coast Guard is the principal provider of research time on icebreakers for US scientists not collaborating with other nations. The dialog between the scientific community which will be using *Healy*, Coast Guard designers and ship builders has been substantially improved. The formation of the Arctic Icebreaker Coordinating Committee (AICC) has been successful and has lead to substantial improvements in the design of research facilities aboard *Healy.* The need for liaison and coordination has now changed from the construction of the ship to planning and scheduling operations. The Commission is gratified that the Coast Guard has worked closely with the AICC drawing upon the US academic community's substantial level of experience in oceanographic operations generally and in Arctic studies in particular.

There is a substantial dearth of knowledge about oil spills in Arctic conditions. The Commission has long recommended a substantial research program on the behavior of oil in ice infested oceans. In addition, the Commission has had substantial discussions with the Oil Spill Recovery Institute. The Commission in collaboration with the Alaska Clean Seas Association and others has recommended test burns in the Arctic Ocean to study the variety of questions associated with this highly effective method of disposing of oil on the sea. The Commission recommends that the Coast Guard in cooperation with the EPA, OSRI, the State of Alaska and others commence such a program soon, before the question is made imperative by an accident in the Arctic. The Commission also notes that the only US vessels capable of responding to an oil spill in the presence of substantial sea ice coverage are the Coast Guard icebreakers. The Commission would be interested in hearing of Coast Guard contingency planning for a spill in the Arctic ice.

8. The National Aeronautics and Space Administration (NASA). The Commission has been briefed on the Programs undertaken by NASA in the Arctic or having a substantial component in

the Arctic. These programs are clearly of a high caliber. The Commission recommends that NASA carry out a program of outreach to the Arctic Research Community to publicize these programs and to encourage broader participation. NASA is always at risk for the engineering side of their programs to overwhelm scientific uses and needs. The Commission believes that by broadening the participation of the research community in their programs, NASA can benefit from the resulting community support.

The Commission notes with particular interest the participation of NASA in the planning for the SEARCH Program. Clearly, remote sensing data with its broads area coverage and frequent collection of data will be essential for this and other coordinated studies in the region. We urge NASA to continue its interagency communication and coordination efforts with a particular emphasis on planning for the Bering Sea Study recommended above by the Commission.

The Commission also notes that NASA is a participating agency in the International Arctic Research Center and supports the Alaska Synthetic Aperture Radar Facility at the University of Alaska. The Commission supports these efforts and looks forward to their continuation and expansion.

9. The National Institutes of Health (NIH). The Commission has recommended a comprehensive, inter-agency study of Arctic Health. NIH has agreed to be the focal point for this effort focused primarily on the environmental health questions outlined by the Arctic Monitoring and Assessment Program and on the study of incidences and trends in the major causes of morbidity and mortality in the Arctic. NIH should lead this effort with the assistance of other agencies especially EPA and NOAA. The potential effects of anthropogenic contaminants such as persistent organic pollutants, heavy metals and radionuclides are a growing concern in the Arctic (see comments above on the efforts of the State of Alaska). The effects of both communicable diseases such as tuberculosis, systemic diseases such as diabetes and cancer and external causes of illness and death such as alcoholism and accident likewise have profound effects in the Arctic. The Commission eagerly awaits the organization of this multi-agency effort under NIH's leadership.

10. The Department of Interior.

A. The US Geological Survey. The US Geological Survey has led the effort by IARPC agencies in the assembly of a data structure for Arctic research. Unfortunately, there has never been a satisfactory funding base for this program. In the past, many IARPC agencies have contributed to this effort but these contributions have faded. Only NSF continues to provide support. The Commission recommends that the USGS and the Department of the Interior accept that this program belongs to them and should be fully supported. The USGS should have the full support of the other IARPC agencies. It is particularly important that an effort be staged to save important earth science data from the former Soviet Union. Much useful data is collected in old paper records which are even more vulnerable now that fuel has become scarce in many places. The Commission has recommended that the NOAA National Data Centers undertake a data rescue project

coordinated with the USGS.

The USGS Water Resources Branch has recently reduced the number of hydrologic monitoring stations in the Arctic. Data from these stations are urgently needed for testing and improving the predictions of large-scale of fresh water runoff in the Arctic. In addition, fresh water runoff affects the stratification of the Arctic Ocean and the distribution of nutrients, tracers and contaminants brought to the Arctic Ocean from the land. The World Climate Research Program - Arctic Climate System Study maintains and Arctic Runoff Data Base for these purposes. The Commission recommends that the USGS rebuild a strong program of Arctic hydrologic measurements.

The Biological Resource Division of the USGS participates along with the Fish and Wildlife Service in the BERPAC program, a US-Russia collaborative program for the study of the Bering-Chukchi-Beaufort Sea ecosystems. The Arctic Research Commission expects this program to play an important role in the interagency program for the study of the Bering Sea and encourages its support and expansion.

B. The Fish and Wildlife Service of the Department has been a stalwart in the work of the Arctic Council's working Group on the Conservation of Arctic Flora and Fauna. The Commission recommends that other divisions of the Department follow the example of the Fish and Wildlife Service in their support of Arctic Council Activities. See also the Commission's comments on BERPAC, above.

C. The Minerals Managements Service (MMS). The MMS has responsibilities for offshore natural resources and, as a result, is a principal participant along with the State Department, USGS and NOAA in the preparation of a US claim under Article 76 of the UN Convention on the Law of the Sea. This provision allows nations to claim submerged extension of their continental margins for the purpose of the exploitation of resources on and under the sea bed. While data is somewhat more abundant and certainly easier to collect in the temperate and tropic waters under US jurisdiction the state of knowledge about the Arctic is so limited that new efforts at bathymetric and geophysical measurements may be required for the US to submit a successful claim. The Commission is observing this process with great interest and urges all agencies to contribute as possible to a successful US claim.

11. The Department of Energy (DOE).

The energy needs of Arctic villages in Alaska are extreme. Poor transportation to remote villages, small communities unable to take advantage of the economies of scale usually associated with municipal energy systems, a mixed economy with only modest cash flow and the lack of a sophisticated technical infrastructure all make the provision of adequate energy resources in the Arctic difficult. The Commission notes the activities of the DOE in developing fuel cell technology. Fuel cells may become a principal source of energy at appropriate scales but the Commission is concerned about cost/benefit ratios and

encourages further development of small scale appropriate technology systems for village energy systems in the north.

The Department of Energy has been an important source of technology transfer to the Russian nuclear power reactor program. Unfortunately, budget reductions threaten this vital activity. The Commission is concerned that the future of US participation is in jeopardy and that in the future nuclear energy production particularly in the Russian Arctic may proceed without the support of the Department of Energy. The budget for interaction with Russia on nuclear power systems should be supported and reinforced.

The Commission has long held serious concerns about radioisotope contamination in Russia derived from fuel reprocessing systems. While national concern focuses on the remaining stockpile of Russian nuclear weapons, the reprocessing cycle which produces the basic fissile material for these weapons has had a far greater actual (as opposed to potential) effect on the environment and the people living in it. The Commission encourages the DOE to continue its interaction with the Russian nuclear power infrastructure and to consider potential environmental remediation, restoration or at least sequestration efforts pointed toward the Russian fuel reprocessing system.

The Commission fully supports the activities in the Arctic under the DOE's Atmospheric Radiation Measurement (ARM) Program. The ARM Program is an important research effort and is also an outstanding example of close cooperation between researchers and native communities and stands as an example for other research programs.

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