UNITED STATES ARCTIC RESEARCH COMMISSION

REPORT ON THE Goals and Objectives for Arctic Research 2015–2016

FOR THE US ARCTIC RESEARCH PROGRAM PLAN

FRONT COVER. The Observing the Arctic Photo Contest Grand Prize winning photo by LT Tim Smith, NOAA. Melting iceberg illuminated by the Arctic sun, Bering Strait, west of Barrow, AK. More information about the photo contest and winners can be found on the inside back cover.

THE US ARCTIC RESEARCH COMMISSION

The US Arctic Research Commission (USARC) is an independent federal agency created by the Arctic Research and Policy Act of 1984. It is a presidentially appointed advisory body supported by staff in Washington, DC, and in Anchorage, AK. In addition to establishing the goals in this report, the Commission recommends US Arctic research policy to the President and Congress and builds cooperative links in Arctic research within the federal government, with the State of Alaska, and with international partners. The law also requires the Commission to report to Congress on the progress of the Executive Branch in reaching goals set by the Commission and on their adoption by the Interagency Arctic Research Policy Committee.

The Commission plays an active advisory role in many organizations, including the White House Arctic Executive Steering Committee that was established on January 21, 2015, by President Obama's Executive Order 13689. USARC is a statutory member of the North Pacific Research Board and the North Slope Science Initiative. It is also a member, participant, liaison, or observer on other entities, including the Interagency Arctic Research Policy Committee, the Interagency Coordinating Committee on Oil Pollution Research, the National Ocean Council, the Extended Continental Shelf Task Force, the Interagency Program Management Committee of the Study of Environmental Arctic Change, the Interagency Working Group on Alaska Energy Permitting, the Department of the Interior's Arctic Landscape Conservation Cooperative, the Civil Applications Committee, the Scientific Ice Expeditions Interagency Committee (Navy submarines), the UNOLS Arctic Icebreaker Coordinating Committee, the State Department's Arctic Policy Group, the Arctic Research Consortium of the United States, the Alaska Ocean Observing System, the International Permafrost Association, and the Consortium for Ocean Leadership. During the last two years, the Commission led special initiatives, gave testimony, held workshops, and published brochures and articles. The Commission occasionally writes editorials and "white papers" that are posted on the Commission's website, http://www.arctic.gov.

HOW THIS REPORT WAS COMPILED

Under the Arctic Research and Policy Act, the Commission biennially recommends key goals and objectives ("Goals Report") for the US Arctic Research Program Plan. To prepare this report, the Commission, through public meetings, sought input from scientific researchers, policymakers, the public in Alaska and throughout the United States, and in the growing number of nations with Arctic interests. The Commission also cosponsored meetings, workshops, and studies, such as the 2014 National Academies studies, "*The Arctic in the Anthropocene*" and "*Responding to Oil Spills in the US Arctic Marine Environment*" to help inform its research goals and policies.

DEDICATION

We dedicate this report to the memory of Mr. Walter Bruce Parker, a former USARC Commissioner, who passed away on June 25, 2014, at the age of 87. Parker, who moved to Alaska in 1946, following his service in the US Navy, was often cited as one of the indomitable few who "created Alaska." He was instrumental in establishing major federal legislation associated with Alaska statehood, including the Alaska Native Claims Settlement Act of 1971, the Trans Alaska Pipeline Act of 1973, the National Fisheries Act of 1976 (Magnuson Act), the Alaska National Interest Lands and Conservation Act of 1980, and the Oil Pollution Act of 1990. Parker served on the US Arctic Research Commission from 1995–2001 and continued to serve as an advisor until his death. He chaired the Alaska Oil Spill Commission associated with the Exxon Valdez spill. In 1996, when the Arctic Council was formed, Parker was a delegate to the Senior Arctic Officials and the Sustainable Development Working Group. Walt avidly embraced the Alaskan lifestyle, he ran beaver and marten traplines, and had dog sled teams when he and his young family lived in the Lake Minchumina region. His contributions to Alaska and to Arctic research were considerable, and he will be greatly missed.

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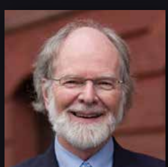

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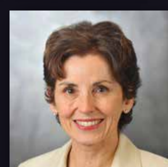

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DUTIES OF THE COMMISSION

- Develop and recommend a national Arctic research policy as well as research goals and objectives
- Assist the Interagency Arctic Research Policy Committee in establishing a national Arctic research program plan to implement the policy
- Facilitate cooperation in Arctic research among federal, state, and local governments and with international partners
- Review federal Arctic research programs and recommend coordination improvements
- Recommend improvements in Arctic research logistics
- Recommend improved methods for data sharing among research entities

Photo credit: Heidi Hatcher

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Photo credit: Cindy Shake

Defining Our Goals

A MESSAGE FROM
USARC CHAIR FRAN ULMER

The nations of the world are discovering the importance of the Arctic. The increased interest by governments, companies, universities, and many others is based on the potential of the region to influence their lives, though they may live and work thousands of miles away. The Arctic's rapidly changing climate, predictions of resource and transportation opportunities, and increased coverage by media that stimulate both curiosity and speculation drive this awareness.

For the four million people who live across the Arctic, this recognition is generally a good thing. We hope that continued investment in research, analysis, planning, and needed infrastructure will improve living conditions for those who call this region home. The focus also provides more awareness of the significant challenges of cold, dark, stormy, remote, and dangerous conditions that must be approached with humility, innovation, and respect for the knowledge of indigenous peoples who have survived in the Arctic for many centuries.

Now more than ever, information based on observation, monitoring, and scientific research is essential to inform the decisions that are being made by the public and private sectors. At a time of constrained budgets, we can be most effective by prioritizing the important questions, choosing the most vulnerable and/or valuable areas to study, and finding optimal ways to work together to advance knowledge and understanding about this very special region.

To meet national goals, the Arctic Research Commission, the Interagency Arctic Research Policy Committee, the White House Office of Science and Technology, the Office of Management and Budget, and Congress must work together to encourage collaboration and commitment of resources.[1] There is a lot of work to be done, and the rate of change happening in the Arctic demands our best efforts to pick up the pace.

[1] Ulmer, F. 2015. One Arctic. *Science*, http://dx.doi.org/10.1126/science.aab3119.

Photo credit: Kerry Koepping

Six Priority Research Goals — An Overview

GOAL 1. OBSERVE, UNDERSTAND, AND PREDICT ARCTIC ENVIRONMENTAL CHANGE

Motivation

Climate change and increasing global demand for natural resources are transforming the Arctic, raising geopolitical awareness. Greater knowledge and comprehension of anthropogenic impacts on the environment, including rates of change, will inform decision making. Ideally, this will maximize the region's strategic value and economic potential while minimizing risks to ecosystems and society. Further, given the far reach of environmental connectivity, understanding the rapid changes observed in the Arctic will provide insight into the rest of the world.

Recommendations

- Understand how increasing ocean acidification will affect marine life, food webs, and fisheries.
- Study the impacts of climate change on the periodic life-cycle events of plants and animals (phenology).
- Advance an Arctic Observing Network from a concept to an integrated, fully operational activity that provides critical information and derivative products for scientific research, as well as operational intelligence and decision support.
- Improve observations and modeling of changes in Arctic Ocean circulation, sea ice extent and thickness, and increased freshwater from melting land ice.
- Project the effects of a changing Arctic climate on ecosystems in sea ice, the upper ocean, and the seafloor.
- Anticipate abrupt impacts from climate change as well as long-term trends.
- Integrate scientific knowledge into discussions and formulation of public policy.

GOAL 2. IMPROVE ARCTIC HUMAN HEALTH

Motivation

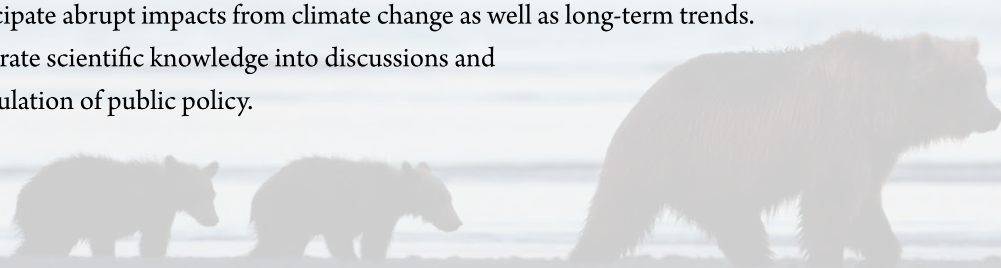
Significant physical and mental health disparities exist between indigenous and non-indigenous peoples in the Arctic, and between Arctic and non-Arctic populations. Decreasing rates of infant mortality, fetal alcohol syndrome, chronic respiratory disease, and accidental injury are offset by increasing rates of substance abuse, domestic violence, and suicide.

Nearly 40% of Alaskan women have been raped or sexually assaulted.[2] Victims of intimate partner violence are more likely to experience adverse health conditions and health risk behaviors.

Water and sanitation are critically important to human health, yet these fundamental needs, and the infrastructure to provide them, are inadequate in many rural Arctic communities.

Recommendations

- Improve the quality, efficiency, effectiveness, and value of health care delivery in the Arctic.
- Investigate factors associated with domestic violence, including prevention, effective interventions, long-term health effects and socio-economic drivers.
- Evaluate and review behavioral and mental health intervention efforts to update research priorities and to guide the scaling of successful local efforts into broader clinical interventions.
- Support integrative approaches to human health that recognize the connections among people, wildlife, the environment, and climate.



[2] 2010 Special Report: UAA Justice Center Domestic and Sexual Violence Research Review and Recommendations, May 2010

Photo credit: © Bob Waldrop - RedPoint Images

GOAL 3. ADVANCE KNOWLEDGE OF ARCTIC NATURAL RESOURCES: A FOCUS ON RENEWABLE ENERGY

Motivation

In light of the high cost of petroleum products in rural Arctic communities and the adverse effects of their combustion or spillage, research is needed to adapt viable and cost-competitive carbon-free energy technologies (e.g., geothermal, hydro-electric, tidal, wind, solar, microgrid) and control systems for local use.

Pressure to develop non-renewable Arctic energy resources will continue to rise because they are abundant, in demand, and constitute the basis of many Arctic economies. Further research is warranted to assess the distribution, quantity, and quality of these resources and to improve the means to develop, recover, and safely transport them.

Climate-change-mitigation opportunities exist beyond renewable energy. Research is needed to improve energy efficiency and conservation, fuel switching technologies, and consumer behavior.

Recommendations

» Assess and characterize renewable and non-renewable energy sources and technology options to identify their potential use in Arctic communities and how to adapt them accordingly.

» Investigate options in the energy sector to mitigate climate change and better understand the role that renewables can play in the changing Arctic climate regime.

» Examine how the Arctic region can serve as a test bed for innovative infrastructure development, such as energy microgrids and battery energy storage systems.

Photo credit: Theodore Dickerson

GOAL 4. ADVANCE THE ARCTIC "BUILT ENVIRONMENT"

Motivation

Rapid environmental change demands improved and updated Arctic design standards for civil infrastructure both on- and offshore. Air temperatures warming two to three times faster than the global average and thawing permafrost affect the Arctic "built environment" in cities, towns, and villages. This includes buildings, their affiliated infrastructure, and other public works (e.g., water supplies, sanitation systems, energy networks, and systems for transportation and communication).

Recommendations

» Conduct integrated Arctic infrastructure mapping, Arctic marine charting, synthesize operational data and information systems, and update engineering atlases. Examples include Arctic Spatial Data Infrastructure and the Statewide Digital Mapping Initiative.

» Assess vulnerability, resilience, and response options of the built environment in light of environmental change and available technologies, and consider compound uncertainties, life-cycle impacts, depreciation rates, risks, scenario planning, and engineered versus social adaptations.

» Perform additional engineering research on methods to protect shorelines, relocate coastal communities, develop evacuation routes and shelters, mitigate floods, improve drainage systems, and protect permafrost.

Background photo credit: Kristine Sowl, USFWS

GOAL 5. EXPLORE ARCTIC CULTURES AND COMMUNITY RESILIENCE

Motivation

Communities in the Arctic are experiencing significant, rapid environmental, economic, and social changes from both natural and anthropogenic sources. Nevertheless, Arctic indigenous groups have a long history of adapting to challenges.

Ensuring the security of subsistence foods, practices, and affiliated social systems is critically important to the health and well-being of indigenous peoples.

To better understand community resilience during times of rapid change, researchers are investigating the adaptive strategies communities use to persevere and grow stronger.

Recommendations

- Identify present and future drivers of change that may affect Arctic residents.
- Integrate social and natural science with traditional and local knowledge.
- Highlight domestic and international research results of Arctic resilience strategies.
- Research shifting patterns of food consumption in the Arctic and the extent and impact of food and nutritional insecurity, with particular focus on effective adaptation strategies.

Photo credit: Mike Brubaker, ANTHC Center for Climate and Health

GOAL 6. ENHANCE INTERNATIONAL SCIENTIFIC COOPERATION IN THE ARCTIC

Motivation

Increasing demands for information and interdisciplinary research results, while research budgets are flat or declining, create a dilemma for Arctic states[3] and stakeholders. Enhanced international cooperation can build synergies between national programs and create efficiencies for the best use of limited resources to address Arctic scientific challenges that often extend beyond the jurisdiction of any one nation.

Recommendations

- During the US Chairmanship of the Arctic Council, the United States should encourage development of agreements that advance international scientific cooperation, including long-term observation and monitoring, and fulfill demands for information and synthesis from interdisciplinary research.
- As part of this initiative, the United States should pursue a formal agreement among governments for scientific cooperation in the Arctic Ocean. Such an agreement should establish a durable institutional structure to enhance and promote international scientific cooperation. This institutional arrangement could be modeled after ICES (the International Council for the Exploration of the Sea) or PICES (the Pacific ICES) but, unlike these two organizations, should be focused solely on the Arctic.
- In addition, the United States should pursue opportunities to strengthen research cooperation along our borders with the Russian Federation and Canada, including ecosystem-level marine research and long-term monitoring.

[3] Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, United States

The following pages (pp. 4–22) provide examples of research topics affiliated with each of the six goals. They are not necessarily to be taken as priorities or as a comprehensive treatment of each goal. Rather, they serve as illustrations of the broad range of Arctic research areas.

Ocean Acidification: Impact on Fisheries

Global ocean acidity has risen by 30% because the ocean has absorbed significant amounts of excess human-produced carbon dioxide (CO_2). Arctic and sub-Arctic waters are particularly prone to ocean acidification (OA) because they are colder and less salty due to freshwater input from melting sea ice and large rivers. These factors allow more CO_2 to dissolve into seawater, thus increasing OA.

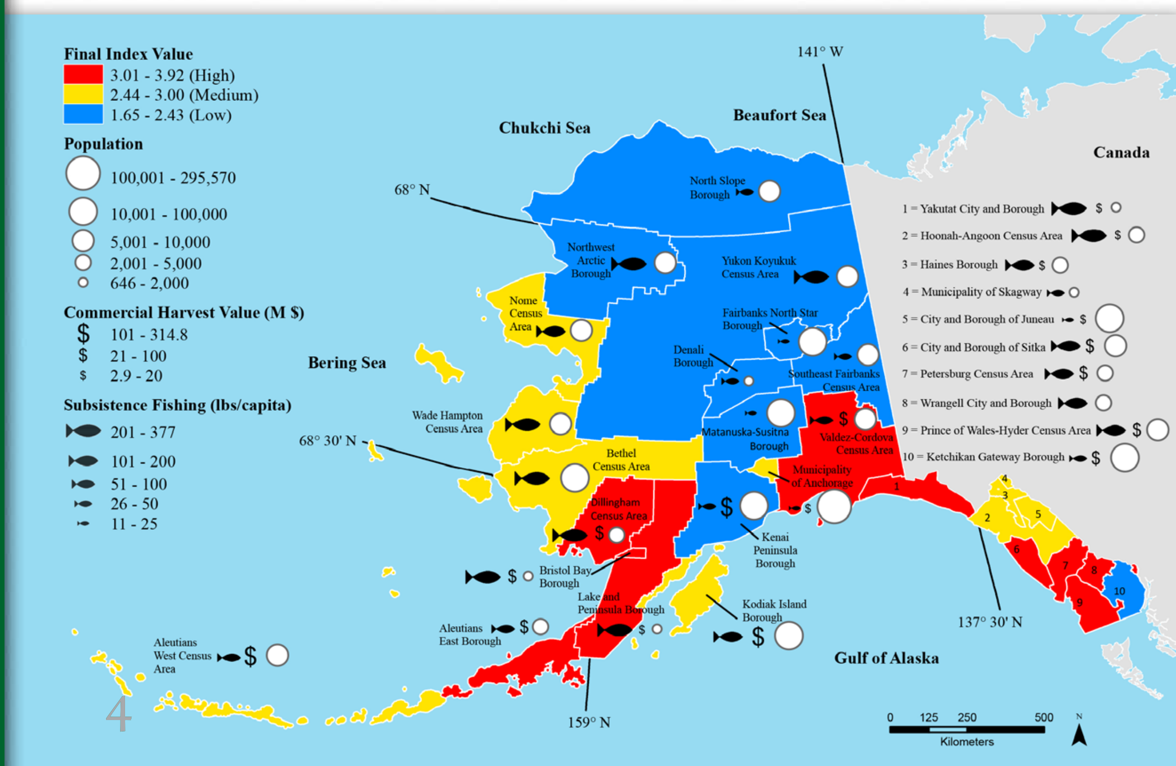
OA research has now broadened into studies of impacts on marine organisms, including shellfish, salmon, cod, pollock, halibut, and other finfish, which are key economic resources in northern seas. Alaskan waters host the nation's most highly productive fisheries, which benefit both commercial and subsistence users. These fisheries will be subjected to greater OA, warming temperatures, decreasing sea ice, and other environmental changes.

OA diminishes the ability of certain algae and animals to form shells. These creatures, at the base of food webs, are consumed by economically important species, such as pink salmon. Scientists have already observed the direct impacts of higher acidity on fish, particularly at the embryonic, larval, and juvenile stages. More research is needed on how increased OA affects fish growth, reproduction, and behavior.

How will these fisheries respond to such environmental pressure? Will some species continue to thrive while others decline? What will be the socioeconomic effects? Are socioeconomic adaptation strategies being developed? As an initial step in addressing these questions, the risk of OA to Alaska's fisheries has been assessed.[4] Regions in southeast and southwest Alaska currently show the highest risk.

USARC continues to support NOAA's OA program, particularly as it relates to fisheries in the Bering Sea and marine mammals in the Chukchi and Beaufort Seas, and calls for reauthorization of the Federal Ocean Acidification Research and Monitoring Act of 2009. USARC also encourages greater international partnering, such as through the Global Ocean Acidification Observing Network, as will be emphasized during the US Chairmanship of the Arctic Council in 2015–2017.

[4] Mathis, J.T., S.R. Cooley, N. Lucey, S. Colt, J. Ekstrom, T. Hurst, C. Hauri, W. Evans, J.N. Cross, and R.A. Feely. 2015. Ocean acidification risk assessment for Alaska's fishery sector. *Progress in Oceanography*, http://dx.doi.org/10.1016/j.pocean.2014.07.001.



Ocean acidification risk assessment by census area. *From Mathis et al. (2015)*

Soot on Snow: The Black Carbon Problem

ABOVE. Fire burns at the Funny River area on May 25, 2014. The Funny River Fire in the Kenai-Kodiak Area Forest in Alaska began on May 19, 2014, from an unknown cause and consumed 195,858 acres. *USFS photo by Josh Turnbow*

RIGHT. Oil rig in the Beaufort Sea (Canada). *Photo credit: Ocean photography*

While increased emissions of human-produced CO_2 remain the primary and long-term cause of warming and climate change, short-lived climate pollutants (SLCPs) also contribute. The good news is that compared to CO_2, SLCP emission reductions may prove easier to implement, and would slow the rate of Arctic snow, sea ice, and sheet ice melting in the near term.

SLCPs include ozone, methane, and most importantly, black carbon (BC) or soot, which absorbs the sun's heat and then warms the atmosphere and melts the snow and ice beneath it. When BC settles on snow and ice, it darkens their bright white surfaces, reducing reflectance of sunlight back into space, and thus heating the surface. BC has warmed the Arctic to about the same extent as methane,[5] but great uncertainty remains about the magnitude and timing of methane release from Arctic sources associated with thawing permafrost, both on land and within the seabed.

Most BC, produced from burning of forests, biomass, and coal, originates outside the Arctic. But in the North, one study[6] suggests that over 40% of BC is produced by "gas flaring" (gas combusted, via stacks, at industrial sites), with lesser amounts from residential combustion (e.g., domestic diesel engines and generators), and exhaust from ships, planes, and other vehicles.

About one-third of BC's warming effects in the Arctic can be attributed to emissions from the eight Arctic states. Scientists estimate that up to 75% of global BC emissions could be eliminated by 2030 by further reducing domestic and commercial fossil fuel burning, agricultural burning, wildfires, and gas flaring.

[5] AMAP. 2015. *Summary for Policy-makers: Arctic Climate Issues 2015.* Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, 16 pp, http://www.amap.no/documents/download/2223.

[6] Stohl, A., Z. Klimont, S. Eckhardt, K. Kupiainen, V. P. Shevchenko, V. M. Kopeikin, and A. N. Novigatsky. 2013. Black carbon in the Arctic: The underestimated role of gas flaring and residential combustion emissions. *Atmospheric Chemistry and Physics* 13:8,833–8,855, http://dx.doi.org/10.5194/acp-13-8833-2013.

USARC calls for greater support of research at NOAA, EPA, DOE, the Aleutian Pribilof Island Association and the Arctic Alliance, among others, to improve the temporal and spatial resolution of SLCP emissions monitoring. This monitoring, as called for by the Arctic Council, and modeling, such as to refine model representation of the BC seasonal cycle in the Arctic and to more accurately treat BC at the microphysical and optical scales, will be helpful. Better quantification of gas flaring emissions of BC is also needed, as are targeted aerosol and atmospheric composition measurements at various distances from sources.

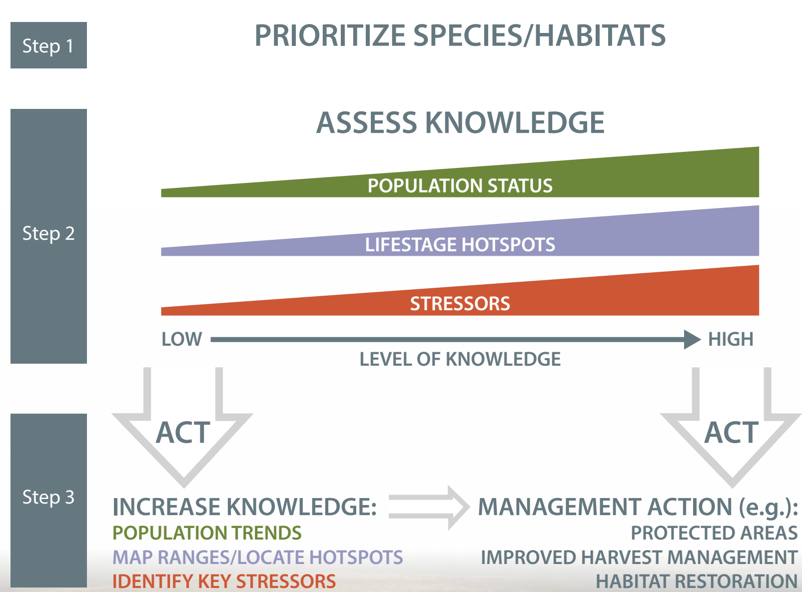
Arctic Biodiversity

Biodiversity (variety of life) is the hallmark of healthy, resilient ecosystems. Maintaining biodiversity is important to humanity because we need healthy ecosystems to provide the natural services on which we rely, such as food and nutrients, building materials, medicine, clean air, and freshwater. Biodiversity is threatened by population growth, resource consumption, climate change, environmental degradation, and invasive species.

Biodiversity is in decline. Because it is measured in many different ways, agreed-upon metrics of biodiversity are urgently needed to improve conservation policy decisions. Biodiversity indicators must be matched to conservation targets. Policy decisions should be sensitive to the anticipated loss of biodiversity. The design of the indicator and the quality of data that underpin it must be rigorously tested.

Species richness in polar ecosystems is inherently lower than in lower latitudes ecosystems, but it can vary spatially and be patchy. For reasons still not entirely clear, populations of Arctic migratory birds, such as the gyrfalcon and peregrine falcon, the willow and rock ptarmigan, the long-tailed jaeger, and Ross's and ivory gulls have declined dramatically in recent years. These declines, likely linked to human-induced climate and environmental change, reverberate through food webs, affecting prey and habitat.

Research by the Department of the Interior and others is needed to better understand how Arctic birds and their prey are faring throughout the circumpolar world. To this end, the Arctic Council's Arctic Migratory Bird Initiative, conducted by the Conservation of Arctic Flora and Fauna working group, is designed to "improve the status and secure the long-term sustainability of declining Arctic breeding migratory bird populations." It will prioritize studies of species or habitats based on the urgency of the conservation need or the benefits to multiple species, assess the state of knowledge for each of the priority species or habitats, and improve the conservation status of priority species by identifying direct actions that should be taken. The Arctic Council's broader assessment of Arctic biodiversity can be found at http://www.arcticbiodiversity.is.



The migratory bird initiative will have three steps. In the first, species and habitats will be prioritized based on conservation urgency or the benefits to multiple species. In the second, the state of knowledge for priority species or habitats will be assessed. The final step will be taking action to improve the conservation status of priority species.

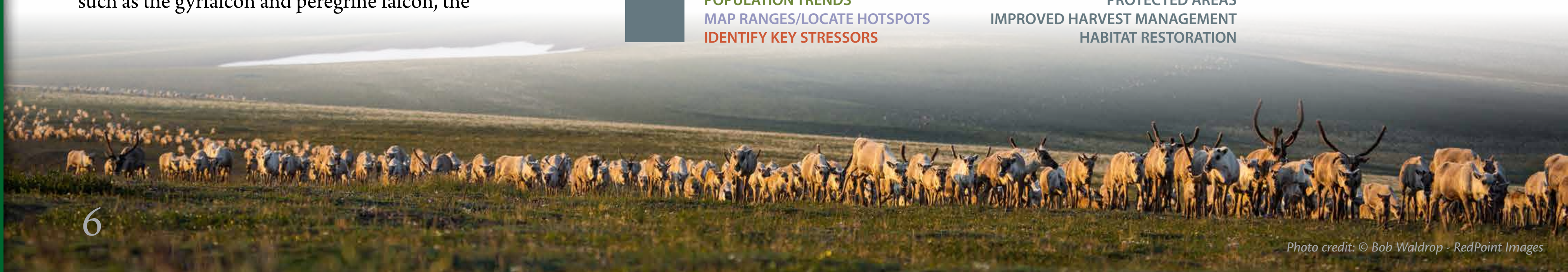


Photo credit: © Bob Waldrop - RedPoint Images

Greater Precipitation...But Drier Ground?

Within 100 years, Arctic precipitation is projected to increase by 50%, the highest rise anticipated globally. The additional rainfall will transform river systems,[7] permafrost, evapotranspiration, and other elements of the landscape. Increased river flow to the Arctic Ocean, coupled with freshwater input from melting of adjacent land ice, will continue to lower ocean salinity, change ocean temperature structure, influence biological productivity, and possibly even slow global ocean circulation.


Photo credit: Derrick Midwinter

What causes this increase in precipitation? Is it due primarily to greater evaporation in the Arctic or to enhanced inflow of moisture from lower latitudes? Recent research favors the former. The evaporation argument[8] suggests that the decline in sea ice, primarily during the winter months, leads to greater moisture transport to the atmosphere, which in turn strengthens the Arctic's hydrological cycle and possibly even weakens the polar vortex.[9] A consequence is invasion of Arctic air masses into the mid-latitudes, such as occurred in recent years in Washington, DC, and, conversely, northward flow of warm air masses far into parts of the Arctic.

Whether the Arctic land surface becomes wetter or drier remains an open question, and a critically important one to address because it affects local vegetation, carbon fluxes, and practically all biological and physical processes in the terrestrial ecosystem. Despite greater overall precipitation, warming-induced degradation of permafrost enables surface waters to infiltrate to the surface groundwater, contributing to increased river runoff and drying the land surface in many regions, but not all. Drying stresses vegetation, and increases the risk of fires.

USARC recommends greater research to untangle the processes associated with the paradox of greater precipitation yet drier land.

[7] Zhang, X., J. He, J. Zhang, I. Polyakov, R. Gerdes, J. Inoue, and P. Wu, 2013. Enhanced poleward moisture transport and amplified northern high-latitude wetting trend. *Nature Climate Change* 3:47–51, http://dx.doi.org/10.1038/nclimate1631.

[8] Binta, R., and F.M. Selten. 2014. Future increases in Arctic precipitation linked to local evaporation and sea-ice retreat. *Nature* 509:479–482, http://dx.doi.org/10.1038/nature13259.

[9] Kim, B.-M., S.-W. Son, S.-K. Min, J.-H. Jeong, S.-J. Kim, X. Zhang, T. Shim, and J.-H. Yoon, 2014. Weakening of the stratospheric polar vortex by Arctic sea-ice loss. *Nature Communications*, http://dx.doi.org/10.1038/ncomms5646.


Photo credit: Alaska EPSCoR NSF award #OIA-1208927 and the state of Alaska

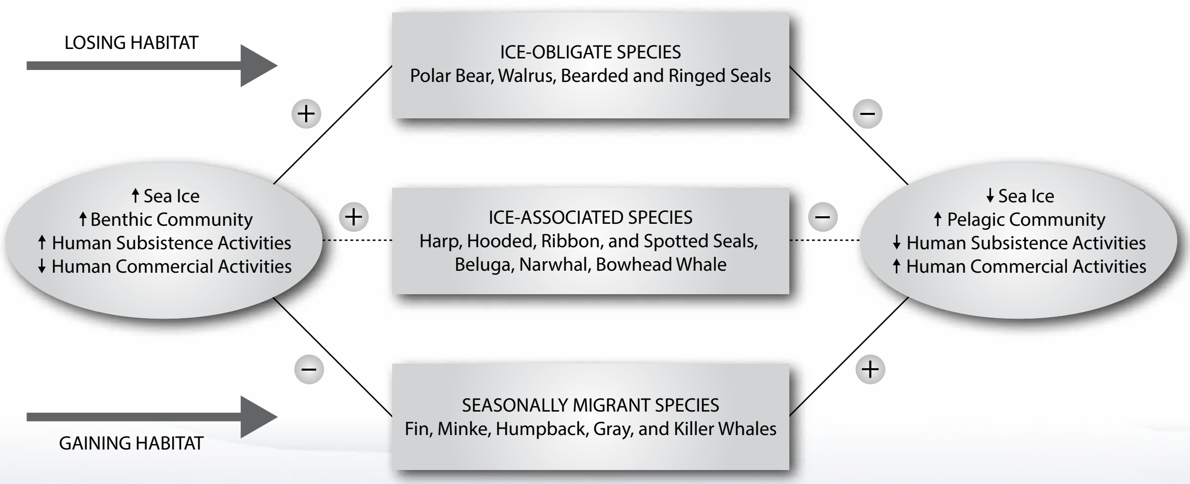
"Winners" and "Losers"

Extreme and rapid reductions in Arctic sea ice are changing ecosystem dynamics, producing "winners and losers" among top predators in the marine fish, bird, and mammal realms. These modifications to the environment directly affect the subsistence and cultural practices of indigenous peoples.

The loss of habitat as sea ice diminishes stresses "loser" species such as polar bears, walrus, and some seals, which rely on sea ice for hunting prey, giving birth, and resting. In response, Pacific walrus are coming ashore in record numbers, such as the haul out of over 35,000 individuals near Point Lay in October 2014. This population has decreased by roughly 50% between 1981 and 1999, the last year for which detailed demographic data are available. In 2017, the US Fish and Wildlife Service is expected to determine whether walrus should be listed as threatened under the Endangered Species Act. Research on population dynamics, such as that conducted by the US Geological Survey, will inform that decision.

"Winner" species are those less or minimally dependent on sea ice, such as bowhead, gray, and humpback whales. There have been significant increases in their population size and improvements to their body condition. The bowhead population is increasing at a rate of 3.7% per year,[10] which is fast for animals that are long-lived with long gestation periods and one birth per pregnancy. The bowhead population is returning to the level that existed before commercial whaling began in the late nineteenth century. Even more surprising is the 7% increase observed in North Pacific humpback whales.[11]

"Winner" status may not endure, however, as change is the norm. For example, as ice diminishes, killer whales, which prey on bowheads, are able to penetrate further north and for longer periods. This increases the odds of attacks not only on bowheads and gray whales, but also on narwhals, belugas, and other marine mammals, potentially affecting calf survival and population status in the future.



The response of marine mammal species to sea ice loss is mediated by their reliance on it for key aspects of their life history. Sea ice loss has stressed some populations of ice-obligate species (losers) but appears advantageous for seasonally migrant species (winners). Modified from Figure 9 in Bhatt et al. (2014, http://dx.doi.org/10.1146/annurev-environ-122012-094357), and used with permission of *Annual Reviews*.

[10] Givens, G.H., S.L. Edmondson, J.C. George, R. Suydam, R.A. Charif, A. Rahaman, D. Hawthorne, B. Tudor, R.A. DeLong, and C.W. Clark. 2013. Estimate of 2011 abundance of the Bering-Chukchi-Beaufort Seas bowhead whale population. SC/65a/BRG01.

[11] Clarke, J., K. Stafford, S.E. Moore, B. Rone, L. Aerts, and J. Crance. 2013. Subarctic cetaceans in the southern Chukchi Sea: Evidence of recovery or response to a changing ecosystem. *Oceanography* 26(4):136–149, http://dx.doi.org/10.5670/oceanog.2013.81.

Background photo credit: Patrick Kelley, US Coast Guard

Arctic Observing Network…
The Long Wait

“Models without data will never get you to reality.
Data without models will never get you to the future.”

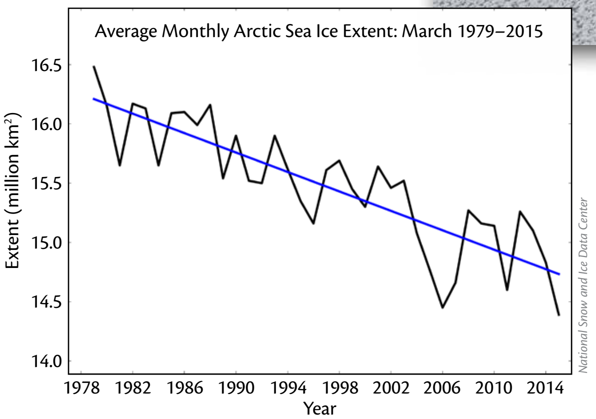
– RADM David Titley (USN retired)

ABOVE. USS *New Mexico* (SSN 779) surfaces during Ice Exercise 2014. The SCience ICe EXercise (SCICEX) program provides Arctic observations collected by submarines, such as water depth, sea ice thickness, and water chemistry and biology. See http://nsidc.org/scicex. *Photo credit: US Navy Mass Communications Specialist 2nd Class Joshua Davies*

Long-term observations of climate and the environment are an essential foundation of Arctic research. Without them, it is impossible to document change, including the spatial extent and rate of change.

One of the most iconic long-term observations is NASA’s satellite record of Arctic sea ice. In the first decade of the times series, minimal changes were observed. A marked decline began in the 1990s and continued in the 2000s. Now, during peak summer, we observe an Arctic Ocean with 50% lower sea ice cover, and a 75% reduction in ice volume, than in 1980. Without the early benchmark results, we would have no basis against which to assess the timing, extent, and rate of the dramatic decline.

Unfortunately, this success has not been widely replicated in the Arctic. Other times series of environmental data exist, but many more observations, and at a higher spatial and temporal resolution, are needed. Integration of these data and the derivation of products for use by researchers and other stakeholders are also required.



Establishing and funding an enduring international program, based on rigorous research standards, to make and provide coordinated observations of key Arctic environmental parameters is no small task. But the broader scientific community, funded by government agencies, has done this before, and so has a template for taking action in the Arctic.

For example, USARC points to campaigns by the international scientific ocean drilling community that stretch back to 1975. The most recent effort is the 10-year International Ocean Discovery Program that started in 2013. Government funding agencies from 26 nations commingle contributions (in excess of $100M per year with about $50M from the US NSF) to support scientific operations aboard vessels and in onshore labs and repositories (http://www.iodp.org/new-program). A regularly updated and rigorously reviewed science plan guides the program. International scientific parties conduct operations, complete research, and publish results.

Climate and Health

Temperature and humidity regulate the development, survival, and reproduction of pathogens, which are biological agents that cause disease or illness. A warming climate also alters the habitat ranges and survival of pathogen hosts and vectors. The Arctic is experiencing a disparate rate of warming compared to non-Arctic regions, and researchers are interested in what impact this will have on climate-sensitive infectious disease agents.

Alaskan subsistence consumers depend heavily on local natural resources, which are affected by climate change. As a result, the relationship between people and their surrounding physical, chemical, and biological environments strongly connects to public health. Wildlife-associated health and safety hazards may present risks to more citizens than ever before.

Among programs examining the climate change/infectious disease connection, the Alaska Native Tribal Health Consortium coordinates an Alaska-based "One Health" group made up of human health experts, biologists, veterinarians, and environmental scientists. The "One Health" concept, also advocated by the Centers for Disease Control and Prevention (CDC), is the interdisciplinary integration of human, animal, and environmental health. Interest in this concept has increased due to the rise of zoonotic[12] infectious diseases over the past decade (e.g., Lyme disease). Wildlife-associated health and safety hazards present risks to more citizens than perhaps ever before, and given the aforementioned rate of climate change in the Arctic, the circumpolar region is likely to be disparately affected.

The International Circumpolar Surveillance Climate Change and Infectious Disease Working Group, affiliated with the Arctic Council's Sustainable Development Working Group, connects public health laboratories, institutes, and academic centers to monitor and share information on infectious diseases in the Arctic, with an emphasis on links to climate change.

USARC strongly supports the efforts of both groups to:

- ***Improve disease surveillance and early detection/intervention planning in the circumpolar North, especially with respect to climate-sensitive diseases***
- ***Improve baseline information on the prevalence of these infectious diseases in humans, wildlife, and the environment***
- ***Monitor the impacts of climate change on potential vectors of disease in the Arctic***


Photo credit: Penny Jack

[12] A zoonotic disease is a disease that can be passed between animals and humans (Centers for Disease Control and Prevention National Center for Emerging and Zoonotic Infectious Diseases, 2013).

Arctic Health Care Delivery

The science of health care delivery focuses on how patients receive care, with the goal of improving health care quality, outcomes, and cost-effectiveness. Health care organizations worldwide are under mounting pressure to deliver greater value and increased efficiency while improving their quality of care. Expectations in the Arctic are no different, despite the huge geographic service areas with low population densities, few to no road systems, extreme weather conditions, and high costs of living.

At the same time, Arctic residents are experiencing rapidly changing patterns of population age distributions, mortality, life expectancy, and causes of death that profoundly affect their health.[13] Although there have recently been significant health and life span improvements, Arctic health systems have a unique set of challenges to contend with, and many health disparities exist between people in a given nation's Arctic regions and their larger, non-Arctic population. Nunavut has the unenviable distinction of having the highest per capita health expenditures in the world, with communities in other Arctic nations close behind. Unfortunately, health care outcomes are not concomitantly high.

Progress is being made to improve the quality of Arctic health care, but more is needed. Ellsworth and O'Keefe provide a comprehensive summary of the major national health care delivery systems operating in the Arctic.[14] While each system is unique, they all require relevant, high-quality, Arctic-specific health data. The provision of robust data is critical to the development of effective health care approaches, and is strongly supported by USARC. Educating local residents, thus allowing them to serve as part of their health care delivery system, is also an effort that has shown promise.[15]

Remote telemedicine systems and other e-health applications can offer significant technical and clinical benefits when applied to broader-based systems serving large, isolated populations. Improving the utility of telemedicine technology for both physical and mental health diagnostics/treatment paired with the use of mobile and other types of self-monitoring devices to track patient-level health data shows great potential and should be supported. Mobile data can provide real-time health information to practitioners, making the job of providing remote health care easier and more accurate, leading to improved health outcomes for Arctic residents.

[13] Bjerregaard, P., G. Mulvad, and J. Olsen. 2003. Studying health in Greenland: Obligations and challenges. *International Journal of Circumpolar Health* 62(1):5–16.

[14] Ellsworth, L., and A. O'Keefe. 2013. Circumpolar Inuit health systems. *International Journal of Circumpolar Health* 72:21402, http://dx.doi.org/10.3402/ijch.v72i0.21402.

[15] Webster, P. 2009. Local control over Aboriginal health care improves outcome, study indicates. *Canadian Medical Association Journal* 181(11), http://dx.doi.org/10.1503/cmaj.109-3072.

[16] Ward, L., I. Gouboury, M. Ladhani, and S. Zlotkin. 2007. Vitamin D-deficiency rickets among children in Canada. *Canadian Medical Association Journal* 177:161–166.

Preventable Conditions Continue to Afflict Inuit Children

Rickets, a childhood bone disorder caused by a deficiency in vitamin D, calcium, or phosphate, is a preventable condition rarely found in developed countries. Research shows the incidence of vitamin D-related rickets to be over 12 times higher in Nunavut than nationwide,[16] and Canadian government surveys find that 80% of Nunavut's expectant mothers receive insufficient vitamin D. These conditions continue despite government protocols aimed at eliminating the problem. Investigations into the reason behind the persistence of these problems are underway, with failure in health care delivery among the possible explanations.

Photo courtesy of ADEC, Alaska Water and Sewer Challenge

Arctic Air Quality and Human Health: Outdoors and Indoors

Despite their remote location, Arctic residents have cause to be concerned about the air they breathe, both outside and inside their homes.

- Diesel generators, used to generate electricity in remote communities, produce particulate soot (black carbon) and other air pollutants via exhaust from combustion.
- The cold climate means people spend a lot of time indoors in heavily insulated, air-tight homes where indoor air pollution and humidity can rise to unhealthy levels. Humidity can also lead to mold growth.
- Indoor smoking causes aerosolized fine particulate pollution.
- Many homes are heated by older, inefficient wood stoves that create air pollution. Indoor carbon monoxide levels can be high from unventilated combustion.
- Frozen ground prevents burying waste in landfills. As a result, many communities burn trash, creating air pollution.
- Dust from unpaved roads may contain pollutants that can be inhaled or deposited on subsistence food sources.[17,18]

Further compounding the problem, the Arctic's unique geographical and climate characteristics make it a reservoir for a variety of pollutants from around the globe. "Arctic haze" is a persistent, brown haze that causes limited visibility on the horizons of the Arctic sky in winter and spring. Made up of a complex mix of microscopic particles and acidifying pollutants such as soot, hydrocarbons, and sulfates, it is caused by pollutants from the heavily populated and industrialized areas of Europe, North America, and Asia. Emissions from marine vessels exploiting newly accessible shipping routes also contribute to the problem.

USARC recommends that the US continue to participate in efforts to monitor black carbon in the Arctic. USARC also encourages research on indoor air quality, such as source testing, modeling, and technologies to improve quality, by using cleaner fuels for ships and more efficient diesel generators/renewable energy sources in villages. Furthermore, the human health impacts of poor indoor air quality, especially on children, warrants further investigation. Finally, USARC suggests research to advance approaches to improve indoor air exchange/filtering that are financially feasible for most Arctic residents.

Photo credit: Frank Matumeak

[17] Alaska Native Village Air Quality Fact Sheet Series: Indoor Air. EPA Region 10, http://www.epa.gov/region10/pdf/tribal/anv_indoor_air_040114.pdf.

[18] Alaska Rural Communities Emissions Inventory, Report No. SR2007-02-01 to the Alaska Department of Environmental Conservation (2007).

Innovative Approaches to Arctic Water and Sanitation Problems

Reliable access to sufficient quantities of clean water is essential for healthy Arctic communities. Access to freshwater sources, as well as to water storage and treatment infrastructure, is under threat in remote Arctic communities, in part due to climate change. Recent research has shown that in communities where there is ample clean water for hand washing, residents are less likely to contract and transmit certain diseases and viruses. In most rural Arctic communities, however, the cost of water is significant and often leads to water rationing and resulting health problems.

Innovative technologies may be a partial solution to this problem. An example of this is the application of gray water[19] recycling technologies to in-home systems in rural Alaska. Flushing toilets with water previously used during showering or while washing clothes not only saves on the amount of delivered water used (and charged for), but also decreases the amount of wastewater that must be hauled away from the home.

To encourage innovation of this sort, the State of Alaska is currently sponsoring "The Alaska Water and Sewer Challenge."[20] In 2013, a request for proposals was released aiming to stimulate worldwide research to develop innovative and cost-effective decentralized[21] water and sewer systems for individual homes in remote Alaska villages.

With decentralized water and sewer technology, homeowners would not have to hook into a community-wide utility. Each home would have its own stand-alone system, likely avoiding much of the cost to users (e.g., labor, fuel, heating, and maintenance) associated with piped and truck haul systems. Similarly, there would be a reduction in capital costs associated with centralized systems, such as distribution and collection pipes, service lines, utilidors,[22] lift stations, water treatment plants, boardwalks, and roads.

The goals of this challenge—decreasing user and capital costs of running water and sewer, and improving access to adequate water quality and quantity—will ultimately improve health outcomes in rural Alaska homes. Six teams have been selected to develop full proposals, due in mid-2015.

For additional information on water and sanitation issues in the Arctic, visit: http://www.arctic.gov/water-san.

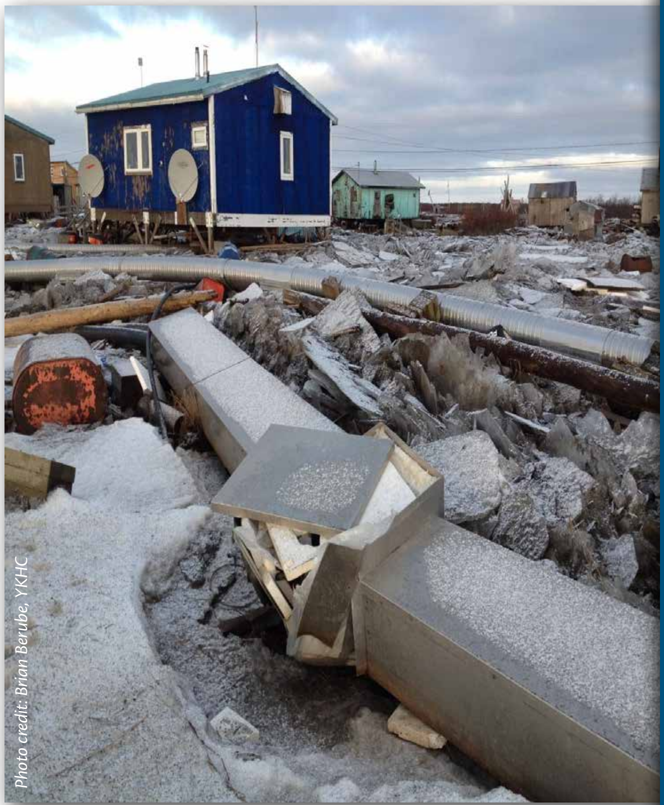


Photo credit: Brian Berube, YKHC

[19] The relatively clean waste water from baths, sinks, washing machines, and other kitchen appliances.
[20] http://dec.alaska.gov/water/watersewerchallenge/index.html
[21] non-piped
[22] A utilidor is a passage built underground or aboveground to carry utility lines such as electricity, water, and sewer pipes.

Domestic Violence in the Arctic

"Victims of 'intimate partner violence' experience severe and negative health and social consequences."

In 2014, Alaska once again ranked highest in the United States for the rate of women murdered by men,[23] and reports of rape are nearly four times the national average.[24] Similar disparities are reported in other Arctic nations, including Canada[25] and the Nordic countries.[26]

Each year, approximately two million women in the United States are physically assaulted by their intimate partners, leading to over 73,000 hospitalizations and 1,500 deaths.[27,28] Research has shown American Indian/Alaska Native (AI/AN) women are 2.5 times more likely to be sexually assaulted compared to all other races, and one in three AI/AN women report having been raped during her lifetime.[29]

The term "intimate partner violence" (IPV) describes physical, sexual, or psychological harm by a current or former partner or spouse. This type of violence can occur among heterosexual or same-sex couples and does not require sexual intimacy.[30] Victims of IPV experience severe and negative health and social consequences, including poorer physical and mental health and lower employment status.[31] Moreover, women with a history of IPV are more likely to display behaviors that present further health risks. Table 1 (p. 14) summarizes the health and behavioral impacts associated with IPV. In addition, child witnesses to IPV also experience significant trauma, and a large overlap exists between IPV and child maltreatment.[32]

Photo credit: Cindy Shake

Nationwide, when victims seek medical care, clinicians often do not screen for and identify domestic violence. In fact, the US Preventive Services Task Force indicates that few research studies exist that can help guide clinicians on how to screen for domestic violence and to manage care for identified victims.[33,34] Programs and counseling that will be effective in helping end this violence must be available for victim referrals. It is critical that health care providers partner with domestic violence and sexual assault programs to create safe, effective interventions and options for victims.

USARC supports the ongoing research and recommendations of the Agency for Healthcare Research and Quality and others. Additional research is needed on:

- *Long-term health impacts on victims and witnesses of IPV*
- *Culturally appropriate screening and treatment of Arctic domestic violence victims*
- *Identification and intervention: creating a coordinated, community-based response to identifying IPV, and creating effective interventions and programs that promote safety and healing*
- *Social and economic drivers of IPV in the Arctic*
- *Designing community responses that hold offenders accountable and offer services that provide opportunities for behavioral change*

Photo credit: Nicole Klauss

Table 1. Health and Behavioral Impacts Associated With IPV[35]

Physical
- Asthma
- Bladder and kidney infections
- Circulatory conditions
- Cardiovascular disease
- Fibromyalgia, chronic pain syndromes
- Irritable bowel syndrome, gastrointestinal disorders
- Migraines and headaches
- Central nervous system disorders
- Joint disease

Reproductive
- Gynecological disorders
- Pelvic inflammatory disease
- Sexual dysfunction
- Sexually transmitted infections, including HIV/AIDS
- Delayed prenatal care
- Preterm delivery
- Pregnancy difficulties like low birth weight babies and perinatal deaths
- Unintended pregnancy

Psychological
- Anxiety
- Depression
- Symptoms of post-traumatic stress disorder (PTSD)
- Antisocial/suicidal behavior
- Low self-esteem
- Inability to trust/be intimate with others
- Sleep disturbances
- Flashbacks/replaying assault in the mind

Social
- Restricted access to services
- Strained relationships with health providers and employers
- Isolation from social networks
- Homelessness

Behavioral
- Engaging in high-risk sexual behavior
- Using harmful substances
- Unhealthy diet-related behaviors
- Overuse of health services

[23] When Men Murder Women: An analysis of 2012 homicide data, Violence Policy Center (2014) http://www.vpc.org/studies/wmmw2014.pdf

[24] Federal Bureau of Investigation's Unified Crime Report for 2013

[25] National Strategy, Pauktuutit Inuit Women of Canada (2006)

[26] European Union Agency on Fundamental Right's Survey on gender-based violence against women (2014)

[27] Campbell, J., A.S. Jones, J. Dienemann, J. Kub, J. Schollenberger, P. O'Campo, A. Carlson Gielen, and C. Wynne. 2002. Intimate partner violence and physical health consequences. *Internal Medicine* 162(10):1,157–1,163, http://dx.doi.org/10.1001/archinte.162.10.1157.

[28] Tjaden, P., and N. Thoennes. 2002. Full report of the prevalence, incidence, and consequences of violence against women. 2002. National Institute of Justice and the Centers for Disease Control and Prevention, Washington D, Nov 2000, Pub No. NCJ 183781, https://www.ncjrs.gov/pdffiles1/nij/183781.pdf.

[29] Ibid.

[30] Saltzman, L.E., J.L. Fanslow, P.M. McMahon, and G.A. Shelley. 2002. Intimate partner violence surveillance: Uniform definitions and recommended data elements, version 1.0. Atlanta (GA). Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, http://www.cdc.gov/violenceprevention/pdf/ipv/intimate-partner-violence.pdf.

[31] World Health Organization. 2013. Global and regional estimates of violence against women: Prevalence and health effects of intimate partner violence and non-partner sexual violence. http://www.who.int/reproductivehealth/publications/violence/9789241564625/en.

[32] Appel, A.E., and G.W. Holden. 1998. The co-occurrence of spouse and physical child abuse: A review and appraisal. *Journal of Family Psychology* 12:578–599, http://dx.doi.org/10.1037/0893-3200.12.4.578.

[33] Nelson, H.D., P. Nygren, Y. McInerney, and J. Klein. 2004. Screening women and elderly adults for family and intimate partner violence: A review of the evidence for the US Preventive Services Task Force. *Internal Medicine* 140(5):387–396, http://dx.doi.org/10.7326/0003-4819-140-5-200403020-00015.

[34] US Preventive Services Task Force. 2004. Screening for family and intimate partner violence: recommendation statement. *Internal Medicine* 140(5):382–386, http://dx.doi.org/10.7326/0003-4819-140-5-200403020-00014.

[35] From the CDC website: http://www.cdc.gov/violenceprevention/intimatepartnerviolence/consequences.html.

Renewable Energy

"The poorest Alaskan households spend up to 47% of their income on energy, more than five times their urban neighbors."[36] In rural Alaskan communities, electricity is generated by small local systems using diesel fuel.[37] In the winter, a village home can use up to five 55-gallon drums of heating oil each month, spending up to $2,000 every 30 days.[38] This phenomenon is not limited to the Alaskan Arctic. High and rising energy costs from fossil fuels create long-term incentives that further support the economic case for expanding renewable energy sources in the Arctic.

ARCTIC WIND POWER

Alaska's most promising wind resources are located in its western and coastal areas, with several projects already producing energy.[39] Though the technology has advanced greatly in the last decade, the wind industry still encounters technical, environmental, and policy barriers to expanded deployment and re-powering, for which technical research and demonstration projects may offer solutions. Needs include: improved anti-icing and de-icing technology and assessment;[40] assessments of transmission requirements and methods to transport wind-generated electricity from remote sites to load centers; improved wind energy forecasting tools; and improved wind plant models for analyzing interaction with the grid.

SOLAR POWER IN THE ARCTIC

Solar energy, among all renewables, is the most abundant energy source available in the Arctic. One might think that winter low-light conditions would preclude the use of solar power in the region, but many areas of the Arctic receive ample amounts of sun year-round, and the cold and reflectivity of ice/snow actually make these systems more efficient. Yet, challenges still exist. As solar irradiation is not evenly distributed throughout the year, there is a great need for energy storage. Many research questions related to usage of solar energy, forecasting, measuring, and storage in cold climates require further examination.

GEOTHERMAL POTENTIAL

Geothermal energy, found in many Arctic locales, may be used to produce electricity for commercial, industrial, and residential direct heating purposes, and for efficient home heating and cooling through geothermal heat pumps. In 2009, Iceland's Krafla-based geothermal drilling project hit magma at 2,100 m below the surface. It became the world's first and only magma-enhanced geothermal system, a serendipitous success that could lead to a revolution in the energy efficiency of high-temperature geothermal areas worldwide. In Iceland, geothermal energy generation is tied into the national electric grid.

Chena Hot Springs (CHS), the lowest temperature geothermal plant operating in the world, was the first geothermal project to be completed in Alaska (2006). In contrast with Iceland, CHS is located in an off-the-grid Alaskan setting, with a 400 kw geothermal plant that displaces approximately 160,700 gallons of diesel fuel each year. Besides CHS, a project is underway in Hot Springs Bay Valley on the island of Akutan, and a feasibility study is being conducted at Pilgrim Hot Springs (near Nome). Additional research is needed in geothermal technology, optimal placement of geothermal power plants, and related economics.

[36] Energy for a Sustainable Alaska: the Rural Conundrum. A Commonwealth North Study Report, February 2012, http://www.alaskapower.org/pdf/CommonwealthN_FINAL.pdf.
[37] Alaska Energy Authority, Rural Power System Upgrade Program, http://www.akenergyauthority.org/Programs/RPSU.
[38] Alaska Energy Brief, Alaska Federation of Natives, May 2012, http://www.nativefederation.org/wp-content/uploads/2012/10/2012-afn-cap-alaska-day-brief.pdf
[39] Renewable Energy Atlas of Alaska, Alaska Energy Authority/Renewable Energy Alaska Project, 2013, http://www.akenergyinventory.org/data.
[40] IEA Wind 2013 Annual Report. August 2014, https://www.ieawind.org/annual_reports_PDF/2013/2013%20AR_small_090114.pdf

IMPROVED ENERGY STORAGE NEEDS

Significant research needs remain in the areas of battery technology and energy storage, needs especially applicable to the Arctic—a place prone to uneven renewable energy supply. Current research being conducted by the Department of Energy and others focuses on technologies such as "flow" batteries and methods that allow the storage of energy for later use as heat. The challenge is to keep these approaches environmentally sustainable, scalable, and cost-effective.

GEOLOGY IS KEY: "ENERGY-CRITICAL ELEMENTS"[41]

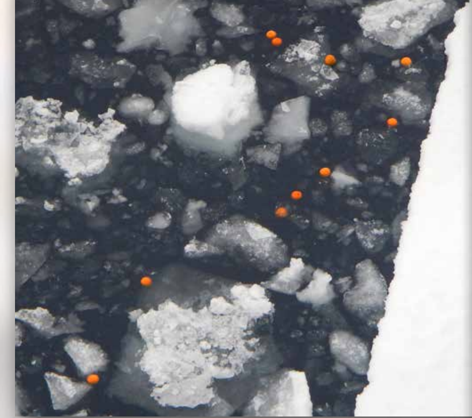
Meeting domestic and worldwide energy needs with renewables, such as wind and solar, requires certain rare earth resources. Significant quantities of these minerals will be needed in the future; shortages could significantly inhibit the adoption of renewable technologies. About 30 rare earth elements are considered critical to renewable energy development, including neodymium, a key component of the magnets used in wind turbines and hybrid vehicles.[42] Presently, China dominates the market for these elements. Reliable access to these elements is vital, and research is needed to better understand the geology, metallurgy, and mining engineering of these critical mineral deposits.

[41] *Energy Critical Elements: Securing Materials for Emerging Technologies*. A Report by the APS Panel on Public Affairs and the Materials Research Society. February 2011. American Physical Society, Washington, DC, 23 pp, http://www.aps.org/policy/reports/popa-reports/upload/elementsreport.pdf.

[42] Humphries, M. 2013. *Rare Earth Elements: The Global Supply Chain*. Congressional Research Service 7-5700, https://www.fas.org/sgp/crs/natsec/R41347.pdf.

[43] National Academy of Sciences. 2014. *Responding to Oil Spills in the US Arctic Marine Environment*. National Academies Press, Washington, DC, 210 pp.

Oranges Are Not Oil



Oranges thrown in ice-infested Arctic waters to simulate an oil spill. *Photo credit: USCG*

In support of the recommendation from the National Academy of Sciences,[43] USARC recommends that the Interagency Coordinating Committee on Oil Pollution Research, in cooperation with other federal entities, develop guidelines to enable researchers to plan and conduct deliberate releases of crude oil in US waters.

Knowledge of how to prepare and respond to Arctic oil spills is gained by conducting scientific research on how oil in the marine environment weathers, how the presence of ice influences the spill, and the effectiveness of response technologies (detection and removal). Test tanks, such as the Ohmsett research facility in New Jersey, have been used to simulate spills in icy conditions, but results are not directly comparable to deliberate releases of oil in marine environments. This underscores the importance of conducting open-water controlled science experiments using a well-designed intentional release.

Norway is one of the few countries that allows researchers to intentionally spill oil, but conditions in the North Atlantic are not sufficiently equivalent to those faced in the US Arctic. Deliberate spills of oil in the field for research purposes have not been permitted in the United States for over 15 years. Instead, scientists have had no choice but to turn to oil surrogates and simulants, such as green and red dye, peat moss, rice hulls, rubber ducks, dog food, and even oranges (see photo). Not surprisingly, scientists conclude that none of these surrogates are effective substitutes for oil.

While small oil releases in the marine environment have few to no discernible negative environmental impacts, the knowledge gained from such experimentation could be substantial, and would also provide an opportunity to train first responders and evaluate response technologies and assumptions.

Toward a Deep-Draft Seaport in the US Arctic Above 60°N

The increase in maritime activity in the US Arctic for scientific research as well as for oil and gas activities, fishing, shipping, and tourism underscores the pressing need for a regional deep-draft harbor as part of a larger US Marine Transportation System. The closest US port to Alaska's North Slope is in Dutch Harbor, 1,000 nautical miles from the Chukchi Sea. This location is too far from the high Arctic to viably serve as a harbor of refuge and a port from which to stage search and rescue activities and spill response north of the Bering Strait. Federal and state entities have been studying this issue and anticipate developing a system of deep-draft harbors throughout northwestern Alaska in places such as Nome, Port Clarence near Brevig Mission, and Teller.

Building upon its own previous studies, and those from the US Coast Guard and the Alaska State Department of Transportation and Public Facilities, the US Army Corps of Engineers (USACE) Alaska District released a draft feasibility report for a $210M project to dredge the existing harbor in Nome to a depth of 28 feet, extend the causeway by 2,150 feet, and construct a 450-foot vessel dock.

Port of Nome. *Photo courtesy of the US Army Corps of Engineers*

The design and construction of this port will hinge on civil engineering research, including considerations of how climate change will affect the port. Given the anticipated design life, how will the project mitigate or adapt to rising sea levels and increased storm surges? The feasibility report cites a study that estimates the 50-year storm surge water level at Nome to be +9.66 feet "mean lower low water." The report also estimates a sea level rise as high as +1.97 feet by the year 2070. How rigorous are these estimates, and their error bars, especially in light of the powerful storms that have hit Nome over the past decade? Engineering atlases may be based on outdated climatological data, given the frequency with which 50- and even 100-year storms are actually occurring.

Given the rapidity of environmental change, USARC recommends more frequent updating of engineering guidance documents that address sea level rise, and the degree and frequency of storm surges and wave setdowns, among other factors. Greater emphasis needs to be placed on civil engineering research in waterways, ports and harbors, resilient infrastructure, coastal and environmental remediation, and ecosystem restoration.

Standards for

Offshore Arctic Operations

The Orlan Platform in the Chayvo field in the sub-Arctic (Sakhalin). *Photo reprinted with permission from Exxon-Mobil (http://corporate.exxonmobil.com/en/energy/arctic/presence/our-arctic-presence)*

"Nothing ever works the same in the Arctic," is one of George Newton's (former USARC Chair and current advisor) five rules for the Arctic. It is certainly true that materials, equipment, and structures designed for operation in non-Arctic environments may fail when deployed in the cold, dark, and distant North.

Fortunately, some standards have been developed and more are on the way to ensure that products and services are safe, reliable, and of good quality. Following these standards may help save lives and protect the environment, and adherence increases the bottom line for businesses, reducing costs, minimizing waste and errors, and increasing productivity.

The International Organization for Standardization (ISO), an independent, nongovernmental membership organization that has published nearly 20,000 voluntary international standards, has standards (see ISO 19906:2010) for Arctic offshore structures for petroleum and natural gas industries.

An associated technical subcommittee (ISO TC 67 SC8) is currently developing additional design standards for Arctic operations. The subcommittee, with participants from 12 countries (including the United States, Canada, and Singapore), is focusing on a number of topics, including: ice management; escape; evacuation and rescue; environmental monitoring; working environment; Arctic materials; and the physical environment. This work is fully supported by the International Association of Oil & Gas Producers (IOGP) with both funding and participating experts.

USARC encourages strong US participation in this effort and incorporation of the most recent scientific and technological results into the standards. For example, the ice management standard should be based on the best available science and technology to assess and monitor sea ice and iceberg conditions, ocean currents and circulation, and meteorology. The standards should also incorporate modern methodologies for breaking ice and for conducting ice management operations that rely on remote sensing (e.g., satellite radar and drone imagery), and aircraft observations and sensors.

Food and Nutrition Security

Arctic indigenous people have seen major changes in their food and nutrition security over the past 60 years, in part due to climate change.[44] In the past two decades, Arctic air temperatures have warmed at a rate two to three times that of the rest of the globe. Warming is becoming more common in autumn and winter, and daily temperature fluctuations have become more extreme. As a result, plants and animals move northward, non-native species appear, traditional food sources become less reliable, permafrost food storage shelters thaw (e.g., p. 3 photo), and ice platforms used for marine mammal hunting disappear.[45] All of these changes threaten Arctic food security.

There is little question that the health and cultural activities of Alaska Native peoples will be harmed by a decline in subsistence practices. Subsistence diets, rich in fish and mammals, offer numerous health, social, cultural, and economic benefits. In many places, store-bought meat is cost-prohibitive, and little or no fresh produce is available. Affordable store-bought replacement food is often of inferior nutritional quality. Several Arctic countries have made efforts to monitor food security. Examples include:

[44] Parkinson, A.J., and J.C. Butler. 2005. Potential impacts of climate change on infectious diseases in the Arctic. *International Journal of Circumpolar Health* 64:478–479, http://dx.doi.org/10.3402/ijch.v64i5.18029.
[45] ACIA. 2005. *Arctic Climate Impact Assessment - Scientific Report.* Cambridge University Press, New York, 1,046 pp.

Alaska Farm to School Program

The Alaska Farm to School Program offers expertise and support to pursue farm-to-school activities and interests. Their main goal is to make food produced and/or harvested in Alaska available in the school food environment. In western Alaska, this program allows the donation and serving of traditional foods in school cafeterias.

Chart courtesy of Johanna Herron, Alaska Farm to School Program. Photo credit: Cale Clingenpeel

CANADA

Nunavut Food Security Coalition (NFSC)

The NFSC's representatives include seven Canadian government departments and four Inuit community organizations. Its mission is to engage a broad group of partner organizations and the public to create a collaborative strategy of programs, policies, and initiatives on food security.

UNITED STATES

Inuit Circumpolar Conference Alaska's "Building a Conceptual Framework on How to Assess Food Security from an Inuit Perspective"

This project aims to: (1) provide an understanding of Arctic food security, from an Inuit perspective; (2) identify drivers of food security; and (3) create a conceptual framework on how to assess food security across both cultural and environmental systems. It will be released in 2015.

USARC recommends additional research on food security, including its prevalence, shifting patterns of food consumption, and adaptation strategies that have been successfully used in some Arctic communities.

Photo credit: US Air Force/Justin Connaher

Research Efforts to Promote Resilience

THE ARCTIC RESILIENCE REPORT (ARR)

The Arctic Council's Arctic Resilience Report, expected to be completed in May 2016, is a science-based assessment of the impacts of change in the Arctic through integrated analysis and interaction with Arctic communities.

The ARR objectives are to:

- Identify the potential for shocks and large shifts in ecosystems services that affect human well-being in the Arctic.
- Analyze how different drivers of change interact in ways that affect the ability of ecosystems and human populations to withstand shocks, adapt, or transform.
- Evaluate strategies for communities and governments to adapt.[46]

[46] Arctic Council. 2013. *Arctic Resilience Interim Report 2013*. Environment Institute and Stockholm Resilience Centre, Stockholm, http://www.sei-international.org/mediamanager/documents/Publications/ArcticResilienceInterimReport2013-LowRes.pdf.

LOCAL EFFORTS, FUTURE LEADERS: BUILDING RESILIENCE

Rural Alaska Honors Institute (RAHI), University of Alaska Fairbanks (UAF)

RAHI allows Alaska Native and rural students to have a "college-esque" experience by spending six weeks at UAF during summer session, living in the dorms while taking college-level courses for which they receive credit.

Alaska Native Science and Engineering Program (ANSEP), University of Alaska Anchorage

ANSEP is a longitudinal education model that provides a continuous string of components beginning with students in sixth grade and on through high school, into science and engineering undergraduate degree programs and through graduate school to PhD-level study.

Teck John Baker Youth Leaders Program, Northwest Arctic Borough School District

This program identifies young people who are respected and trusted by their peers and trains them to be effective supporters and role models in their school and village communities. In addition, two students from each school site are elected by their school's youth leaders to be team captains and to receive additional training in Alaska Native and Western leadership principals, group dynamics, and other relevant skills.

Tribal Youth Program (TYP), Nulato, AK

This culturally based youth development program, operated by local Alaska Native residents, serves children under 17 to promote healthy, culturally connected youth. The program provides activities that focus on mental health and builds connections between peers, their families, and tribal members, including Elders. The TYP uses Native language, local culture, and traditions to provide a sense of connection and community.

Young Hunters Program, Native Village of Barrow

This seasonal program pairs Inupiat youth with Elders who accompany them out on the land/sea, teach them how to hunt, and communicate traditional knowledge. Now in its seventh year, it is an established, popular, and well-attended program.

USARC encourages research into evidence-based strategies that promote resilience.

Enhancing International Scientific Cooperation in the Arctic

The rapidly changing global climate is driving major alterations in Arctic marine ecosystems. Unprecedented reductions in ice cover are opening areas formerly closed to human activity.

In response, Arctic states and stakeholders with an interest in the Arctic face an increasing need for marine ecosystem information, using limited research funds. This is a pan-Arctic dilemma, and many key research needs are transboundary in scope or are in international spaces beyond national jurisdictions. The need for enhanced international cooperation in the Arctic has never been stronger.

In recognition of this need, the ministers of the Arctic Council, at their 2013 meeting, including US Secretary of State John Kerry, declared that they:

> *Agree that cooperation in scientific research across the circumpolar Arctic is of great importance to the work of the Arctic Council, and establish a Task Force to work towards an arrangement on improved scientific research cooperation among the eight Arctic States.*

The Task Force has met several times, and discussions have focused on improving access to research areas on land and at sea, improving access to data, and simplifying the movement of scientists, their equipment, and samples across borders. A draft Memorandum of Understanding (MOU) is being negotiated and may come into force during the US Chairmanship.

This MOU may be legally binding, and it will be a good first step. But it most likely will not address the need for durable institutional arrangements, established by formal agreement among governments, that will promote multilateral scientific cooperation and long-term planning.

Most international research coordination and cooperation in the Arctic marine environment is currently accomplished through a mosaic of committees, institutes, informal organizations, bilateral arrangements, or specific multinational programs with limited scope or duration. This arrangement has provided important information, but as interest in the Arctic grows, and as the demand for timely scientific information increases, the need for improved and more efficient international coordination has also grown.

For marine research, examples of successful institutional arrangements exist in both the North Atlantic under ICES (International Council for the Exploration of the Sea) and the North Pacific under PICES (Pacific ICES). An ad hoc approach is already underway whereby ICES/PICES are looking for ways to cooperate in the Arctic. However, both organizations already cover vast geographic areas outside the Arctic, with missions focused on sub-Arctic and temperate ocean research needs. The Arctic is secondary to these other pressing needs.

Creating an Arctic marine science organization with explicit commitments by governments to cooperate on Arctic marine research could improve cooperation, streamline and maximize logistical coordination and the use of research platforms, reinforce efforts to standardize data collection and management protocols, and provide for a central repository for Arctic research information.

USARC recommends that the United States, during its Chairmanship of the Arctic Council, pursue negotiations to conclude an international agreement for an institutional arrangement that coordinates and promotes research related to oceanography, the marine environment, the marine ecosystem, and living marine resources in the high Arctic Ocean.

Secretary of State John Kerry and Alaska Senator Lisa Murkowski arrive in Iqaluit, Canada, for the 2015 Arctic Council Ministerial meeting.

Communication and Coordination

White House Leadership

The White House has paid increasing attention to the Arctic region, with a particular focus on scientific research. In 2009, President Bush issued an update on Arctic policy in NSPD-66/HSPD-25. In 2013, President Obama released the "National Strategy for the Arctic Region" that implements the policy by guiding, prioritizing, and synchronizing three lines of effort to: (1) advance US security interests, (2) pursue responsible stewardship, and (3) foster international cooperation. Just prior to the release of the strategy document, the White House released the IARPC Arctic Research Plan FY2013–2017, in February 2013. The heart of this science plan was then combined with other material and released in a January 2014 White House publication titled "Implementation Plan for the National Strategy for the Arctic Region." A progress report on this plan was issued in March 2015.

To further enhance communication and coordination of national efforts in the Arctic, President Obama issued Executive Order 13689, in January 2015, that created an Arctic Executive Steering Committee (of which the USARC Chair is a member). This committee, which has called for an Arctic budget cross-cut analysis and an assessment of gaps and overlaps in Arctic region activities, is also working on ways to support the two-year US Chairmanship of the eight-nation Arctic Council that began in April 2015, and to improve how the federal government can more effectively and coherently communicate with the state and tribal entities that have direct stakes in Arctic affairs.

Impressive Progress — The Interagency Arctic Research Policy Committee (IARPC)

IARPC, a subgroup of the National Science and Technology Council (NSTC) Committee on Environment, Natural Resources, and Sustainability, is chaired by the National Science Foundation, and has made significant progress in several areas of its Arctic Research Program Plan (2013–2017). Examples include:

- A new website (http://www.iarpccollaborations.org) that is organized around 12 topical collaboration teams and establishes and enhances interinstitutional and interdisciplinary conversations.
- An IARPC Imperatives Subgroup that has produced an "IARPC Imperatives" document, a succinct list of recommendations to advance interagency dialogue, to elucidate the common research themes that bridge multiple agencies, and to inform the next IARPC five-year plan.
- An IARPC 2015 Biennial Report that outlines progress.

IARPC by the Numbers

"IARPC envisions a prosperous, sustainable, and healthy Arctic understood through innovative and collaborative research coordinated among Federal agencies and domestic and international partners."

IARPC entities are implementing the milestones and conducting the activities listed in the National Strategy for the Arctic Region, planning for the next update to the IARPC five-year plan (2015–2016), and supporting efforts associated with the US Chairmanship of the Arctic Council. Learn more at http://www.iarpccollaborations.org.

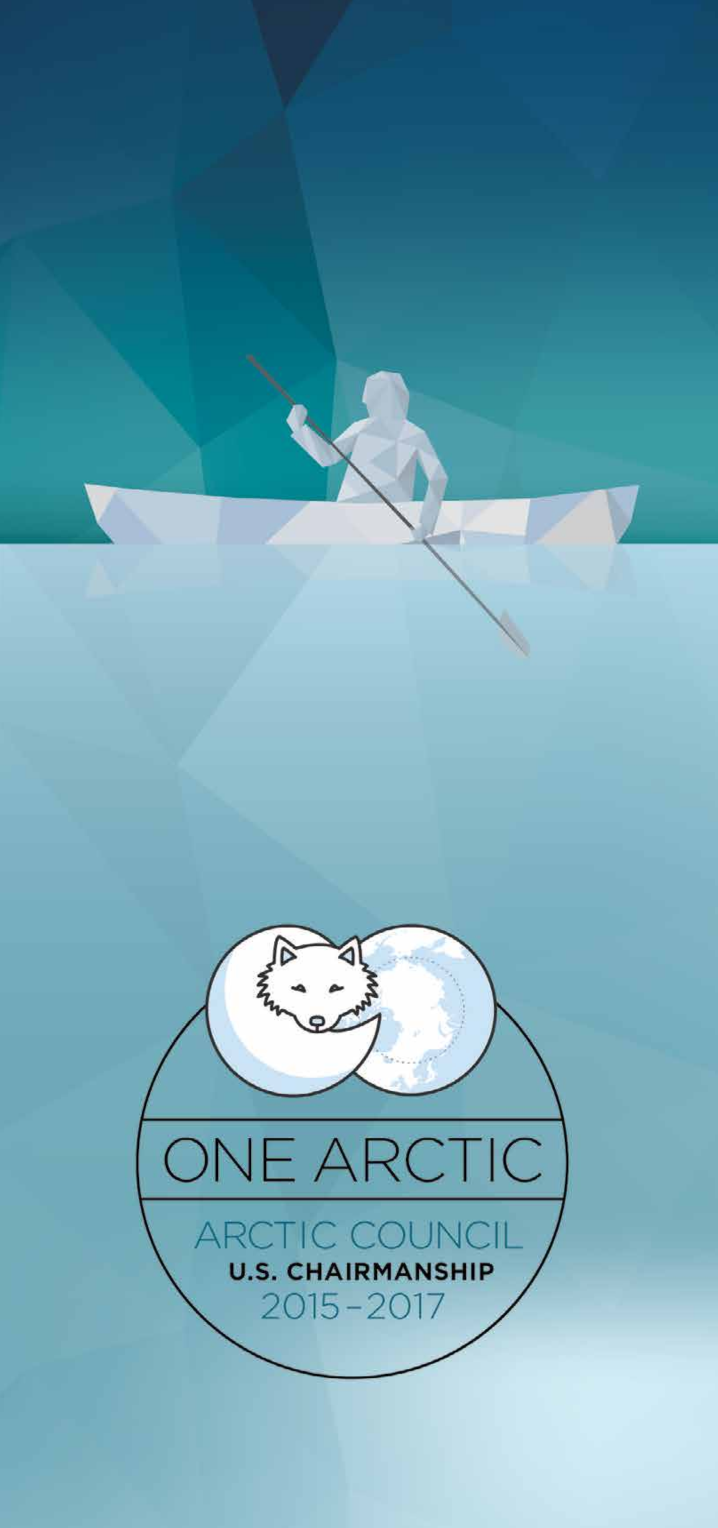
14 Federal agencies

12 Collaboration teams

7 Research areas

145 Milestones

Background photo credit: Ilka Raupach



Priorities for the US Chairmanship of the Arctic Council (2015–2017)

One Arctic: Shared Opportunities, Challenges, and Responsibilities

The three main goals of the US Chairmanship of the Arctic Council are to: (1) continue to strengthen the Arctic Council as a intergovernmental forum, (2) introduce new long-term priorities, and (3) raise awareness of the Arctic and climate change in the United States and around the world. Under the auspices of these goals, three "thematic areas" have been selected.

1. Arctic Ocean Safety, Security, and Stewardship by conducting search-and-rescue exercises; coordinating marine environmental protection research and information, including that related to oil spills; enhancing activities to develop marine protected areas to manage resources; and promoting regional programs to coordinate research, notably on ocean acidification.

2. Improving Arctic Economic and Living Conditions by demonstrating the potential of renewable energy to replace expensive diesel sources; internationalizing efforts to improve access to clean drinking water, reliable sanitation, and freshwater supplies; developing telecommunications infrastructure; and adapting suicide/mental illness prevention research and resources to suit the unique circumstances of Arctic communities.

3. Addressing the Impacts of Climate Change by implementing efforts to reduce, monitor, and study short-lived climate pollutants; promoting and evaluating recommendations for climate adaptation and resilience for Arctic residents; and enhancing Arctic climate science.[47]

In addition, the Department of State will aim to raise awareness of the Arctic region by initiating a public outreach program and by sponsoring a Fulbright Arctic Initiative to create a network of scholars, professionals, and applied researchers for a series of seminar meetings and exchange experiences.

[47] Description summaries: IARPC 2015 Biennial Report

Emerging Topics in the Arctic

FROZEN DEBRIS LOBES

Alaska's Dalton Highway faces a new hazard in the southern Brooks Range in the form of "frozen debris lobes" (FDLs). These slow-moving landslides have the potential to deposit tons of debris onto the highway, and recent investigations indicate that the speed at which FDLs are moving is increasing. They also may be early warning indicators for general slope instability in permafrost regions where the climate is projected to warm. Not enough is known about FDLs to develop appropriate mitigation plans. Recommended research includes geotechnical exploration and instrumentation to acquire more subsurface data, and modeling to predict future movement. More information on FDLs can be found at: http://fdlalaska.org.

ABOVE. Dalton Highway in the Brooks Range near Atigun Pass, Alaska. *Photo credit: Scott McMurren*

LEFT. Frozen debris lobe along the Dalton highway in Alaska, that has broken away from the slope and moved about 150 feet per year for several years. *Photo credit: Margaret Darrow, UAF*

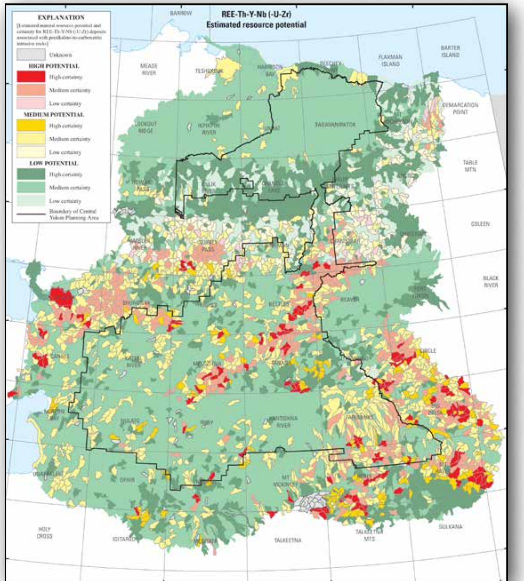
THE "SCIENCE COMMUNICATION PROBLEM"[48]

A number of recent studies examined the nature of people's beliefs and why some rational, educated people choose to ignore scientific evidence.[49] Many of these studies focus on climate change, with recent findings noting an association between higher literacy and stronger viewpoints, both in support and denial of climate change. Results show that people tend to use scientific knowledge to reinforce beliefs that have already been shaped by the dominant position within their cultural group. Other research shows people's feelings about the connection between a warming Arctic and mid-latitude weather to be influenced by issues as arbitrary as the weather on the day the survey took place.[50] Investigations into the ability of citizens to make sense of climate change and other risk issues and their links to scientific consensus are part of an evolving area of research.

[48] Achenbach, J. 2015. Why do many reasonable people doubt science? *National Geographic*, March 2015, http://ngm.nationalgeographic.com/2015/03/science-doubters/achenbach-text.

[49] Kahan, D.M. In press. What is the "science of science communication"? *Journal of Science Communication*, http://dx.doi.org/10.2139/ssrn.2562025.

[50] Hamilton, L., and M. Lemcke-Stampone. 2014. Arctic warming and your weather: Public belief in the connection. *International Journal of Climatology* 34:1,723–1,728, http://dx.doi.org/10.1002/joc.3796.



LEFT. Alaska's rare earth element potential. *Reprinted from Alaska Strategic and Critical Minerals Evaluation (2015)*

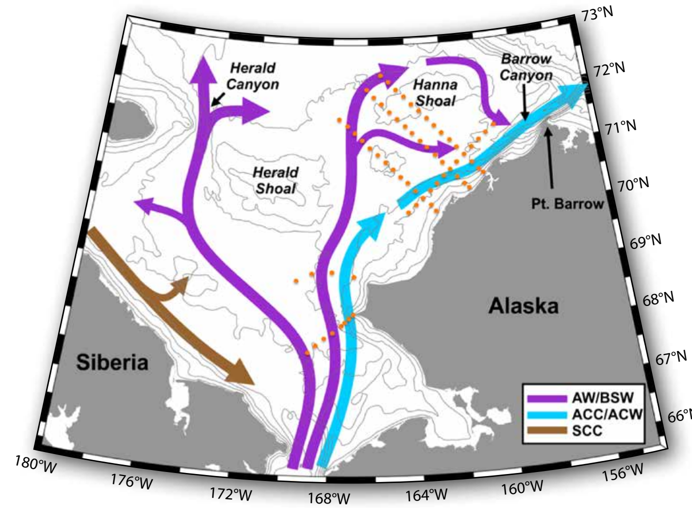
THE ARCTIC'S RARE EARTH ELEMENT POTENTIAL

Rare earth elements (REEs) are a group of 15 elements that possess specialized properties critical to modern technology. China has been the primary supplier of the world's REEs, but a recent USGS and Alaska Division of Geological and Geophysical Surveys study has mapped a number of areas in the US Arctic that hold high REE potential. The Alaska Strategic and Critical Minerals Evaluation's identification of regions of highest strategic and critical mineral potential contributes to better land-use decisions, allows industry to focus future exploration efforts on areas of most immediate impact to national defense and security, and helps the USGS target areas for new studies because of identified mineral potential and/or need for additional data.[51]

[51] US Department of the Interior | US Geological Survey, Alaska Strategic and Critical Minerals Evaluation information page: http://alaska.usgs.gov/science/program.php?pid=51.

US ARCTIC MARINE BIODIVERSITY OBSERVING NETWORK (AMBON)

AMBON is a new project (2015–2020) that will build an operational marine biodiversity network "from microbes to whales" in the Chukchi Sea. It is a five-year academic-federal research partnership based at the University of Alaska Fairbanks. This project will measure environmental parameters (hydrography, chlorophyll *a*, nutrients, sediment) and biodiversity (microbes, phyto/zooplankton, benthos, fish, seabirds, marine mammals) to fill research gaps that exist in the Chukchi shelf region. One outcome will be a sustainable model of continuous biodiversity monitoring.



ABOVE. Map of the AMBON study region. The orange dots are sampling stations, aligned in transects that cover areas of existing data as well as regions of high biological interest and/or industrial interest. Surface ocean currents in the region are as follows: AW = Anadyr Water; BSW = Bering Sea Water; ACC = Alaskan Coastal Current; ACW = Alaskan Coastal Water; and SCC = Siberian Coastal Current. *Image credit: Katrin Iken, UAF*

MARINE ARCTIC ECOSYSTEM STUDY (MARES): PARTNERSHIP IN OCEAN RESEARCH

The Bureau of Ocean Energy Management (BOEM)-coordinated MARES was developed by nine funding partners (eight federal agencies, one industry group) as a multi- and interdisciplinary study of the Beaufort Sea ecosystem. This five-year (2014–2019) integrated approach is investigating the interrelationship among the physical, biological, chemical, and social science components of the Beaufort Sea ecosystem from Barrow, Alaska, to Canada's Mackenzie River Delta. This partnership aims to advance understanding of the Arctic ecosystem while also delivering high-quality science to inform decision making on environmental matters.

The Arctic in the News


Photo credit: Jack Molan


Photo credit: Karen Bollinger

ARCTIC UPDATE, SCIENCE PORTAL, AND SOCIAL MEDIA

To increase communication on Arctic research issues, USARC publishes a daily "Arctic Update" electronic newsletter. It is distributed freely through a listserv, and readers may safely self-subscribe at http://www.arctic.gov. Each edition consists of four sections: Today's Events, Media, Legislative Action, and Future Events. As of 2015, the update has over 2,400 subscribers and issues back to November 2010 are archived on USARC's website. USARC welcomes feedback on the product and contributions of content, such as events to announce. The USARC website also hosts an Arctic Science Portal, and we can be followed on social media, including Facebook (US Arctic Research Commission) and Twitter (@US_ARC).

ALASKA NATIVE SCIENCE

Alaska Natives in Barrow and in Kotzebue have entered into multimillion-dollar cooperative scientific agreements with the Shell Oil Company that provide financial support for research projects, ecosystem baseline studies, and assessments designed and conducted by and with the support of local community members. The results of these growing programs may be found on the websites of the North Slope Borough (http://www.north-slope.org/departments/wildlife-management/nsb-shell-baseline-studies-program) and the Northwest Arctic Borough (http://www.nwabor.org/science.html#shell-agreement).

Social Sciences Program of Kawerak Inc., a regional nonprofit corporation organized by the Bering Straits Native Association, has recently published a significant number of high-quality documents related to Alaska traditional knowledge of the Arctic environment. Articles, reports, guides, and glossaries have been published on a number of subjects, including: (1) traditional knowledge of walrus in the Bering Sea; (2) knowledge and use of ocean currents, fish, and other marine life; (3) human health; and (4) a synthesis of subsistence data. They are available at http://www.kawerak.org/socialsci.html.

Background photo credit: Jack Molan

Photo credit: Mauricio Antón

Photo courtesy of the Academy of Science of the Republic Sakha

BABY WOOLLY RHINO

The first-ever remains of a 10,000-year old baby woolly rhino, approximately 18 months old at the time of death, were recently discovered in Siberia's Sakha Republic. A hunter found it in the thawing permafrost along the banks of a stream flowing into the Semyulyakh River. The remains of the creature have been given to scientists from the Academy of Sciences in Yakutsk, and they hope to extract DNA. Woolly rhinos are far less common than mammoths, and there is minimal knowledge about the conditions in which they lived, how they developed, and their links to modern rhinos.

SIKULIAQ OPERATIONS BEGIN

In early 2015, the 261-foot long icebreaking research vessel R/V *Sikuliaq* (pronounced "see-KOO-lee-auk," meaning "young sea ice" in Inupiaq) successfully conducted ice trials in the Bering Sea and tested a variety of oceanographic and ice sampling gear. The first scientific expeditions begin in summer 2015.

As outfitted, *Sikuliaq* enables researchers to collect seafloor sediment samples, use remotely operated vehicles, use several types of winches to raise and lower scientific equipment, and conduct surveys throughout the water column and sea bottom employing a variety of research instruments. The ship, which is able to transmit real-time information directly to classrooms all over the world, is designed to have the lowest possible environmental impact, and is quiet to minimize effects on marine mammal and fisheries research. *Sikuliaq* will have accommodations for up to 26 scientists and students at a time, including those with disabilities. *Sikuliaq* was designed by Glosten and Associates, built by the Marinette Marine Corporation, is owned by the National Science Foundation, and is operated by the University of Alaska Fairbanks School of Fisheries and Ocean Sciences.

R/V *Sikuliaq* seen from the "headstone" along the line of the performance test. *Photo by Roger Topp*

Photo credit: Ted Dunton

OBSERVING THE ARCTIC PHOTO CONTEST WINNERS

USARC thanks the participants in our first "Observing the Arctic Photo Contest." The winning photographs can be found on the following pages of this report. For more information on the contest and winners, please visit http://www.arctic.gov/photo_contest.html. Several other photo contest entries were also chosen to appear in this publication.

GRAND PRIZE PHOTO

- (Cover) LT Tim Smith, NOAA – Melting Iceberg

FIRST PLACE PHOTOS

- (Table of Contents) Cindy Shake – Barrow Ice Fishing
- (Intro from the Chair) Kerry Koepping – Small Against Time
- (p. 2) Theodore Dickerson – Commercial Fishing
- (p. 3) Mike Brubaker, ANTHC Center for Climate and Health – Eroding Shoreline and Ice Cellar
- (p. 10) Penny Jack – Freshly Cut Salmon
- (Inside Back Cover) Ted Dunton – Snow Fences

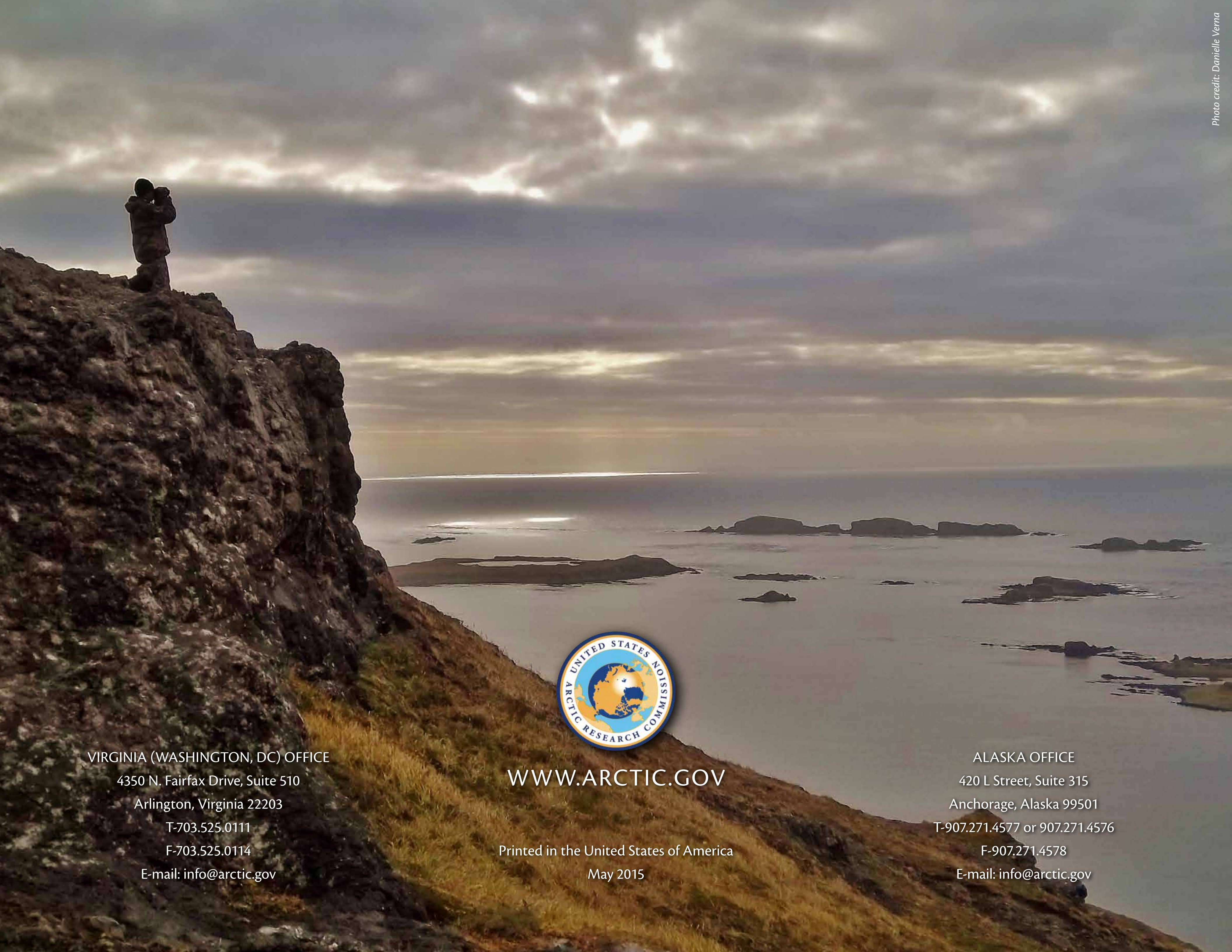


Photo credit: Danielle Verna

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