Alaska Park Science

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Park Science in the Arctic

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Arctic Alaska Park Science Symposium
and Beringia International Conference

Volume 8, Issue 2

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Natural and Cultural Healing Places Within Publicly Managed Lands

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Cover photograph: Layover check point of the annual dog race *Nadezhda* (Hope Race). Provideniya, 2006.

Photograph © A. Borovik

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Serpentine Hot Springs in Bering Land Bridge National Preserve.

NPS Photograph

Courtesy of K.K. Uyaganskiy

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INTERNATIONAL POLAR YEAR
2007-2008

Introduction

By Sue Masica, Alaska Regional Director

This symposium, the third in a series focused on science and scholarship in and around Alaska's national parks, is a joint effort with the Beringia Days International Conference. Our theme "Park Science in the Arctic – the Natural and Cultural Heritage of Greater Beringia" is focused on very special places deliberately set aside by nations to preserve their exceptional, natural, cultural, historic, and inspirational significance. Beringia is an area of worldwide significance for its cultural and natural resources. With unusually intact landforms and frozen remains, Beringia provides unparalleled opportunities for comprehensive study of the earth, the character of past climates and the ebb and flow of earth forces at continents' edges. As one of the world's truly great and ancient crossroads, Beringia is still revealing secrets about how the first people came to North America, how and when they traveled, and how they survived under such harsh climatic conditions.

Figure 1. Leonid Kutylin, an elder of the Chukchi village Yanrakynnot, winter fishing in 2006.

Photograph © A. Apalyu

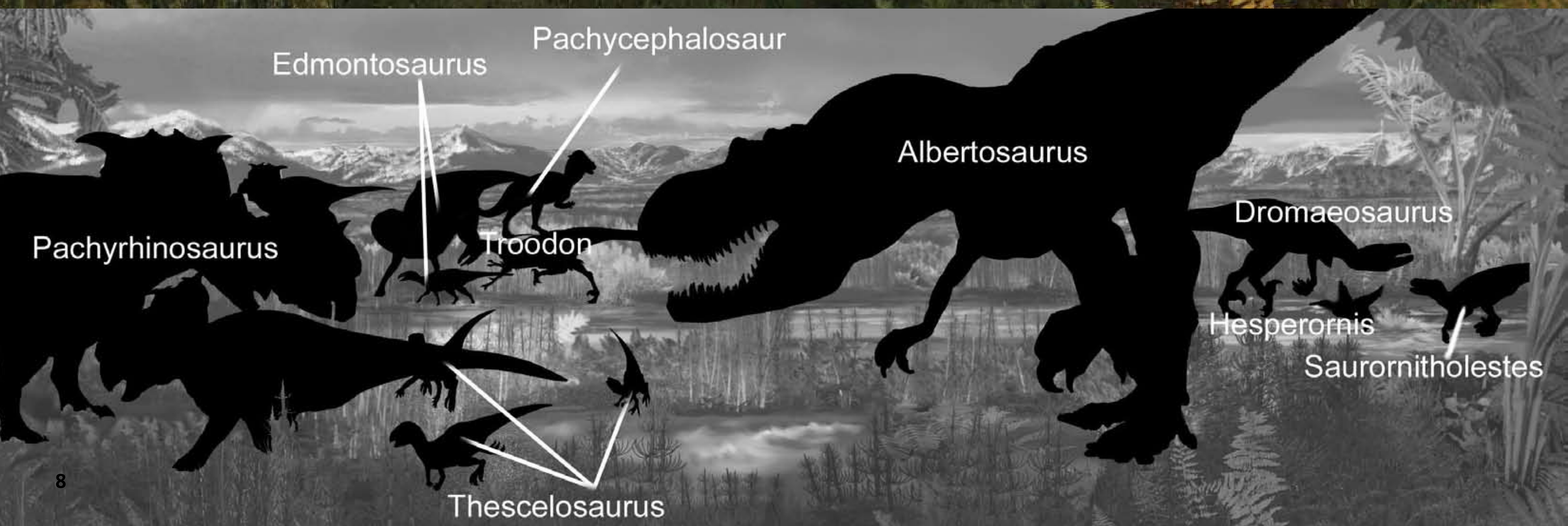
This International Polar Year is an auspicious time for science in the Arctic. Fifty years ago, the International Geophysical Year (IGY) was also a time of great discoveries and excitement. Despite Cold War tension, scientists from across the globe jointly explored the physical structure and working of the earth's crust, oceans, polar ice caps, and atmosphere. Today, we sometimes take those accomplishments for granted, but we shouldn't, for IGY brought major accomplishments in international science, conservation, cooperation and peace.

Events of intervening years also pertain closely to this symposium. In 1980, President Jimmy Carter signed the Alaska National Interest Lands Conservation Act, a sweeping piece of legislation that established the parks, preserves and monuments of northern Alaska.

In 1991, the presidents of the United States and the Soviet Union endorsed a proposal to establish an international park agreement between the two countries. The Shared Beringian Heritage Program grew from that agreement and today recognizes and celebrates the contemporary and historic exchange of biological resources and cultural heritage shared by Russia and the United States on both sides of the Bering Strait.

The Natural Resource Challenge, which was initiated by the National Park Service in 1995, led to the creation of 32 Inventory and Monitoring Networks nationwide including the Arctic Network. Additionally 17 Cooperative Ecosystem Studies Units were created with over 100 partner institutions and agencies nationwide, including the North and West Alaska unit centered at the University of Alaska Fairbanks. Seventeen Research Learning Centers, including the Murie Science and Learning Center at Denali were created nationwide to provide opportunities for scientists, educators, and the public to research and experience science in our parks.

Fifty years after IGY—and 50 years from passage of the Alaska Statehood Act by the U.S. Congress—scientists and scholars from many nations have again joined to better understand, protect, and share what they are learning. How can we not be energized by the new and expanded opportunities for science and scholarship in parks in the Arctic? This Symposium is truly a celebration of both science and scholarship and of national parks, America's gift to the world. And, where better to hold this event than in Fairbanks, below the shimmering aurora borealis, and a world leader in research and development of the next generation of scientists, scholars, educators, and other leaders. I trust the wonder of the place, the people, the culture, and the historic moments will infuse and saturate our experience completely.


Pachycephalosaur
Edmontosaurus
Albertosaurus
Dromaeosaurus
Pachyrhinosaurus
Troodon
Hesperornis
Saurornitholestes
Thescelosaurus

Park Science in the Arctic: A Thematic Synthesis

By Robert A. Winfree, Alaska Regional Science Advisor

In October 2008, about 200 scientists, resource managers, decision makers, educators, students, and local residents from Alaska and Russia came together to share knowledge about the physical, biological, and social sciences, history and cultures of the area known as Beringia. The event that brought the speakers and audience together was the combined meeting of the Alaska Park Science Symposium: Park Science in the Arctic, and the Beringia Days International Conference. About 100 oral and poster presentations were given during the three-day meeting, many of which are summarized as articles in this issue of Alaska Park Science. The following "synthesis" was originally presented as the final summary presentation. It focuses on several themes that became evident while listening to and perusing presentations, posters, and abstracts.

Vast and unique Beringia

What is it that makes Beringia so unique? The area's geology is complex, to say the least. It seems safe to say that the origins of Beringia are firmly rooted in plate tectonics (*Fiorillo et al.,* this issue). Scientists now know that during the Cretaceous Period there were temperate forests, wetlands and rivers in the areas of today's Colville River and Denali National Park and Preserve. Some of the flora discovered in the Cantwell formation at Denali appears similar to species that might be at home in a botanical garden today (*Figure 2*), but this is definitely not the case for the megafauna (*Tomsich et al., Fiorillo et al.*, both this issue). Are scientists, educators, and the public ready to include dinosaurs in their personal vision of Beringia and the Arctic (*Figure 1*)?

Figure 1. (Left) Dinosaurs of Alaska.

Image by Karen Carr, used with permission

Beringia is among the world's truly great and truly ancient crossroads, having intermittently served as an important bridge between continents for thousands, millions, and even tens of millions of years (*Masica*, this issue). Much of the world's water was trapped in glaciers during the Pleistocene Period. Sea level fell by perhaps 400 feet (120 m) during the last glacial maximum, exposing a broad land bridge between the continents of Asia and North America (*Figure 3*). During this time, the Bering Land Bridge was a barrier to some species and a filter for others, but overall it served as a major highway for Asian plants to reach North America (*Ickert-Bond et al.*, this issue). Some species successfully moved west, but many more species of animals, plants, and people came east, perhaps repeatedly.

Beringia still has many secrets to reveal about the first people to come to North America: how and when they traveled here, and how they survived under such harsh climatic conditions. New research at Cape Krusenstern National Monument is expanding on Giddings' studies of 4000+ years of human and environmental history that are preserved in a series of raised beach ridges (*Anderson et al.*, this issue). Similar beach ridge formations have also recently been identified near historic village sites in Chukotka (*Gal 2008*). Some Arctic sites, such as from the ancient Eskimo settlement of Kivak, contain graceful and intricately carved artifacts that are associated with ancient Bering Sea cultures, while others are simple and utilitarian (*Figure 4*) (*Orekhov*, this issue).

The information contained in ancient archaeological sites is of great significance to all people, but the presence of ancient sites today does not guarantee their continued existence. In the United States, the National Historic Protection Act directs federal agencies to monitor and protect archaeological sites. However, finding sites can be a formidable challenge in vast landscapes, especially in designated Wilderness where access can be limited. Geographic Information System (GIS) models can help archaeologists to predict the probable locations of ancient travel routes and campsites, and to prioritize locations for future field surveys (*Devenport*, this issue).

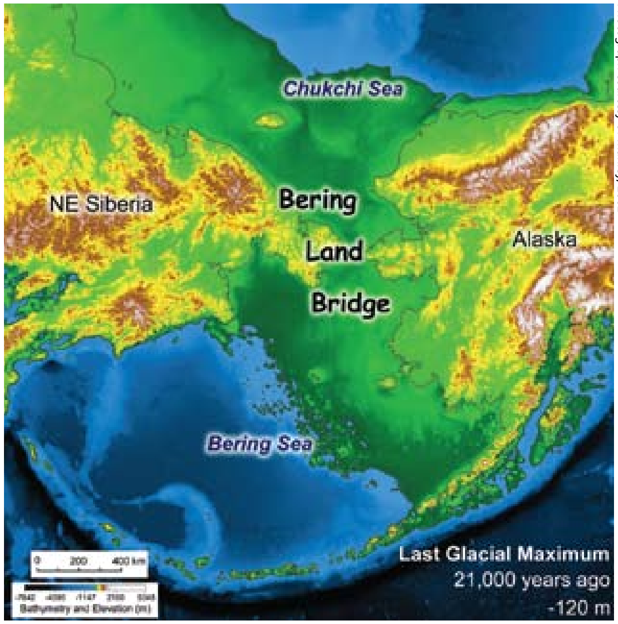
Photograph courtesy of Todd Jacobs

Figure 2. Partial platanoid leaf fossil from Cretaceous deposits in Denali National Park and Preserve.

Environmental sustainability and change

The people who successfully migrated across the Bering Land Bridge during the Ice Age were already equipped with much of the knowledge and tools that they would need to survive and flourish in harsh Arctic and subarctic climates, and to continue their journeys to lands further east or south. Native people in the Arctic have traditionally lived in biologically rich and diverse areas. They understood the concept of sustainability, lived in small settlements that would not outstrip the vegetation and other resources, and they shifted harvest pressures as species abundance waxed and waned. These tribes of hunters and gatherers knew that their own survival was linked to the abundance of fish and wildlife, and a healthy environment. They viewed nature not just as an environment containing the resources necessary for life, but as a living and full-fledged member of their tribe (*Bogoslovskaya*, this issue). Subsistence hunting, fishing, and gathering were basic to their survival as a people, so much so that they have remained core cultural values to the present day (*Figure 5*).

Beringian landscapes provided refugia for many species of plants, animals, and even humans during the Pleistocene glaciation (*Bigelow et al. 2008, Fedorov and Goropashnaya 2008, Parker and Ickert-Bond*, this issue). Will it continue to do so in the future? Beringia still contains some of the world's healthiest terrestrial and marine wildlife populations. Much of this is due to the continued presence of large and intact ecosystems that have been protected from over exploitation in parks, Zapovedniks (scientific nature reserves), and wildlife refuges. Another important factor has been the presence of healthy populations of terrestrial predators, such as wolves, bears, and cats, that culled weaker individuals and constrained population growth among prey species (*Berger 2008*). Caribou and reindeer exhibit resilience to variable food supplies, which may be related to their ability to alter the timing and allocation of body protein to reproduction (*Barbosa 2008*), but overgrazing of preferred food types still remains a serious concern (*St. Martin et al. 2008*).



Photograph courtesy of Manley, 2002

Figure 3. The Bering Land Bridge during the Last Glacial Maximum, about 21,000 years ago.

The Arctic's abundant natural resources made natural resource extraction both attractive and profitable. A century ago, commercial whalers and traders from Russia and the United States decimated marine mammal populations in their search for oil and furs. In their rush to exploit seemingly unlimited resources, they repeatedly put species, ecosystems, Native communities, and even their own lives at extreme peril (*Figure 6*) (*Barr*, this issue). In one historic attempt to stave off the resulting famine in Native communities, a few hundred reindeer and four Chukchi reindeer herdsmen, were brought to Alaska's Seward Peninsula by the U.S. Government in 1892. The working relationship with the Inupiaq was not good, and the Chukchi left. In 1894 Saami reindeer herding families from Lapland were hired to come to Alaska to work with the Inupiaq; their collaboration was successful (*Figure 7*) (*Fjeld 2008*).

It is abundantly clear that many past models of nature use must be replaced. Past mistakes have resulted in numerous ecological crises and the intensification of global problems connected with climate change, alteration of atmospheric composition, pollution, loss of biological diversity, and degradation of ecosystems, and as a consequence of these, the exhaustion of the natural resource base and the continuous expansion of demographic and social problems (*Kachur*, this issue). The discovery of petroleum as a substitute for whale oil came none too soon for the whales, but the search for oil returned to the Arctic again in the twentieth century. Today, much of the Bering and Chukchi Seas are being mapped for oil exploitation. The search for oil and gas is accelerating and expanding into areas of critical importance to migratory caribou, water birds and whales (*Yokel et al.*, this issue). While today's managers have access to much more information than did their predecessors 50 or 100 years ago, the scale and pressures of development are enormous, and many questions remain about the effectiveness of safeguards to protect sensitive arctic environments, communities, and people from the undesirable impacts of large-scale natural resource extraction. Even seemingly benign developmental infrastructure can have unexpected deleterious effects on wildlife populations, by sheltering and providing perches for nest predators such as arctic fox, ravens, and gulls (*Zack and Liebezeit 2008*).

Among the lessons that have been learned through resource inventories, monitoring and research, is that political boundaries and property lines are insufficient to preserve parks and protected areas in perpetuity. Cape Krusenstern National Monument is adjacent to the world's largest zinc and lead mine, and research at the Monument has turned up greatly elevated concentrations of heavy metals across broad areas of tundra (*Neitlich 2008*). Modeling of shipping exhausts in the Gulf of Alaska has indicated significantly elevated concentrations of atmospheric pollutants (NOx, SOx, and PM 2.5) that can severely degrade air quality and cause significant damage to coastal waters and ecosystems (*Porter and Molders 2008*). The recent installation of a comprehensive air quality monitoring station by the NPS in Bettles, Alaska, will expand capacity for monitoring air pollution from global and regional sources (*Blakesley and Lawler 2008*). But knowing about the problems will clearly not be enough to solve them.

Climate change

Climate change and its related effects may be the most severe threat yet to preserving intact arctic ecosystems and cultures. The arctic is warming, and apparently faster than much of the rest of the world. The Sea Ice Knowledge Utilization (SIKU) project is working with local people in Alaska and Chukotka to preserve their traditional knowledge about ice in native language dictionaries, so that climate change will not prevent the knowledge from passing between generations (*Krupnik*, this issue). Rapidly diminishing sea ice no longer protects many coastal communities, archaeological sites, and natural environments from the erosive action of storms. Most of the approximately 375 mile-long (600 km) coast from Wales to Kivalina has experienced erosion in the past five decades, with long-term average losses of up to 10 feet (3 m) per year (*Figure 8*) (*Manley et al. 2008*). Other modeling indicates that loss of sea ice may increase warming on the Seward Peninsula from ocean heat flux (*Cherry and Hinzman 2008*).

Many scientists and resource managers are deliberating on how climate change is likely to affect wildlife and other resources in Beringia. Musk oxen are among the last surviving species of Pleistocene megafauna in the Arctic, but new DNA research from fossil and modern musk oxen indicates severe losses of genetic diversity have occurred (*Groves et al. 2008*) (*Figure 9 a-b*). Pika may already be at the edge of their climatic tolerance zone, with many populations `trapped´ at the top of mountains where there is no where else to go. Little is known about the threshold values of environmental conditions under which pikas may persist or disappear (*O'Donovan 2008*).

The evidence of recent expansion of shrubs into tundra is widespread and strong (*Bret-Hart et al. 2008, Tape 2008*). Satellite-based models are now being applied to distinguish climatic effects on boreal forests from other disturbances in the Yukon River basin (*Wylie et al. 2008*). Downscaled climate models indicate a high probability of increased precipitation in the national parks of northern Alaska during the coming century. However, soil conditions may actually become drier in many areas, as evapo-transpiration will likely increase with warmer temperatures and longer growing seasons (*Figure 10 a-b*) (*Loya et al. 2008*). Permafrost thaw and changes to precipitation and hydrologic patterns will affect the distribution and availability of vegetation communities and aquatic habitats. They will also affect phenology, the timing of animal migration and plant and insect emergence, potentially having profound consequences for many wildlife species. Some shorebird species are already nesting near Teshekpuk Lake on Alaska's North Slope two weeks earlier than two decades ago (*Zack and Liebezeit 2008*). The USGS, FWS, and NPS are cooperating to develop projections of changes to potential wildlife habitat north of the Alaska Range (*Martin et al. 2008*).

The toolbox of scientific and traditional ecological methods for estimating climatic and environmental change continues to expand. Pollen analysis in lake sediments from Lake Clark and elsewhere has enabled researchers to reconstruct how trees have spread across Alaska (*Bigelow 2008*). Similar research in the Noatak has enabled determination of fire frequency in grass and shrub communities into the past (*Allen et al. 2008*). Recent research indicates that fire may be more common in Northwest Alaska than has generally been recognized. However, relatively little tundra (about 10%) has burned in the last 40 years. Caribou can graze recently burned tundra during spring growing seasons, but when searching for lichens during winter months, they avoided sites that have burned in the last 55 years (*Joly et al.*, this issue).

There is no effective substitute to long-term monitoring for understanding how climate change and disturbance affects species population dynamics, food habits, behaviors and health. And the best time to establish those programs is well before the anticipated disturbances. The NPS Inventory and Monitoring Program is developing and testing monitoring protocols for a wide range of "vital signs" to track resource status and trends into the future, and in some cases into the past. New tools for wildlife surveys, such as handheld computers, and Global Positioning System (GPS)-linked digital photo documentation can increase the accuracy of aerial surveys over large landscapes (*Rattenbury and Lawler 2008*). Traditional and local knowledge can provide a window into changes witnessed through multiple generations of observers (*Bogoslovskaya, Hild et al., Krupnik,* all this issue) (*Fjeld 2008, Irisova 2008, Kalyuzhina et al. 2008, McMillan 2008, Metcalf and Robards 2008*).

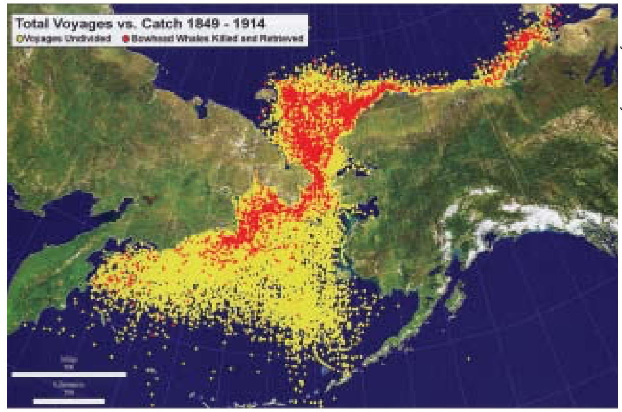
Photograph courtesy of A.A. Orekhov

Figure 4. Winged artifact from the ancient Eskimo settlement of Kivak, Chukotka, Russia.

Climate warming is accelerating permafrost thaw in the Arctic, is affecting surface and groundwater quantity and quality, and is sometimes resulting in rapid and dramatic slope collapse (*Figure 11*) (*Balser et al. 2008*). Slope thaw and collapse in the Noatak has released huge quantities of sediment into riparian systems. Water flowing from these thermokarst sites also contains about triple the normal concentrations of dissolved nitrogen (nitrate and ammonium) and dissolved carbon compared to reference groundwater (*Jones et al. 2008*). The wetlands habitats of the Beringian Arctic are critical for migratory birds from several continents, but these habitats are also changing as a result of permafrost thaw and thermokarst. Pond formation is an early result of permafrost degradation, but as the

Photograph courtesy of L.S. Bogoslovskaya

Figure 5. Harvesting walrus.



Courtesy of Bradley Barr

Figure 6.Voyages and harvests of bowhead whales 1969-1914.

Courtesy of William Hamilton, from the Nathan Muus Collection for Saami Báiki

Figure 7. Some of the first group of Saami herding families who came to Alaska from Norwegian Lapland in 1894, photographed at their camp at Teller Reindeer Station, Port Clarence, Alaska. When their three-year contract was up four of the six families returned to Norway, and two stayed in Alaska. In 1898 they were joined by 50 more herding families from Lapland. Their descendants often married into Inupiaq families, and together they developed the herds that provided food, clothing and transportation for Native villages throughout western Alaska and St. Lawrence Island, as well as for miners during the gold rush.

downward thaw continues, water levels can either fall or rise, depending on local groundwater hydrology and other factors (*Bryan et al. 2008*). Modeling is already underway to determine potential effects of thermokarst development in the Yukon River basin over the next 50-100 years.

Tourism

There will likely be winners, and losers, as a result of climate change. The ecological importance of national parks, *Zapovedniks*, refuges, and other terrestrial, aquatic, and marine sanctuaries is great (*Bersenev 2008*). Tourism, in parks and other federally managed lands, is a vitally important contributor to Alaska's economy (*Fix et al.*, this issue). From a tourism-related perspective (perceived temperature, wind, visibility, and absence of severe weather), climate has improved in some areas of Alaska since the 1940s. Although the skiing season has been ending significantly earlier, the sightseeing season has also been starting earlier. These conditions were significantly correlated with the increased visitation to Denali National Park and Preserve in early summer (*Trainor et al.*, this issue). In Russia, there are already 135 national parks and strict federal reserves (*Zapovedniks*) totaling over 100 million acres, which are well positioned for expanding ecotourism (*Soboleva 2008*). The Kamchatka Peninsula, for example, is emerging as a popular nature based vacation destination in Russia (*Overbaugh et al. 2008*). Ecologically sustainable tourism may also become an increasingly important viable option for preserving healthy environments and traditional subsistence cultures in more remote areas of the Russian Arctic (*Irisova 2008, Uyaganskiy*, this issue).

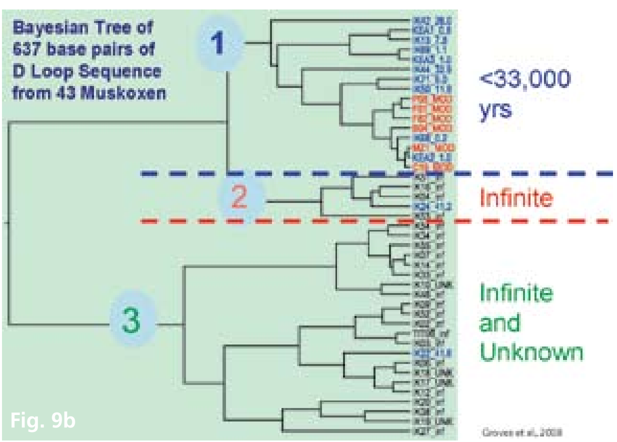
Outreach, education and the importance of community participation in learning and sharing information

The importance of science and scholarship to society cannot be overestimated, but it can be, and often is, underappreciated. Scientists, scholars, educators, and other professional communicators have a moral imperative to communicate their findings and their enthusiasm for science and for preservation of the arctic. Many innovative and exciting approaches are being used to communicating with diverse audiences. Technology, through podcasts, short films, public service announcements, weather stations or other means, can be effective for reaching out and letting people experience science in the remote and wild parks of the Arctic (*Andler 2008, O'Connell*, this issue). Such experiences can also help to generate passionate park stewards and potential future researchers and interpreters. High school students from Anchorage, Alaska, are collaborating with their counterparts in Chukotka, Russia, to examine how climate change is affecting their environments and their lives, and to identify concrete steps whereby they can be part of the solution (*Whaley 2008*). A project in the Western Arctic National Parks provides students in rural communities with opportunities to gain experience in scripting, recording, and producing podcasts on a wide range of topics of interest to their communities (*Devinney 2008*). Polar Trek, and the Murie Science and Learning Center offer experiential learning programs where educators accompany researchers in the field. Field-level biologists with the Northern Forum's Brown Bear Working Group are sharing information, tools, and solutions to foster coexistence of bears and humans across multiple countries (*Van Daele 2008*). Go North's "What's Climate Change to You" program visits Arctic communities by dogsled, while sharing local knowledge about climate change through real-time broadcasts and curriculum-based learning (*Figure 12*) (*Porsild et al. 2008*). The Takahula Lake symposium project in Gates of the Arctic facilitates writers

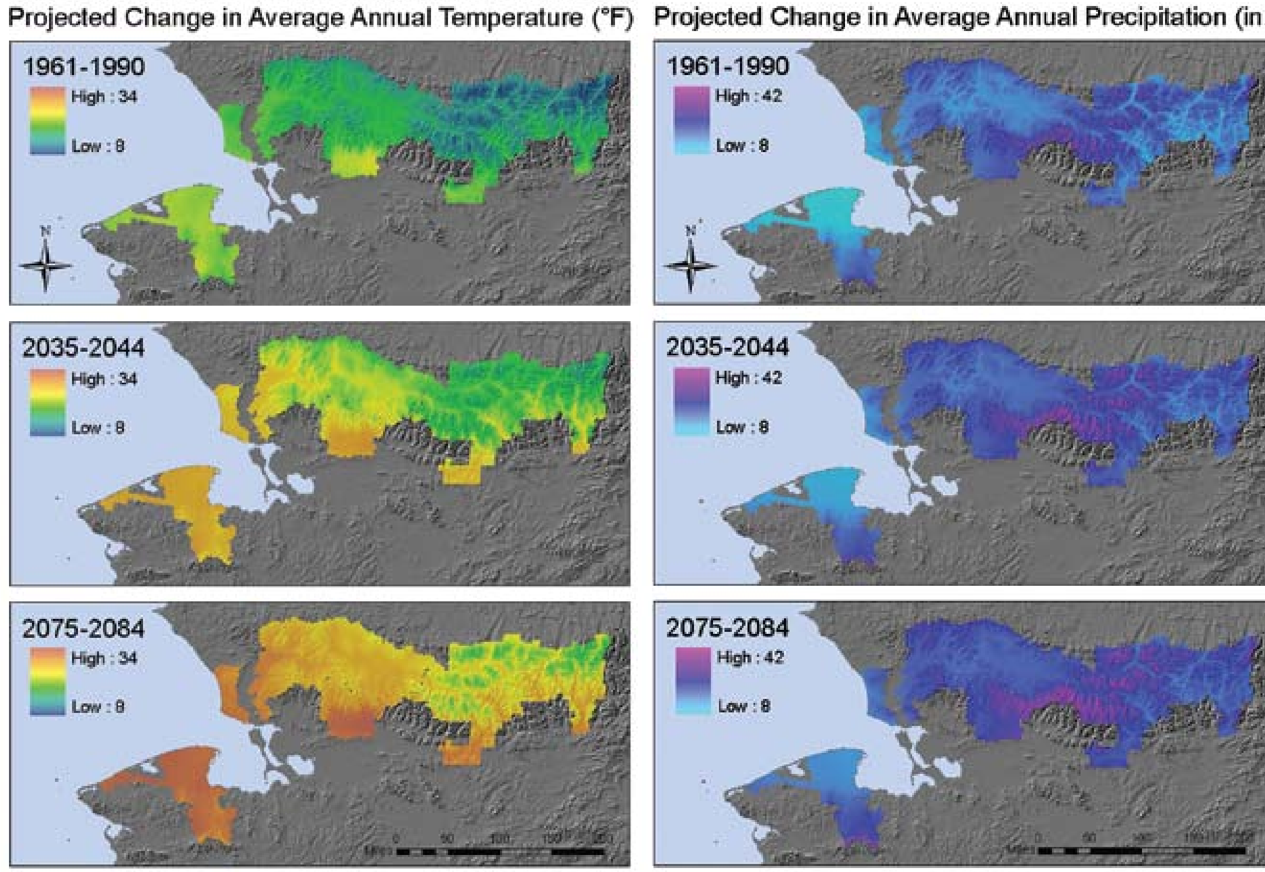
Photograph courtesy of Jim Jordan

Figure 8. Storms have caused severe coastal erosion in coastal Alaska, including parts of Cape Krusenstern National Monument.

Photograph courtesy of Pam Groves



Figures 9a-b. Analyses of DNA recovered from fossil musk ox indicate major losses of genetic diversity have occurred at least twice in the fossil record.



Courtesy of The Wilderness Society

Figure 10. Mean historic annual temperature and precipitation regimes and future composite model projections for 2040 and 2080 decadal averages.

Photograph courtesy of Andrew Baker

Figure 11. Massive hill slope collapse resulting from permafrost thaw near Okoklik Lake, Noatak National Preserve. Note helicopter at left and the person in the center (small red box) to gauge the scale of this event. The red box with the person is also enlarged at right.

coming together to discuss how to foster a healthy relationship with nature and to promote resource stewardship (*McMillan 2008, Mills 2008*). Denali's Artist-in-Residence program is proving the arts to be viable alternatives for communicating information, concepts, and passion to large audiences (*Duffy*, this issue).

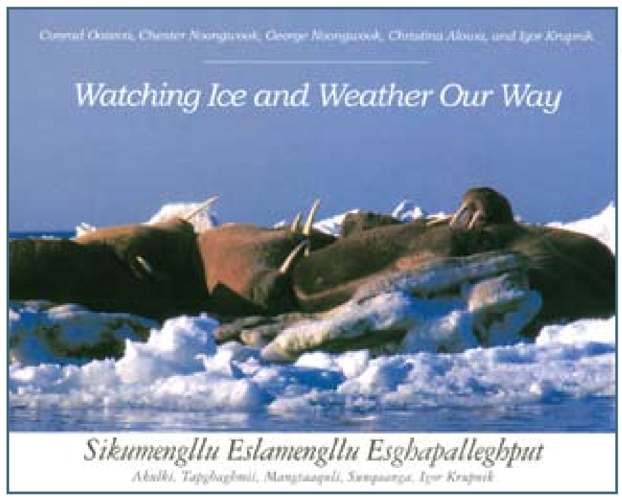
The differences that set people apart across Beringia are much less than the similarities that unite them. The vibrancy of contemporary links can be seen in Go North's project, which shares community observations throughout the world (*Porsild et al. 2008*), in the SIKU project's development of dictionaries based on local and traditional knowledge (*Figure 13*) (Krupnik, this issue), and in Project Environment's student exchanges across the Bering Straits (*Whaley et al. 2008*). In the future, there is concern for intergenerational transmission of cultural and traditional knowledge, retention of traditions, and development of economic opportunities that are respectful of tradition. Tourism development needs conscious consideration of potential impacts to Native villages in Chukotka and in Alaska.

Though vast and unique, Beringia is, after all, just geography. Whether the region was exposed as the land bridge, or is now united by great marine waterways of the Bering Straits, the connections between people, traditions, physical and biological components of the land remain strong, contemporary and interesting.

Acknowledgements

The author was assisted in collecting information for this synthesis by Lois Dalle-Molle. This synthesis report and the proceedings would not have been possible without the generosity of many presenters who shared their special knowledge, experience, and images. Readers interested in more information about these and other presentations are encouraged to review abstracts posted at: http://nps.arcus.org/meetings/2008/abstracts.html

Figure 12. Team GoNorth! delivering "What is Climate Change to You?" in the field with nomadic Chukchi reindeer herders in the remote region of Chukotka, Russia, during the live GoNorth! Chukotka 2007 adventure learning program.



Courtesy G. Carleton Ray

Figure 13. Cover page of a recent book documenting traditional knowledge of the Yupik people of St. Lawrence Island, Alaska, Watching Ice and Weather Our Way/ Sikumengllu Eslamengllu Esghapalleghput (2004), a joint production of the Smithsonian Institution, Marine Mammal Commission, and the Yupik communities of Gambell and Savoonga.

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Vast and Unique Beringia

Beringia from a Cretaceous Perspective

A.R. Fiorillo, D.W. Norton and P.J. McCarthy

National Park Service units in Alaska contain some of the most informative fossil-bearing rocks anywhere in North America. These park units fall within the dynamic subcontinental region denoted by "Beringia," the hypothesized land bridge connection between Asia and North America during the Plio-Pleistocene (*Hultén 1937*). By linking similar aged rock units in National Park Service lands with the fossil resources found on other federally-administered public lands, important paleoecological insights on specific ecosystems can be obtained. Here we provide summaries of how pertinent regions address the antiquity of terrestrial Beringian ecosystems, the implications of this antiquity, and suggest that the NPS–Alaska Region is ideally situated to adopt leading roles in exploration of this concept.

Role 1: Sites for field research on Cretaceous Beringia

Late Cretaceous rocks of Denali National Park and Preserve (Denali), Yukon-Charley Rivers National Preserve (Yukon-Charley), Wrangell-St. Elias National Park and Preserve (Wrangell-St. Elias), and the North Slope of Alaska provide some of the most significant opportunities to examine a regional ancient terrestrial ecosystem in detail. Additionally, paleontological work on similar aged rocks in southwestern Alaska in Aniakchak National Monument has shown that this ecosystem is recorded across the state (*Fiorillo and Parrish 2004*). This ecosystem supported a rich dinosaurian fauna as well as other fossil vertebrates such as mammals, birds, and fishes (*Fiorillo 2006, Gangloff 1998*). The floral component of this ecosystem also was diverse and included angiosperms, gymnosperms, and ferns.

Figure 1. Map of Beringia with NPS units highlighted (green) and the National Petroleum Reserve (yellow). The three NPS units with known records of dinosaurs (Aniakchak National Monument, Denali National Park and Preserve, and Wrangell-St. Elias National Park and Preserve) are shown here in darker green.

The Cantwell Formation is an extensive rock unit exposed throughout much of Denali and is now known to contain thousands of fossil vertebrate footprints (*Fiorillo et al. 2007, Fiorillo et al. 2009*). The rock unit is thousands of meters thick and consists of an upper, dominantly volcanic unit and lower, dominantly fluvial unit. Pollen analysis for the lower Cantwell Formation shows the rock unit to have been deposited during the latest Cretaceous. Sedimentation was dominated by stream and lacustrine environments, at times with a marginal marine influence. The vegetation at the time was dominated by conifer forests, and a mosaic of angiosperms in the forest understory.

Unnamed rocks in Yukon-Charley have been mapped as Cretaceous-Tertiary in age based on fossil floral remains (*Brabb 1965, Dover and Miyaoka 1988*). The depositional environments of these rocks, like the Cantwell Formation, represent rivers and floodplains. Given that they may be similar in age to those in Denali they are included here. The forest of this park unit was dominated by *Metasequoia*. No dinosaur remains have been found in these rocks.

Similar to Yukon-Charley, Wrangell-St. Elias also contains unnamed rocks of Cretaceous age (*Richter 1976*). Recent preliminary paleontological field work has now shown that these rocks contain multiple dinosaur footprint types attributable to predatory dinosaurs and herbivorous dinosaurs. Whereas forests dominated the landscape in other regions, the rocks of this park suggest that forest cover was limited and instead the vegetative cover was dominated by expansive fern prairies. The limited forest cover replaced by fern cover may have been the result of a more dynamic river system that flooded the landscape more frequently compared to any of the other regions.

NPS units containing a fossil vertebrate record discussed here are so far based solely on fossil footprints. By contrast, comparably aged rocks on the North Slope contain an abundance of fossil bones, mostly dinosaurian, with only a minor record of fossil footprints. These two types of records then provide independent means to test ecosystem hypotheses.

Figure 2. Cretaceous hadrosaur (duck-billed dinosaur) footprint from Denali National Park and Preserve.

Florally, an abundant and diverse assemblage of pollen, spores, amber, algae, and other microscopic plant debris has been recovered from the North Slope. The vegetation for this region of Alaska during the latest Cretaceous was dominated by conifer forests across the coastal plain and a mosaic of broad-leafed deciduous forest in riparian areas. The understory probably consisted of ferns and smaller angiosperms.

The depositional environment for the Late Cretaceous dinosaur-bearing units was that of a low-energy alluvial coastal plain. The floodplain was wet, but water levels probably fluctuated from shallow standing water to dry and subaerially exposed, possibly on a seasonal basis.

Beringian ecosystems have fostered specializations of flora and fauna over time, as is especially evident among those vertebrates that leave abundant fossils. Striking faunal and floral structural parallels in ecosystems are manifest in the Cretaceous of this region. Current paleontological investigations on correlative fossil-bearing rocks in these three regions, combined with revised tectonic reconstructions of the region lead us to conclude that Beringia originated some 100 million years ago (*Fiorillo 2008*). This extension of Beringia back in time requires a reordering of the importance we assign to underlying mechanisms. Atmospheric and oceanic phenomena remain important climate variables to explain the Quaternary changes in Beringia. Accepting Beringia's origins in the Cretaceous, however, implies that Beringia is rooted in its accretionary rather than in its climatic history. In other words, tectonics has been the defining parameter for Beringia Paleoclimate data show that temperatures in the northern polar regions were significantly warmer during the Cretaceous compared to the modern data (*e.g., Barrera and Johnson 1999*). Studying ancient Beringia provides a unique opportunity to compare high latitude ecosystem dynamics under contrasting greenhouse and icehouse conditions.

Role 2: Opportunities for synthesis of the Cretaceous origins of Beringia

The concept of Beringia as limited to the Plio-Pleistocene depends entirely on glacial advances and retreats to drive falls and rises in sea level. High sea levels facilitate exchanges of marine biota between the Pacific Ocean and Arctic Basin; lower sea levels enable terrestrial faunal and floral exchanges between Asia and North America. Recent advances in resolution of geochronologic methods show us that climate-driven sea level changes have been relatively recent and weak determinants of biogeographic patterns—the final epilogue to a Beringia story spanning 100 million years.

Some analysts convinced of Beringia's Quaternary reality are still surprised to learn that Beringia's influence on regional and circumarctic biogeography had begun by the early Tertiary. Pre-Quaternary connection of Asia to North America was acknowledged with the broad acceptance of plate tectonic theory (*Hopkins 1967a, Cox 1974, Marincovich et al. 1990*). Quaternary Beringia enjoys a 400-year head start over the concept of Mesozoic Beringia. A South American Christian missionary in 1590 first proposed that dry land connected northeastern Asia to the Alaskan tip of northwestern North America, to explain the peopling of the New World (*O'Neill 2004*). Not until 200 years later, at the end of the eighteenth century, had Vitus Bering's and Captain James Cook's voyages confirmed close physical, biological and cultural connections between the two continents. About 150 more years passed before Hultén's *(1937)* phytogeographic studies gave the subcontinental region a name and accelerated the subsequent proliferation of geological and biogeographic

Museum of Nature and Science photograph

Figure 3. Cretaceous sedimentary rocks representing ancient river channels and floodplains in Denali National Park and Preserve.

Museum of Nature and Science photograph

Figure 4. Cretaceous fossil fern from Wrangell-St. Elias National Park and Preserve.

investigations (*O'Neill 2004*). After 50 more years, the dinosaur fauna of Arctic Alaska began to persuade analysts that Beringia's global influence is immense, temporally as well as spatially.

Hultén's original concept was limited. He conceived of Beringia as the major ice-free refugium for terrestrial northern vascular plants being excluded and extirpated elsewhere by glaciers and continental ice sheets during glacial maxima. Since the mid-twentieth century, biogeographers and paleontologists have credited Beringia with additional functions in the diversification of biota over increasing spans of geological time in the Northern Hemisphere (*cf. Abbott and Brochmann 2003, Sanmartín et al. 2001*). Collectively, these scientific efforts remain compartmentalized and under-recognized across boundaries separating disciplinary specialties. Evidence from dinosaur paleontology in Alaska, however, suggests that reaffirming the Cretaceous underpinnings of Beringia can lead to a timely synthesis of ideas between biogeographers and geologists.

Viewing Beringia as rooted in the Cretaceous reminds us that details of current phenomena and of the more recent past blur into broader generalizations further back in time. Likewise, subtle taxonomic affinities and distinctions among extant biota are replaced by larger, more radical, taxonomic distinctions in the more distant past. The interdisciplinary challenge for paleontologists is nevertheless to remain conversant with the nuances that modern sciences bring to bear on understanding current biological systems.

A synthesis of disparate pieces of evidence for Beringia's being a determinant of phenomena characterizing the Northern Hemisphere is likely to elude the efforts of disciplinary specialists until they are brought face to face in collaboration. The U.S. Geological Survey once carried out this facilitation (*e.g., Hopkins 1967b*), which clearly needs to be resumed. The NPS has a history of recognizing the significance of Beringia through its administration of the Shared Beringian Heritage Program. Given that much of the key geology defining the antiquity of Beringia falls within NPS boundaries, these NPS units are ideally situated for addressing fundamental questions regarding ancient ecosystem dynamics in deep geologic time.

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Late Cretaceous Flora in an Ancient Fluvial Environment: The Lower Cantwell Formation at Sable Mountain, Denali National Park, Alaska

By Carla Susanne Tomsich, Sarah J. Fowell and Paul J. McCarthy

Abstract

The lower Cantwell Formation is a late Cretaceous fluvial deposit that contains dinosaur footprints and plant fossils. Facies analysis of numerous conglomerate, sandstone, siltstone, and shale successions in the Sable Mountain area in Denali National Park and Preserve reveals a variety of depositional settings, including channels, overbank, crevasse splays, lakes and ponds, located in close proximity on an ancient floodplain or alluvial fan. Plant megafossils preserved in the finer-grained facies indicate that the Cantwell flora was a polar broad-leaved deciduous mixed forest with diverse angiosperms and several deciduous conifers. Combined sedimentological and paleobotanical studies allow identification of distinct local plant communities associated with each of the depositional settings. Dicotyledonous angiosperm leaf morphology was used to compute a mean annual temperature of 51.1°F (10.6 °C), a warmest monthly mean of 69.1°F (20.6 °C), and a coldest monthly mean of 34.7°F (1.5 °C). Climate in this high-latitude region was temperate, with mild winters and considerably warmer summers than those that prevailed on Alaska's North Slope during the Late Cretaceous.

Introduction

The Cantwell Formation crops out in the foothills and northern mountains of the Alaska Range in southcentral Alaska. In Denali National Park and Preserve (Denali Park) the formation can be readily recognized from the park road by its precipitous cliffs and dramatic bluish black, yellow and reddish colors. Exposures in the Sable Mountain area in Denali Park consist of numerous successions of conglomerates, tabular and lenticular sandstones, organic-rich siltstones and shales. Plant fossils and recently discovered dinosaur footprints, bird footprints, and diverse invertebrate traces indicate a flourishing terrestrial ecosystem in a high-latitude environment (*Fiorillo et al. 2007*), as the Cantwell basin was probably located at a paleolatitude > 65 °N at the time of deposition (*Spicer et al. 1987*). Analyzed in lithological context, the plant fossils of the lower Cantwell Formation provide new information about the landscape, vegetation, climate and depositional processes for this Late Cretaceous basin.

Geologic Background

Beginning about 90 million years ago, Alaska grew in size as small segments of northward-displaced lithospheric crust (terranes) collided with the former southern Alaska plate margin (*Plafker et al. 1994*). The terrestrial Cantwell Formation was deposited during the final accretionary phase of the composite Wrangellia terrane to the North American continent (*Ridgway et al. 1997*). Now located within the Denali Fault system, the Cantwell Formation forms a 22 mile (35 km) wide, about 78 mi (125 km) long, east-west trending belt along the northernmost edge of the Alaska Range. The formation comprises a 2.5 mi (4 km) thick fluvial sedimentary succession of late Campanian to Maastrichtian age (75 to 70 million years in age) (*Ridgway et al. 1997*) and an upper volcanic unit of Paleocene and Eocene age (60 to 55.5 million years in age) (*Cole et al. 1999*). Both the upper and lower Cantwell Formation were folded and faulted during subsequent tectonic deformation and then uplifted during the rise of the Alaska Range. At Sable Mountain, the older sedimentary rocks are well exposed (*Figure 1*).

Fluvial Lithofacies and Facies Associations

A floodplain constitutes a low-gradient land surface that is drained by a major river and its tributaries. It is not a static environment. Here streams erode, transport and redistribute sediments as they change their course. In between streams and rivers, marshes, lakes and ponds develop in low-lying areas where drainage conditions are poor. Fine sediment accumulates slowly during ephemeral floods as the basin subsides. Levees form where coarser sediment builds up during overbank floods or where channels incise into older sediments. As a result, different depositional environments such as channels, levees,

Photograph by C.S. Tomsich

Figure 1. The sedimentary lower Cantwell Formation exposed at Sable Mountain in Denali National Park.

crevasse splays, lakes, ponds and floodplain develop next to each other and succeed one another; the changing dynamics produce a variety of lithologies (facies) and facies assemblages in an alluvial setting. Habitat preference, frequency of recurring floods and soil quality determine the types of vegetation that will grow in these different fluvial environments. Sedimentary and fossil records thus harbor complementary paleoenvironmental information.

Sedimentary Facies of the lower Cantwell Formation

Facies 1: Massive conglomerate

This facies contains clasts up to 6 inches (15 cm) in diameter with a predominantly matrix-supported texture. Deposits are often trough-shaped, winnow out laterally and are rarely more than 13 ft (4 m) thick. Moderately sorted clasts are subangular to wellrounded and occur in coarse to very coarse, subangular to subrounded sand. Typically conglomerates contain lenses of sand or thin layers of mud, dividing the deposits into multiple stories. Bedding is cross-stratified or massive. Tree trunk impressions are common. Facies 1 is interpreted as gravelly channel fill.

Facies 2: Pebbly sandstone

Facies 2 consists of tabular or lens-shaped coarse- to medium-grained, pebbly sandstones less than 20 ft (6 m) thick that grade laterally into finer-grained, organic-rich facies. Angular to well-rounded pebbles ranging in size from 0.1 to 2 in (0.3 to 5 cm) commonly rest on low-angle foresets. Deposits are massive or trough cross-stratified and grade upward into medium sandstone. Facies 2 is interpreted as levee, small channel or crevasse splay channel fill.

Facies 3: Coarse- to medium-sandstone

Tabular and lenticular coarse- to medium-grained sandstone bodies embedded in finer-grained deposits are typically less than 3.3 ft (1 m) thick. Deposits are massive,

Photograph by C.S. Tomsich

Figure 2. (A) Twig of the taxodiaceous conifer *Metasequoia*. (B) A 6.6 ft (2 m) high in situ *Metasequoia* tree trunk and shallow root impression in channel sands. The tree was growing in the floodplain before being incorporated into the deposits of a migrating channel.

planar, or trough cross-bedded and may have granules on foresets. Sand grains are predominantly subangular and moderately sorted. Facies 3 is interpreted as levee, small shallow channel fill and overbank sheetflood deposits.

Facies 4: Fine sandstone

Facies 4 is a tabular or lenticular sandstone embedded in finer-grained deposits consisting of subangular to subrounded grains. Bedding is massive, rippled or trough cross-stratified with rare mud on foresets. This sandstone is typically burrowed and moderately rooted. It frequently contains twigs and cones of *Metasequoia*, *Equisetum* rhizomes and stems, leaf impressions and wood. Facies 4 is interpreted as small channel fill, crevasse splay, and sheetflood deposits.

Facies 5: Interbedded fine to very fine sandstone and siltstone

This facies consists of laterally extensive decimeter- to centimeter-scale tabular beds of interbedded fine-to very fine-grained sandstone and siltstone that often grade into siltstone. Sandstone is massive or rippled. Deposits contain invertebrate trace fossils and abundant plant macrofossils. Roots and concretions indicate weak soil development.

Figure 3. Pinnately-veined leaf impressions. Such fossils occur in crevasse splay and overbank deposits.

Facies 5 is interpreted as crevasse splay, sheetflood, levee and overbank deposits.

Facies 6: Interbedded fine to very fine sandstone and mudstone

Facies 6 is a centimeter to millimeter-thick fine- to very fine-grained, tabular sandstone interbedded or interlaminated with mudstone. It may be rippled, trough cross-bedded or laminated and contain small traces made by beetles, gastropods, ostracodes and annelids. Plant macrofossils are abundant; and roots and concretions are evidence for soil development. This facies is interpreted as distal crevasse splay, sheetflood, levee and overbank deposits.

Facies 7: Siltstone

Facies 7 is a dark grey to black siltstone, centimeters to tens of meters thick. It is organic-rich and may be interlaminated with mudstone. This facies contains conifer needles, *Equisetum* rhizomes, carbonaceous roots and other plant fragments. Iron concretions or nodules are very common. Beds typically show irregular relief at the top that was likely caused by dinoturbation. This facies is interpreted as distal crevasse splay, floodplain and lake margin deposits.

Facies 8: Mudstones and shales

This very fine-grained facies consists of dark grey to black organic-rich mudstone and shale that is usually 0.4 in to 3.3 ft (1 cm to 1 m) thick, rich in clay, and locally calcareous. Mudcracks may be seen at the surface or beds may be irregular due to erosion and bioturbation. Facies 8 typically occurs in coarser-grained deposits in the form of rip-up clasts. Fossils consist of *Equisetum* segments, small, frequently coalified, plant fragments, carbonaceous rootlets, and bivalve and gastropod shells. This facies is interpreted as floodplain, shallow lake or pond deposits.

Facies 9: Unorganized deposits

Facies 9 contains clasts of all sizes, pieces of wood, and mud rip-up clasts in a sandstone or organic-rich mudstone matrix. Deposits are often poorly consolidated, infrequent and occasionally contain in situ tree stump impressions. We interpret Facies 9 as debris flows.

Alluvial deposition

The facies and facies associations in the lower Cantwell Formation indicate that the rocks at Sable Mountain represent alluvial sheetfloods, braided channels, crevasse channels and splays, overbank and levee deposits, small shallow lakes or ponds and floodplain sediments. Lithologies reflect sedimentary processes typical of low-lying fluvial environments. The sedimentary environment has been characterized as an alluvial fan system drained transversally by an axial sandy braided river (*Ridgway et al. 1997*). The many tabular sandstones and floodplain fines at Sable Mountain indicate that deposition occurred close to the center of a fluvial valley either at the distal end of an alluvial fan lobe where ephemeral floods would have been common (*Leeder 1999*) or in the floodplain of a trunk river and its tributaries. Poorly organized colluvial deposits (Facies 9) in the Sable Mountain area and elsewhere in the basin (*Ridgway at el. 1997*) suggest that the tabular sheetflood sandstones may be periodic, distal alluvial fan stream flow deposits. However, trough-shaped conglomerates and coarse sandstones in extensive floodplain fines signify that alluvial fan sediments interfinger with the floodplain deposits of the main river system that drained the ancient valley.

The different lithologies and geometries of the sediment created a variety of local habitats with different drainage conditions. For example, the numerous successions of shallow, fine-grained sandstones and siltstones suggest that overbank floods were frequent but that deposition was quickly abandoned as waters receded. Abundant roots in the interbedded sandstones suggest that these facies allowed for a rapid re-vegetation of the disturbed areas. The lithology of the deposits becomes finer-grained with increasing distance from active streams. Marshy lowlands and standing water bodies developed in poorly drained areas. Minor paleosol development in floodplain fines signals predominantly wet conditions. As fluctuating water tables generally affect soil formation and consequently plant species distribution, a riparian vegetation would have been required to readjust with each change to the depositional setting (*Dwire et al. 2006*).

The Fossil Flora of the Lower Cantwell Formation

The lower Cantwell Formation yields abundant plant impressions including the stems and rhizomes of horsetails (*Equisetum*); fronds of schizaceous and gleichenaceous ferns and of *Cladophlebis*, an extinct fern; leaves, cones and seeds of the deciduous conifers *Metasequoia* (*Figure 2*) and *Glyptostrobus*; fragments of ginkgophytes, cycadophytes, diverse dicotyledonous angiosperm leaves (*Figures 3-4*), and the monocot *Sparganium* (Thypha) and other unidentified blade-like leaves. Also present are log impressions (*Figure 2B*) and lithified wood. Sparse and poorly preserved fossil pollen grains and spores extracted from organic-rich mudstones yielded the angiosperm pollen taxa *Alnipollenites* and *Aquillapollenites*, the coniferous pollen taxa *Taxodiaceaepollenites*, few cycad or ginkgo pollen grains, and abundant horsetail and fern spores.

Angiosperm leaf fossils have simple forms with palmately, pinnately or palmately-pinnately venation, but fragments of large palmately-lobed leaves also occur. Leaf sizes range from 0.6 in (1.5cm) to an estimated 20 in (50 cm), based on vein spacing. The majority of the taxa belong to the families Platanaceae, Nymphaeaceae, Menispermaceae and Hamamelidaceae. Of the platanoid types forms such as *Pseudoprotophyllum* are rare while leaves of betulaceous morphology (cf. *Corylites* and *Alnites*) are especially abundant. Other taxa such as *Viburniphyll* and the trochodendroid, zizyphoid and the vine-like menispermoid groups often occur in association with the platanoids and remains of taxodiaceous conifers. In all, 21 angiospermous morphotypes were identified from the study area on the basis of leaf organization.

The depositional habitat environments

Plant fossils recovered from fluvatile facies approximate the composition of an ancient local flora (*Spicer and Parrish 1990*). At Sable Mountain the sandier deposits apparently favored leaf preservation due to better drainage and rapid accumulation. Fossil assemblages are more diverse in levee, crevasse splay, and overbank deposits than in floodplain and lake facies, and plant community associations are interpreted to correspond to three sub-environments: stream margin, elevated floodplain and low-lying floodplain.

Angiosperm leaf taxa appear individually or as part of a mixed forest litter. Platanoid trees or shrubs grew predominantly along streams (*Facies 2 and 3*). A more complex assemblage containing *Metasequoia* leaves and cones and diverse hamamelid angiosperm leaves are found primarily in sandy overbank deposits and embankments (*Facies 3-6*). The finer-grained and more organic-rich floodplain facies (*Facies 5-7*) contain elements of the conifer *Glyptostrobus*, the angiospermous leaves *Alnites*, *Menispermites*,

Photograph by C.S. Tomsich

Figure 4. Palmately-veined trochodendroid leaf impression. These leaf fossils are common in crevasse splay, overbank and levee deposits, and to a lesser degree in floodplain and lake margin deposits.

and *Sparganium*, rare cycad leaves, *Equisetum* and a variety of ferns.

The different fossil assemblages signify that soil and drainage conditions varied within the floodplain according to facies distribution and frequency of river sand and fertile mud deposition. In better-drained and more built-up areas diverse angiosperm shrubs and small-diameter trees may have formed an open canopy forest together with *Metasequoia*. In contrast the dominant lowland vegetation in the floodplain and along the lake and pond margins consisted of a low-diversity flora, which included platanoids, nymphaelalean vine-like plants, a variety of ferns and hydrophilic gymnosperms. Cycads, *Equisetum* and herbaceous plants covered the marshes.

Geographic species distributions and paleoclimate

The Cantwell Flora contains elements that are present in other Arctic floras. Taxodiaceous conifers such as *Metasequoia* and *Glytostrobus* and species of the dicot leaf genera *Trochodendroides*, *Menispermites*, *Zizyphoides*, *Pseudoprotophyllum*, *Corylites*, the monocot *Sparganium* and the ferns *Gleichenia* and *Cladophlebis* were widespread in the Arctic during the late Cretaceous (*Hollick 1930, Spicer et al. 1987, Budantsev 1992, Herman and Spicer 1995*). Yet, even though as these genera are well represented in the Cantwell flora, it is still unclear how they relate at the species level given that very few species could be identified.

Fossil leaf character correlation with modern leaf physiognomies and climate variables has proven effective in computing ancient climate parameters (*Wolfe and Spicer 1999*). Using Climate Leaf Analysis Multivariate Program (CLAMP) (*Wolfe and Spicer 1999*), our first estimate for a mean annual temperature (MAT) is 51.1°F (10.6 °C), a warmest monthly mean (WMMT) is 69.1°F (20.6 °C) and a coldest monthly mean (CMMT) is 34.7°F (1.5 °C). In comparison, Spicer and Parrish (*1990*) calculated a MAT of 35.6 to 43°F (2 to 6 °C); and Parrish et al. (*1987*) estimated the WMMT at 50 to 53.6°F (10 to 12 °C) and the CMMT at 35.6 to 39.2°F (2 to 4 °C) for the Maastrichtian flora of the Prince Creek Formation which crops out on Alaska's North Slope. These results indicate that the Earth was much warmer at the time and that winters were mild. Variables computed for the Cantwell basin, however, show greater disparity between summer and winter temperatures. While the CMMT calculated for the two floras is very similar, average summer temperatures are significantly higher for the Cantwell data. This disparity could be a symptom of terrain and latitudinal differences. The North Slope at the time was a fluvio-deltaic setting facing the Arctic Ocean. It was located at approximately 85 °N, and angiosperm diversity was reportedly low (*Spicer and Parrish 1990*). The Cantwell basin, in contrast, was located further inland, 10 degrees or more to the south, opening toward an epicontinental sea to the east, the Cretaceous Western Interior Seaway (*Ridgway et al. 1997*). Results suggest a strong pole-ward summer temperature gradient possibly due to southward increases in insolation. Taxa and calculated temperatures indicate that the Cantwell flora like other late Cretaceous Arctic floras can be categorized as a polar coniferous and broad-leaved deciduous forest flora (see *Wolfe 1987*).

Conclusion

The late Cretaceous lower Cantwell Formation at Sable Mountain represents braided channel, small channel, crevasse splay, levee, overbank, floodplain, and lacustrine sediments and occasional debris flows typical for floodplain and/or distal alluvial fan deposition. Plant fossils analyzed in the context of lithofacies show that coniferous and angiospermous plants formed distinct floral community associations in a variety of depositional environments. Vertical facies successions and accompanying changes to the floral communities reflect altered hydraulic conditions during floodplain evolution. Taxodiaceous conifers and dicotyledonous angiosperms achieved significant diversity; taxa at the family and genus levels correspond to those described from other Arctic floras. Accordingly, the Cantwell flora is classified as a polar broad-leaved deciduous mixed forest flora. CLAMP analysis implies that climate in this high-latitude region was temperate, with mild winters and considerably warmer summers than those predicted for Alaska's North Slope during the Late Cretaceous. In this way, the paleofloristic data amend our understanding of vegetation distributions and past climate variability in ancient greater Beringia.

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Contrasting Patterns of Plant Distribution in Beringia

By Stefanie M. Ickert-Bond, David F. Murray and Eric DeChaine

We dedicate this science summary to the memory of Les Viereck (1930-2008), fellow Alaskan botanist, ecologist and contributor of many superb herbarium specimens to the ALA herbarium.

Abstract

The Bering Land Bridge has been a major highway for Asian plants into North America, but also a barrier to some and a filter for others. Additionally, there are widely separated and highly local occurrences of Asiatic species in Alaska and adjacent Yukon that are thought by some to be relicts of late-glacial steppe-tundra. Molecular sequence data successfully clarify historical dispersal and vicariance events and will help resolve the role that Beringia played in facilitating and/or inhibiting plant migrations. Furthermore, hypothesis testing through coalescence-based analyses of molecular sequence data provides a powerful means of investigating the region's floristic history.

Introduction

Nearly 80 years have passed since the term Beringia was coined by E. Hultén (*1937*) to refer to the immense unglaciated areas of Alaska and the adjacent regions of northwestern Canada and northeastern Russia. A vast literature on Beringia is now available that addresses questions of persistence in the glacial refugium, exchanges of plants between Asia and America, diversification of plants in the refugium, and Beringia as a source of tundra plants for post-glacial expansion into deglaciated areas beyond its borders.

Beringia as first proposed by Hultén has since been enlarged to encompass the entire region between the Lena River in northeast Russia, and the Mackenzie River in northwest Canada (*Figure 1*). At its closest point, North America is separated from Asia by only 50 miles (80 km), and portions of the strait are less than 100 feet (30 m) deep. Beringia was mostly exposed during the Tertiary, but the intercontinental land connection was flooded 4.8-5.5 million years ago (*Marincovich and Gladenkov 2001*). Throughout the Pleistocene, the sea level changed repeatedly, exposing and flooding the region accordingly (*Hopkins 1959*). During the Last Glacial Maximum, the Bering Land Bridge was extant between 60,000 years ago and 25,000 years ago, and a sea-levels fell of as much as 397 ft (121 m) between 20,000-18,000 years ago, causing the maximum extent of the dry land connection between Asia and America during the Last Glacial Maximum. Only limited exchange was possible after about 11,000 years ago (*Hoffecker et al. 1993*).

It is quite impossible to understand fully the origin of Alaska's flora without knowing a great deal about its Asian antecedents. During the Tertiary, easternmost Asia and northwestern North America were fully connected and essentially identical biotically. The Tertiary vegetation was dominated by mixed broad and needle-leafed trees. As climate cooled, forests receded from the region, but certain Tertiary floristic elements remained (*Matthews and Ovenden 1990, Murray 1992*).

The major contribution of Asian tundra plants arrived in Alaska throughout the Quaternary, via the land bridge while it was exposed. Successive changes directly related to the waxing and waning of glaciers and consequent rising and falling of sea level caused the repeated appearance and disappearance of the Bering Land Bridge. These dynamics have together created conditions for plant dispersal and also diversification. Even when the land bridge was submerged, plant propagules, driven by wind, are presumed to have crossed from Asia to America in winter when the Bering Strait was ice covered (*Savile 1972*).

Whereas one might suspect that when the land bridge was exposed it provided relatively unimpeded dispersal routes between Asian and America, the distribution of plants shows that for some species the land bridge was a filter or even a complete barrier to movement. There are examples of some species that barely reach the opposite shore (*Populus balsamifera* and *Viburnum edule* on Chukotka and *Potentilla fragiformis* and *Ranunculus monophyllus* in Alaska) (*Figure 2, pattern IV*). A complex biogeographic history with distinct spatial and temporal components has created a flora rich in the circumpolar element but also one of vicariant taxa, intercontinental disjunctions and, for this latitude, a high level of endemism.

Several molecular studies support Hultén's hypothesis that unglaciated Beringia was a Quaternary refugium for plants (*Tremblay and Schoen 1999, Abbott et al. 2000, Thompson and Whitton 2006, Eidesen et al. 2007a,b*). Beringia is therefore key to understanding post-glacial dynamics within and among species. Much of our understanding of Ice Age Beringia is based on the study of

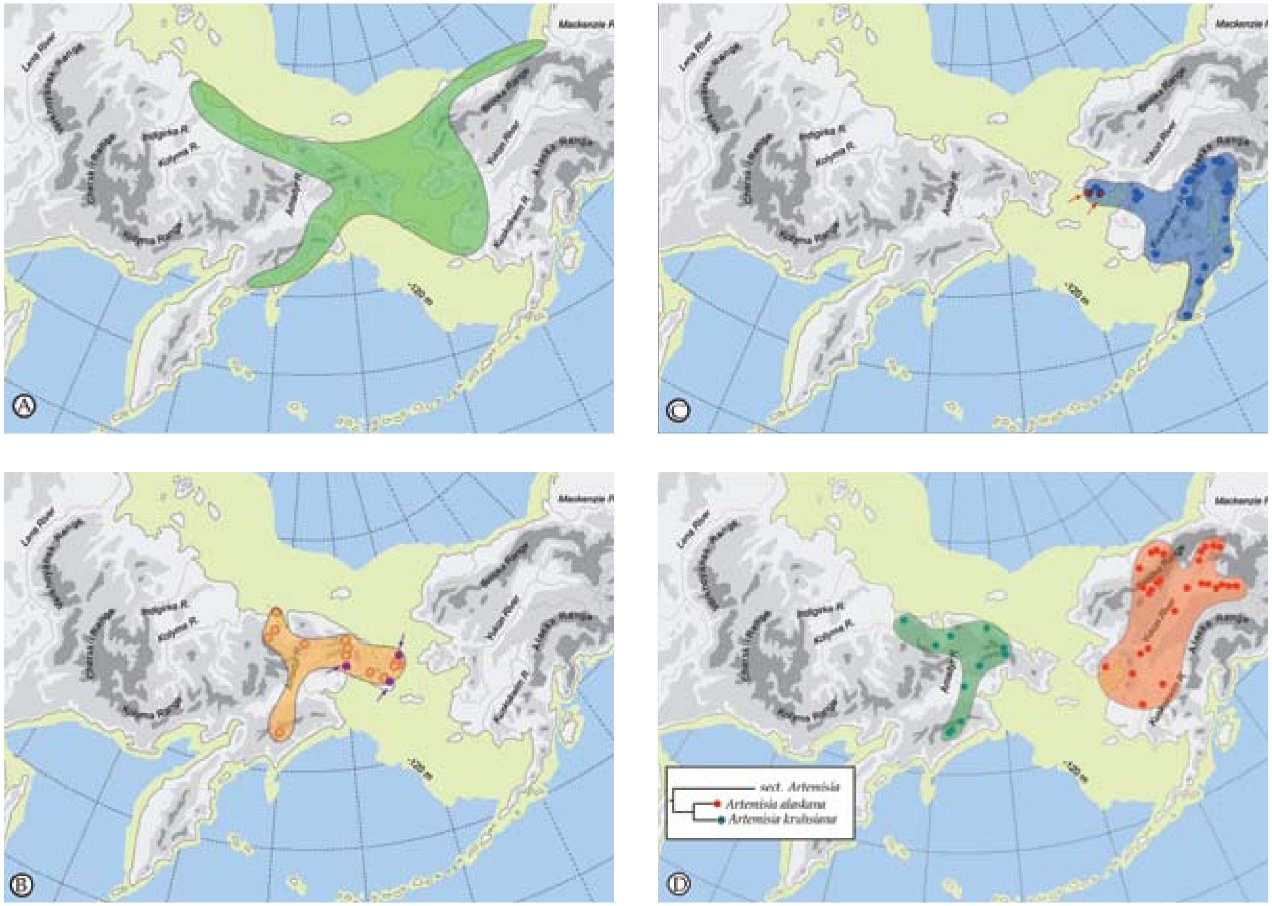

Figure 1. Large scale biogeographic patterns in Beringia with the maximum extent of the Bering Land Bridge during the Last Glaciation showing in yellow (modified from Elias and Crocker 2008). Distribution of (A) Amphiberingian *Primula borealis* (light green) after Guggisber et al. 2006; (B) Western Beringia *Carex melanocarpa* (orange) based on specimens at ALA (orange dots) and of Western Beringian endemic *Cardamine sphenophylla* (purple polygons at arrows) (after Petrovsky 1975); (C) Eastern Beringia *Douglasia alaskana* (light blue) based on specimens at ALA (blue dots) and of Eastern Beringian endemic *Parrya nauruaq* (red polygons at arrows based on specimens at ALA) and (D) vicariant species pair *Artemisia kruhsiana* (blue dots based on ALA specimens) and *Artemisia alaskana* (red dots based on ALA specimens), inset shows reduced phylogeny after Tkach et al. 2007.

botanical specimens, and one of the largest collections for Alaska and adjacent areas is at the Herbarium (ALA) of the University of Alaska Museum of the North.

Botanists in Alaska and adjacent Chukotka have long noticed a high degree of morphological and cytological diversification in well-established genera (*Yurtsev 1999*). We have now reached the limits of understanding diversification through traditional means, and we expect new molecular genetic evidence will shed light on the historical biogeography of Beringia.

Large scale biogeographic patterns observed in Beringia, aside from the fully circumpolar species, include taxa with an (a) amphiberingian distribution (taxa present on both sides of the Bering Strait and confined to the area between the Lena and Mackenzie rivers), (b) taxa restricted (endemic) to Western Beringia, (c) taxa that are endemic to eastern Beringia, and (d) taxa vicariant or with disjunct occurrences.

Reconstructing histories of taxa has long been an interest of botanists and requires the careful integration of phylogeny, biogeography, ecology and paleodistribution over time. The development of better analytical tools to infer historical biogeography as well as the ability to estimate dates for dispersal and diversification has set the stage for a new look at the origin and evolution of Beringia plants. This paper reviews the advances in studies of biogeographic patterns found in Beringia in the spirit of Eric Hultén's visionary statement made in 1937: "…This land-mass, which I shall hereinafter call Beringia, must have been a good refugium for the biota during the glacial period…".

Hypotheses and goals

Evidence from ecology, biology, geology, and biogeography has revealed complex patterns of diversification. It is now time to review these patterns, ask questions, and seek answers with molecular data as to the role Beringia played in shaping the composition of the flora today. We have developed four questions: (i) is there evidence for the Bering Land Bridge acting to structure genetic diversity? (ii) which factors allowed the Bering Land Bridge to act as a dispersal route for some plants, but not others? (iii) which plant groups show effects of a refugial existence in Beringia? (iv) are certain plant groups disjunct in Asia and America and recent arrivals to Beringia or are they relicts?

Materials and methods

Literature Review: Using Web of Science® we searched by keywords 'Beringia' and 'plant' (= 53 records) for an initial estimate of studies that have been conducted in Beringia. To focus the review further we surveyed the following journals for studies from 2003 (the last thorough review on the subject by

I. Amphi-Beringian, well established on both sides of the Bering Strait, endemic to Beringia

Aconogonon hultenianum var. *hultenianum*
Anemone multiceps
Artemisia glomerata
Cardamine blaisdellii
Cherleria chamissonis
Eritrichium chamissonis
Oxytropis czukotica
Papaver gorodkovii
Pedicularis pacifica
Phlox alaskensis
Podistera macounii
Primula borealis (Figure 1A)
P. tschuktschorum
Puccinellia wrightii
Rumex beringensis
Rumex krausei
Salix phlebophylla
Saxifraga nudicaulis
Smelowskia porsildii
Therorhodion (Rhododendron) glandulosum

II. Eastern Beringian endemic

Artemisia globularia subsp. *lutea*
Douglasia alaskana (Figure 1C)
Douglasia beringensis
Eritrichium splendens
Oxytropis sordida var. *barnebyana*
Oxytropis kobukensis
Oxytropis kokrinensis
Parrya nauruaq (Figure 1C)
Primula anvilensis
Saxifraga spicata

III. Western Beringian endemics

Androsace filiformis
Cardamine sphenophylla (Figure 1B)
Carex melanocarpa (Figure 1B)
Numerous taxa of Oxytropis, Papaver, and Poa

IV. Plants well established on one side of the Bering Strait, known from few localities on the opposite shore

Asia

Gentiana auriculata	St. Lawrence Island
Hierochloe annulata	Seward Peninsula
Kobresia filifolia subsp. *subfilifolia*	Seward Peninsula
Potentilla fragiformis	Western shore Bering Strait
Ranunculus monophyllus	Western shore Bering Strait

America

Aphragmus eschscholtzianus	Chukotka Peninsula
Populus balsamifera	Chukotka Peninsula
Viburnum edule	Chukotka Peninsula

V. Asian taxa reaching the Bering Strait but not in America

Artemisia lagocephala
Dicentra peregrina
Eritrichium villosa
Polygonum tripterocarpum
Rhododendron aureum
Silene stenophylla
Smelowskia (Ermania) parryoides

VI. American taxa reaching the Bering Strait but not in Asia

Boykinia richardsonii
Lupinus arcticus
Mertensia paniculata
Saxifraga reflexa

VII. Vicariants with gaps in the Bering Strait

Asia	America
Artemisia kruhsiana (Figure1D)	*Artemisia alaskana (Figure 1D)*
Artemisia senjavinensis	*Artemisia androsacea*
Astragalus tolmaczevii	*Astragalus richardsonii*
Astragalus tugarinovii	*Astragalus aboriginum*
Salix boganidensis	*Salix arbusculoides*

VIII. Asiatic steppe taxa with restricted occurrence in Eastern Beringia

Asia	America
Alyssum obovatum	*Alyssum obovatum*
Artemisia rupestris subsp. *rupestris*	*Artemisia rupestris subsp. woodii*
Carex sabulosa subsp. *sabulosa*	*Carex sabulosa subsp. leiophylla*

Figure 2.

Abbott and Brochman in 2003) to Dec. 2008: Systematic Botany, American Journal of Botany, Systematic Biology, Journal of Biogeography, Evolution, Molecular Ecology, and Science. We have limited our discussion to taxa that have a major distributional range within Beringia and have eliminated studies that are only marginal to the region.

Evaluation of biogeographic patterns: The literature review revealed a large disparity in taxon sampling, molecular markers and general genetic patterns recorded. For each paper we recorded the type of material (mostly genetic marker) used and the general pattern of biogeographic diversification reported, as well as whether diversification in the refugium was recent or ancient as a function of observed genetic diversity (*Figure 4*).

Results

New studies underscore the importance of Beringia in diversification of plants. Our survey of the literature from 2003 to 2008 identified 32 articles that involved 'plants' and 'Beringia'. Overall, the majority of papers corroborates Hultén's hypothesis of Beringia as an unglaciated Quaternary refugium, with some additional interesting findings relating to survival of certain boreal tree species in Beringia (*Figure 4*).

Beringia as a Glacial Refugium: Numerous studies have shown that Beringia acted as a refugium for arctic herbs and shrubs (*Figure 4*), but little is known about the role of this refugium for trees. A study by Brubaker et al. (*2005*) based on pollen and microfossils supports a glacial refugium for boreal *Larix* and *Picea glauca* in eastern Beringia, and *Pinus pumila* in Western Beringia. Similarly, Anderson et al. (*2006*) documented several populations with unique halpotypes and high allelic diversity in Alaska for *Picea glauca*, providing evidence that white spruce survived the Last Glacial Maximum in Eastern Beringia refugia, rather than having arrived by long-distance dispersal from areas outside of Beringia.

Bering Land Bridge – A Dispersal Highway: That the Bering Land Bridge has acted as a dispersal highway is supported by numerous studies and is evident in the large component of circumpolar plants studied thus far (*Figures 2-3*). In addition, species diversity with an amphiberingian distribution is very high (*Figure 1A; Figure 2, pattern I*), attesting to the evolution in Beringia due to glacial cycles. These dynamics have resulted in high levels of allopolyploidization and other evolutionary reticulations during speciation in Beringia tundra plants (*Abbott and Brochmann 2003*).

Photograph by Dave Murray

Figure 3. *Primula borealis* (Primulaceae) a common species known from both sides of the Bering Strait (amphiberingian).

Bering Land Bridge acting as a Filter: The Bering Land Bridge as a filter may be reflected in those taxa just managing a foothold on the opposite shore (*Figure 2, pattern IV*).

Bering Land Bridge acting as a Barrier: Although Western and Eastern Beringia share many species, more interesting are those taxa that are limited to either side of the Bering Strait (*Figure 1B-C; Figure 2, patterns II, III*). Other taxa are widespread throughout Asia and North America, reach the Bering Strait, but not the opposite side (*Figure 2, patterns V-VI*). We interpret these distributional patterns as evidence for the land bridge acting as a barrier to the "free" dispersal of taxa. Recently, Elias and Crocker (*2008*) documented a moisture barrier for the dispersal of steppe-tundra biota as an explanation for the disparate distribution of taxa common to Western Beringia but absent from Eastern Beringia.

Relicts or Recent Arrivals: While the geologic history of the Bering Land Bridge provides explanations for the complexity of today's flora, the disjunct distribution of vicariant grasses and sagebrush (*Artemisia*) species of the same genera on either side of the Bering Strait are presumed related to relict tundra or steppes that were more widespread in the past (*Murray et al. 1983*) (*Figure 2*). In an exemplary study Alsos et al. (*2007*) document long-distance dispersal from several source regions to the arctic-archipelago Svalbard using DNA fingerprinting, and similar studies can now be undertaken for testing postglacial dispersal versus relictual distributions in Beringia.

For example the recent study by Tkach et al. (*2007*) shows that *Artemisia kruhsiana* from Western Beringia and *Artemisia alaskana* from Eastern Beringia are sister taxa based on analysis of molecular data in a large phylogeny of the genus *Artemisia* (*Figure 1D; Figure 2, pattern VII*). We intend to use a larger number of accessions throughout their biogeographic range to confirm whether these two morphologically very close taxa are indeed distinct. Subspecies rank for these taxa has recently been proposed by Elven and Murray (*2008*).

Future prospects

Explicit tests of the aforementioned hypotheses are needed to clarify the role that the changing Beringia environment played in the distribution of its flora. Molecular analyses at the intraspecific level, focused on the historical associations among populations, promise to reveal historic dispersal and vicariant events (*Avise 2000*). Because of the variation inherent in the evolutionary process among genetic loci, an approach for testing the fit of gene trees to models of population divergence is necessary. Genetic simulations based on coalescent theory (*Kingman 2000*) provide such tests by generating expected distributions of gene trees given population models. DeChaine (*2008*) demonstrated the utility of this approach for the Beringia flora, while underscoring the limited number of datasets available for such analyses and the demand for further analyses.

Pattern	Expansion	Taxon	Markers	Reference
Bering Land Bridge (BLB; Miocene) North Atlantic Land Bridge (NALB)	Expansion Ancient (BLB), Quaternary (NALB)	*Cerastium* (Caryophyllaceae)	*cp*DNA	Scheen et al. 2004
Beringia Glacial Refugium	Ancient	*Arabis drummondii, A. holboellii* (Brassicaceae)	*cp*DNA	Dobes et al. 2004
Beringia Glacial Refugium	Recent	*Vaccinium uliginosum* (Ericaceae)	*cp*DNA	Alsos et al. 2005
Beringia Glacial Refugium	Recent	*Townsendia hookeri* (Asteraceae)	*cp*DNA	Thompson & Whitton 2006
Beringian Glacial Refugium	Ancient?	*Vaccinium uliginosum* Beringian/ N Canadian group (Ericaceae)	*nr*DNA, *cp*DNA, AFLP	Eidesen et al. 2007a
Beringia Glacial Refugium	Recent	*Artemisia arctic species* (Asteraceae)	*nr*DNA	Tkach et al. 2007
Beringia Glacial Refugium	Recent	*Cassiope tetragona* (Ericaceae)	*cp*DNA, AFLP	Eidesen et al. 2007b
Beringia Glacial Refugium	Recent	*Populus, Larix, Picea, Pinus, Betula, Alnus/Duschekia*	Pollen from LGM	Brubaker et al. 2005
Beringia Glacial Refugium	Recent	*Oxyria* (Polygonaceae)	*cp*DNA	Marr et al. 2008
Beringia Glacial Refugium and BLB Filter/Barrier	Ancient	*Saxifraga rivularis complex* (Saxifragaceae)	AFLP	Jorgensen et al. 2006
Beringia Glacial Refugium and BLB Filter/Barrier	Recent	*Rubus chamaemorus* (Rosaceae)	AFLP	Ehrich et al. 2008
BLB Filter/Barrier	Not avail.	*Cardamine digitata aggregate* (Brassicaceae)	*cp*DNA	Jorgensen et al. 2008
Beringia Glacial Refugium + other long distance dispersal W to E	Recent?	*Potentilla sect. Niveae* (Rosaceae)	*cp*DNA, AFLP	Eriksen & Toepel 2006

Figure 4.

Photograph by Rob Lipkin

Figure 5. *Parrya nauruaq* (Brassicaceae), newly described Eastern Beringian endemic from the Seward Penninsula, Alaska.

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Recent Notable Floristic Records from Northwestern Alaska

By Carolyn Parker and Steffi Ickert-Bond

Abstract

Botanical surveys in northwestern Alaska, including the National Park Service's Inventory and Monitoring (I&M) Arctic Network and Shared Beringian Heritage Program inventories, have made several contributions to our knowledge of the regional flora. Three species new to science have been described: *Parrya nauruaq*, *Primula anvilensis*, and *Douglasia beringensis*. The occurrence of six species, previously known only from the Russian Far East and westward, have been documented: *Potentilla fragiformis, Ranunculus monophyllus, Saussurea triangulata, Hierochloe annulata, Calamagrostis tenuis,* and *Kobresia filifolia* ssp. *subfilifolia*. Major westward and northward range extensions within Alaska have been documented for several rare species that link northwestern Alaska with the circumpolar high arctic (*Draba pauciflora*), the Canadian arctic (*Festuca edlundiae* and *X_Dupoa labradorica*), and with endemic-rich interior East Beringia (*Oxytropis tananensis, Lupinus kuschei, Symphyotrichum yukonense, Carex deflexa, Eriophorum viridicarinatum,* and *Schizachne purpurascens*). Future botanical inventories on both sides of the Bering Strait will certainly yield additional new records and increase our knowledge of this shared Beringian floristic heritage.

New to Science

Primula anvilensis S. Kelso (Primulaceae) was first described from Anvil Mountain, near Nome (*Kelso 1987*). Recent collections, including I&M Arctic Network inventories, have documented the species from several additional Seward Peninsula sites, the Nulato Hills, the Baird Mountains, and from Cape Krusenstern National Monument (NM) and Noatak National Preserve (NP) (*Parker 1999, 2006a, 2006b*).

Douglasia beringensis S. Kelso, Jurtzev, and D. F. Murray (Primulaceae) was first collected during an inventory of Bering Land Bridge NP sponsored by the Shared Beringian Heritage Program and undertaken by a team of Russian and Alaskan botanists in 1992-1993 (*Kelso et al. 1994*). Additional populations have since been found in the Moon Mountains, northwest of Nome, and in the Nulato Hills, Lime Hills, and Kokrines Hills (*Parker 1999, 2000, 2006a, 2006b*). The species is ranked imperiled both globally and in Alaska (G2S2).

Parrya nauruaq Al-Shehbaz et al. (Brassicaceae) was first found along the Solomon River on the Seward Peninsula in 1982, but incorrectly identified. It was not recognized as being a new species until after a large population was found in 2003 in the Moon Mountains, northwest of Nome. (*Al-Shehbaz et al. 2007, Parker 2006b*). The known distribution of this new species remains restricted to these two localities. *Parrya nauruaq* is ranked imperiled both globally and in Alaska (G2S2).

New to North America

Potentilla fragiformis Willd. (Rosaceae) was collected at Sheshalik in Cape Krusenstern NM during the 2001 I&M Arctic Network inventory. This was thought to be the first record in Alaska for this attractive cinquefoil, previously known only from the Russian Far East. However, a careful review of specimens from several herbaria disclosed that it had been collected previously in Alaska, but had been misidentified (*Parker 2006a*). *P. fragiformis* is now documented from Kivalina, St. Paul Island, St. Lawrence Island, and the lower Baldwin Peninsula, south of Kotzebue. The species is currently ranked imperiled to critically imperiled in Alaska, although it is widespread globally (G4S1S2).

Ranunculus monophyllus Ovczinn. (Ranunculaceae), a bright yellow buttercup, was collected in 1998 during a BLM survey in the Nulato Hills (*Parker 1999*). The species is widespread in Russia, Europe, and Greenland. Following the collection in Alaska, a re-

Photograph by C. Parker

Figure 1. *Parrya nauruaq* was described as a new species in 2007. It is currently known from only two localities on the Seward Peninsula.

view of herbarium specimens of the similar-looking *R. pedatifidus* revealed that *R. monophyllus* had been collected previously at Bluff, on Norton Sound, and at Serpentine Hot Springs in Bering Land Bridge NP, but had been misidentified (*Parker 1999*). During the 2003 I&M Arctic Network inventory, *R. monophyllus* was collected in the Hugo Creek headwaters of Noatak NP. The species is currently ranked secure globally and imperiled in Alaska (G5S2).

Saussurea triangulata Trautv. & C.A. Mey. (Asteraceae) was first collected in the Waring Mountains in Kobuk Valley NP, and was quickly recognized as being unlike any *Saussurea* species known from North America (*Parker 2001*). Taxonomists specializing in the genus from both Russia and U.S. have reviewed this collection and agree the species is new to North America, and possibly new to science. It is provisionally being called *S. triangulata*, a species known from the Russian Far East and Korea (*Keil 2006*). During the 2002 I&M Arctic Network inventory, the first known population was revisited, and a second very small population was found approximately 2 miles (3 km) to the northeast. Regardless of its ultimate taxonomic resolution, the species is ranked critically imperiled in Alaska (G?S1).

Hierochloe annulata V.V. Petrovsky (Poaceae); *Calamagrostis tenuis* V.N. Vassil. (Poaceae); *Kobresia filifolia* (Turcz.) C.B. Clarke ssp. *subfilifolia* T.V. Egorova, B. Jurtz. and V.V. Petrovsky (Cyperaceae). These three graminoid species were collected in the central and northern Seward Peninsula during an inventory of Bering Land Bridge NP sponsored by the Shared Beringian Heritage Program in 1992 and 1993 and undertaken by a joint team of Alaskan and Russian botanists. Each of these species has a broad northern Russia distribution; however, these are the first records for each from North America. Rankings for rarity in Alaska have not been established.

Photograph by C. Parker

Figure 2. *Draba pauciflora* is an arctic circumpolar species that only recently was found in Alaska. When in fruit, it easily blends into the background vegetation.

Photograph by C. Parker

Figure 3. *Oxytrotis tananensis*, an Alaska endemic of dry rocky slopes, has showy butter-yellow flowers and whorled (verticillate) leaflets.

Photograph by C. Parker

Figure 4. I&M volunteer botanist Heather McIntyre arranges plant presses for drying at Onion Portage, Kobuk Valley NP.

New to Alaska

Draba pauciflora R. Br. (Brassicaceae) was collected from two localities on the north slope of the Endicott Mountains during the 2002 I&M Arctic Network inventory in Gates of the Arctic National Park and Preserve (NPP) (*Parker 2006a*). These were the first records from Alaska for this high arctic circumpolar species. A review of similar looking *Draba* herbarium specimens disclosed that it had been previously collected near Barrow, Alaska, but misidentified. Also known from the Canadian Arctic Archipelago, Greenland, Svalbard, and northern Chukotka, Russia, these Alaskan records fill a distribution gap for the species. *Draba pauciflora* is ranked widespread globally and critically imperiled in Alaska (G4S1).

X_Dupoa labradorica (Steud.) J. Cay. & Darbyshire (Poaceae) was collected from both Cape Krusenstern NM and Shishmarof Lagoon in Bering Land Bridge NP during the 2001 I&M Arctic Network inventory. During the 2003 I&M inventory it was found in the vicinity of Kotzebue, and along the Espenberg River in Bering Land Bridge NP (*Parker 2006a*). These were the first records for this grass hybrid (between *Poa eminens* and *Dupontia fisheri*) since it was originally described from Hudson Bay, Canada (*Cayouette and Darbyshire 1993*). More recent collections have documented the hybrid from Goodnews Bay and the lower Yukon River Delta in southwestern Alaska. *X_Dupoa labradorica* should be expected to occur in any northern Alaskan coastal region where both parental taxa are found. Rarity status is not applied to hybrid species.

Festuca edlundiae S.G. Aiken, Consaul, & Lefk. (Poaceae) was collected on the north slope of the Endicott Mountains in Gates of the Arctic NPP during the 2002 I&M Arctic Network inventory. This first Alaskan record fills a distribution gap for this high arctic circumpolar species that also occurs in the Canadian arctic, Greenland, Svalbard, and the Russian Far East (*Parker 2006a*). *Festuca edlundiae* is ranked rare to widespread globally and critically imperiled in Alaska (G3G4S1).

Range extensions of East Beringian rare plants into northwestern Alaska and the Arctic Network parklands

Carex deflexa Hornem. (Cyperaceae) was collected in a dry meadow near Reed Hot Springs in Gates of the Arctic NPP during the 2002 I&M Arctic Network inventory (*Parker 2006a*). The species is known from boreal North America and Greenland, and is found in the Yukon-Tanana uplands of interior Alaska. This record of *C. deflexa* is a northwestward range extension of over 250 miles (400 km). The species is ranked globally secure and critically imperiled to imperiled in Alaska (G4S1S2).

Schizachne purpurascens (Torr.) Swallen (Poaceae) was also found growing in a dry meadow adjacent to Reed Hot Springs in Gates of the Arctic NPP during the 2002 I&M Arctic Network inventory (*Parker 2006a*). This grass of boreal Asia and North America is known from south of the Alaska Range, hence this record documents a northward range extension of approximately 375 miles (600 km). *Schizachne purpurascens* is ranked secure globally and imperiled in Alaska (G5S2).

Eriophorum viridicarinatum (Engelm.) Fernald (Cyperaceae) was collected in a species-rich bog meadow southwest of Walker Lake in Gates of the Arctic NPP during the 2002 I&M Arctic Network inventory (*Parker 2006a*). A cottongrass of boreal North America, this record is a northward range extension of over 315 miles (500 km). *Eriophorum viridicarinatum* is ranked secure globally and imperiled in Alaska (G5S2).

Oxytropis tananensis Jurtzev (Fabaceae) is a yellow-flowered oxytrope that was first described from a xeric steppe bluff above the Tanana River in interior Alaska (*Yurtsev 1993*). A review of herbarium specimens has extended the known range of the species to additional Tanana River sites and the Porcupine River valley. The 2001 I&M Arctic Network inventory documented the species from the Anisak River valley in Noatak NP, a northwestward range extension of 375 miles (600 km) (*Parker 2006a*). *Oxytropis tananensis* is ranked imperiled to rare (G2G3S2S3).

Photograph by C. Parker

Figure 5. Bob Uhl, Cape Krusenstern NM resident, discusses the local flora with his guests, Norwegian botanists and I&M volunteers Heidi Solstad and Reidar Elven.

Lupinus kuschei Eastw. (Fabaceae) was first known from sandy habitats in northern British Columbia and southern Yukon, Canada (*Dunn and Gillett 1966*). An NPS inventory in Wrangell-St. Elias NPP documented the species from the Sanford River, and additional collections document the species from Nogahabara Dunes (Koyukuk National Wildlife Refuge), the Kugarak River headwaters (Selawik National Wildlife Refuge), Great Kobuk Sand Dunes (Kobuk Valley NP), and from the vicinity of Whitehorse, Yukon. The disjunct distribution within East Beringia of *L. kuschei*, as well as those of *Symphyotrichum yukonense*, noted below, could be linked to the ancient East Beringian landscape on which the open sandy and gravelly habitats they prefer were more widespread. *Lupinus kuschei* is ranked rare globally and imperiled in Alaska (G3S2).

Symphyotrichum yukonense (Cronquist) G.L. Nesom (Asteraceae) was first described (as *Aster yukonensis*) from the Kluane Lake area of southwestern Yukon, Canada, where it grows on saline flats of the Slims River (*Cronquist 1945*). The species was later documented from the Great Kobuk Sand Dunes in Kobuk Valley NP, from the central Bettles

River valley, and from the Oolah Valley in Gates of the Arctic NPP. During the 2003 I&M Arctic Network inventory, *S. yukonense* was found along the middle Noatak River floodplain in Noatak NP at several localities. The species is ranked rare (G2S3).

Photograph by C. Parker

Figure 6. Reidar Elven and Heidi Solstad, botanists from Oslo, Norway, participated in the Arctic Network I&M inventory for three seasons (seen here in a snowbed meadow in Cape Krusenstern NM).

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Genetic Studies Point to Beringia as a Biodiversity Hotspot for High-latitude Fungi

By József Geml, Frank Kauff, Gary A. Laursen, and D. Lee Taylor

Abstract

Despite the critical roles fungi play in the functioning of ecosystems, especially as symbionts of plants and recyclers of organic matter, their biodiversity is poorly known in high-latitude regions. Among these, Beringia, including Alaska and north-eastern Siberia, has long been a focal point for biogeographical research in a wide range of plant and animal taxa. However, the biodiversity and biogeography of fungi in Beringia are virtually unknown. We analyzed DNA sequence data from various boreal and arctic macrofungi using phylogenetic and coalescent methods to assess the genetic diversity at the species and intraspecific levels. Our results suggest that Beringia, particularly Alaska, harbors very diverse fungal communities and that most arctic and at least some boreal fungal taxa survived the last glacial maximum in Beringia.

Introduction

Climatic changes in the Quaternary have dramatically influenced the distribution of mycota, flora and fauna in high-latitude ecosystems, and had major impacts on past speciation events and present population structures. While plants and animals have been extensively studied, very little is known about the community and population structures of fungi in arctic and boreal biomes. This is particularly undesirable, because fungi play key roles in the decomposition, mobilization, and the transfer of nutrients to plants in these nutrient-poor ecosystems.

Beringia, including Alaska and north-eastern Siberia, has long been a focal point for biogeographical research in a wide range of plant and animal taxa. This high level of interest arises for two principal reasons. First, due to its diverse landscape and climate and the fact that much of the region remained ice-free during glacial maxima, Beringia served as a refugium for arctic and subarctic flora and fauna (*Adams and Faure 1997, Brubaker et al. 2005, Edwards et al. 2000, Hultén 1968*). Second, during much of the Tertiary and Quaternary periods, Beringia was the major land connection between Asia and North America and provided migration routes to a wide variety of organisms (for example, see *Elias et al. 2000*; *Qian 1999, Swanson 2003*).

As opposed to plants and animals, there has not been a comprehensive cataloging of fungi in Alaska, and the richness and biogeograhic origins of Beringia's mycota remain unknown. Therefore, one of our primary goals was to initiate the first biodiversity assessment of boreal and arctic fungi in Alaska, conducting genetic analyses based on curated sporocarp collections. Here, we present an example of a genus-wide diversity assessment in the ectomycorrhizal *Lactarius* Pers.

Beside exploring species-level diversity, we hypothesized that, similar to patterns documented in various plants and animals (*e.g., see MacNeil and Strobeck 1987, Sperling and Harrison 1994, Abbott* and *Comes 2003*), high intraspecific genetic diversity can be found in Beringian fungi. To test it, we sampled populations of selected boreal and arctic fungi from regions across the Northern Hemisphere and carried out phylogenetic and coalescent analyses.

Methods

For the genus-wide diversity assessment of *Lactarius*, 383 specimens were collected and deposited in the Mycological Herbarium (GAL) at the University of Alaska Fairbanks (UAF). To reduce redundancy, 58 of these, representing morphological groups and geographic areas of origin among the collections, were selected for molecular work. Nucleotide sequences of the desired portions (ITS and LSU rDNA) of the DNA samples were obtained using standard molecular protocols (DNA extraction, polymerase chain reaction, cycle sequencing etc.). Additional sequence data of all *Lactarius* species available in GenBank was downloaded and incorporated into multiple sequence alignments and phylogenetic analyses for reference. Putative Alaskan species groups were detected as phylogenetic groups of sequences.

Four species (*Amanita muscaria, Lichenomphalia umbellifera, Flavocetraria cucullata*, and *Flavocetraria nivalis*) were chosen for intraspecific analyses, based on their circumpolar distributions and the availability of materials from the major northern geographic regions. Molecular data was obtained as described above and was subjected to phylogenetic and coalescent analyses to study the population histories and characteristics.

Results

Phylogenetic analyses revealed 28 putative species groups in the genus *Lactarius* in Alaska. These were broadly distributed on the genus-wide tree and grouped with several major infrageneric groups. It was often possible to identify these groups to known species, al-

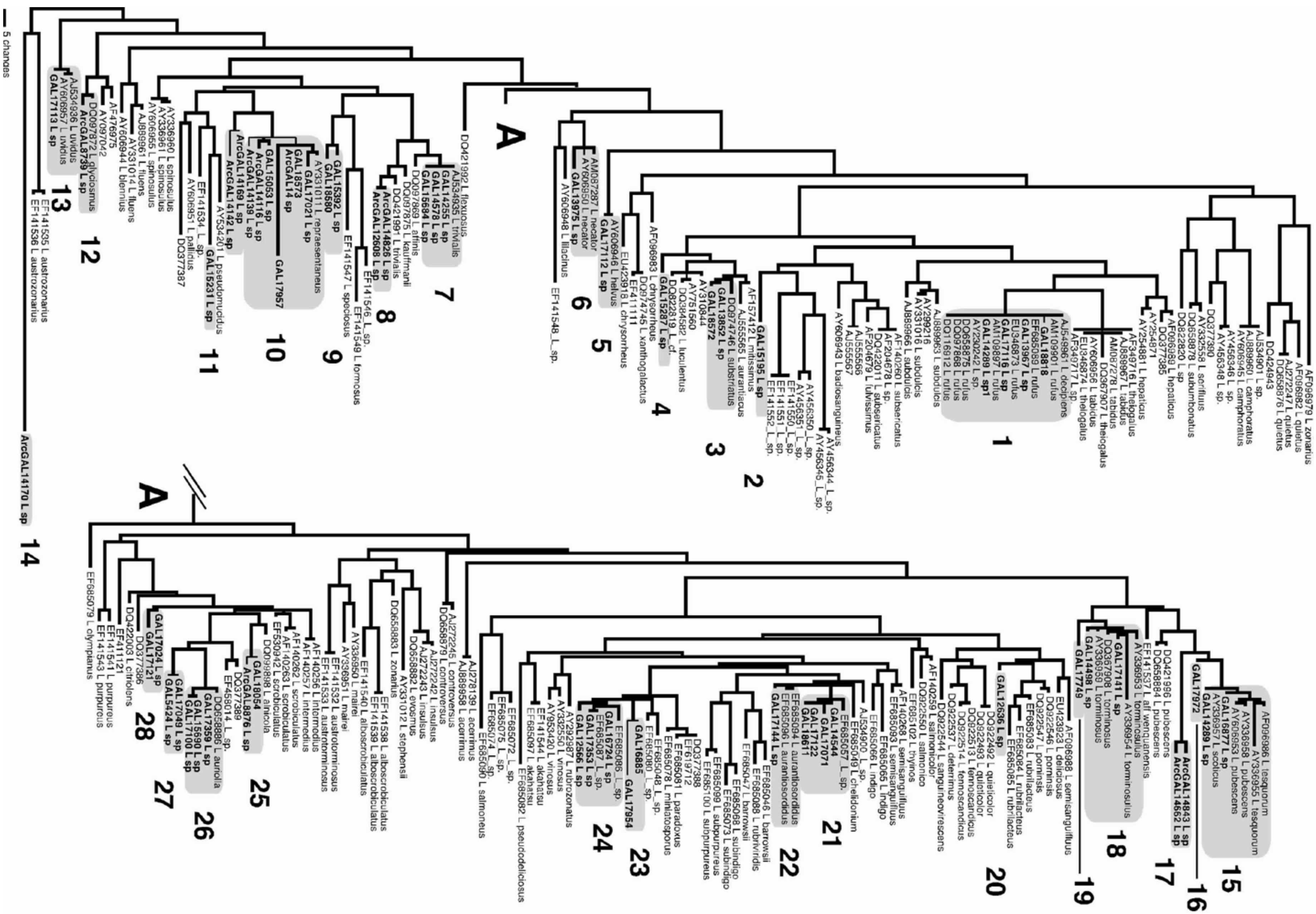

Figure 1. One of the equally parsimonious, midpoint-rooted trees showing the phylogenetic spread of Alaskan *Lactarius* sequences (in bold) generated in this study among representatives of *Lactarius* taxa in GenBank. Sequences with 'GAL' and 'ArcGAL' numbers were derived from boreal and arctic herbarium specimens, respectively. Phylogroups including Alaskan sequences are indicated with grey boxes. GenBank sequences with no name attached are from unidentified environmental samples.


Photograph courtesy of J. Geml

Figure 2. The *Amanita muscaria*, the Fly Agaric, morphological species includes at least three distinct, sympatric phylogenetic species in Alaska.

though in many cases Alaskan sequences formed unique, unidentified clades that may represent newly discovered entities (*Figure 1*).

The intraspecific analyses showed very high genetic diversity in Alaska, particularly in the boreal ectomycorrhizal mushroom *Amanita muscaria*. In this morphological species, we discovered three non-interbreeding phylogenetic species that occur in sympatry in Alaska (*Figures 2-3*). Two of these are 'Eurasian' clades (*Clades II-III*), while one is 'North American' (*Clade I*), based on their geographic distribution. To our knowledge, the 'Eurasian' clades do not occur in North America outside Alaska. Furthermore, coalescent analyses revealed the genetic isolation of the endemic Alaskan sequence types from the rest of their ancestral population, suggesting local survival for an extended period, including at least one glacial maximum.

All three arctic fungi sampled in our study also showed high intraspecific diversity, but they lacked significant phylogeographic structure, likely as a result of frequent, long-distance dispersals across the Arctic. Despite the effective strategies for rapid postglacial colonization, there were slight differences among different arctic regions, Alaska hosting reliably the most diverse populations.

Discussion and conclusions

Biodiversity: Arctic and boreal plant communities are frequently described as relatively species poor and having simpler patterns than those in more southern biomes (*e.g., Whittaker 1975, Scott 1995, Walker 1995*). Our genus-wide diversity assessment suggests that at least one group of ectom corrhizal fungi, the genus *Lactarius*, likely is diverse in Alaska, particularly when comparing our data to the other estimates of basidiomycete diversity (*O'Brien et al 2005, Allison et al 2007*). Based on the phylogenetic breadth of our sequences, most, if not all, known major phylogenetic groups of *Lactarius* are represented in Alaska. This is in sharp contrast to the trend seen in the non-mycorrhizal saprotrophic *Agaricus* L.:Fr., where only three section-level phylogenetic clades (half of the six known globally) are represented in Alaska (*Geml et al. 2008*). Our future plan is to assess the diversity of other important Alaskan genera: *Russula*, *Cortinarius*, *Hebeloma*, *Inocybe*, *Galerina* etc.

Putative forest refugia during the Last Glacial Maximum in Alaska: Whether fragments of boreal forest existed in Beringia during the Last Glacial Maximum (LGM) is a major, but, as yet, unanswered question in quaternary science. Because most of the discussion has been centered on palynological data, using molecular phylogeography of ectomycorrhizal fungi, as presented here, may help us better understand past vegetation patterns in Beringia. The likely importance of host trees in the distribution of ectomy corrhizal fungi has been repeatedly noted, given the obligate nature of the symbiosis, particularly from the fungal perspective.

Our data show support for at least two endemic regional populations of *A. muscaria* in different parts of Alaska, both of which exhibit genetic isolation and differentiation from other populations. Because non-Alaskan populations most likely survived the LGM in refugia south of the major ice shields, the lack of migration between these and the Alaskan ones suggests local survival of the latter, implying forest refugia in Alaska. Our findings support the existence of at least two independent such glacial forest refugia: 1) boreal forest in Interior Alaska; and 2) maritime rainforest in Southeast Alaska and the Pacific Northwest. The possible existence of isolated forest refugia in Interior and Southeast Alaska is also supported by several other independent lines of evidence (e.g., see *Flemming and Cook 2002, Carrara et al 2003, Brubaker et al 2005, Weckworth et al 2005, Anderson et al 2006*).

High intraspecific diversity and long-range dispersal in arctic fungi: Despite the high genetic diversity observed, we found no phylogeographic structure in the three arctic species examined (*L. umbellifera, F. cucullata,* and *F. nivalis*), indicating high levels of gene flow across the Arctic. Several sequence types, particularly the ancestral ones, were distributed over multiple continents, suggesting effective dispersal. As opposed to morphological species from boreal and temperate regions that often comprise multiple evolutionary lineages, morphological species and phylogenetic species seem to correspond well in the arctic fungi we analyzed. In other words, there appear to be no genetic isolation among populations inhabiting different geographic areas. On the other hand, slight differences still remain in the overall genetic diversity among different regions, and the high diversity values observed in Alaska, for example, could be explained by the glacial history and/or the climatic and landscape variability.

Management implications

We are providing pioneer data on the diversity of Alaskan fungi, including the discovery of several putatively novel species. Such baseline information is crucial for preserving biodiversity and ecosystem function in Alaska national parks. Also, the resulting 'DNA barcode' database is useful for current and future ecological and biodiversity studies. Finally, insights into fungal migration histories and observed common patterns contribute to improved inferences concerning glacial refugia and to the understanding of the present geographical structure of genetic diversity in arctic organisms. Knowledge of both past migration history, a key to prediction, and present day genetic diversity are essential to respond intelligently to global change.

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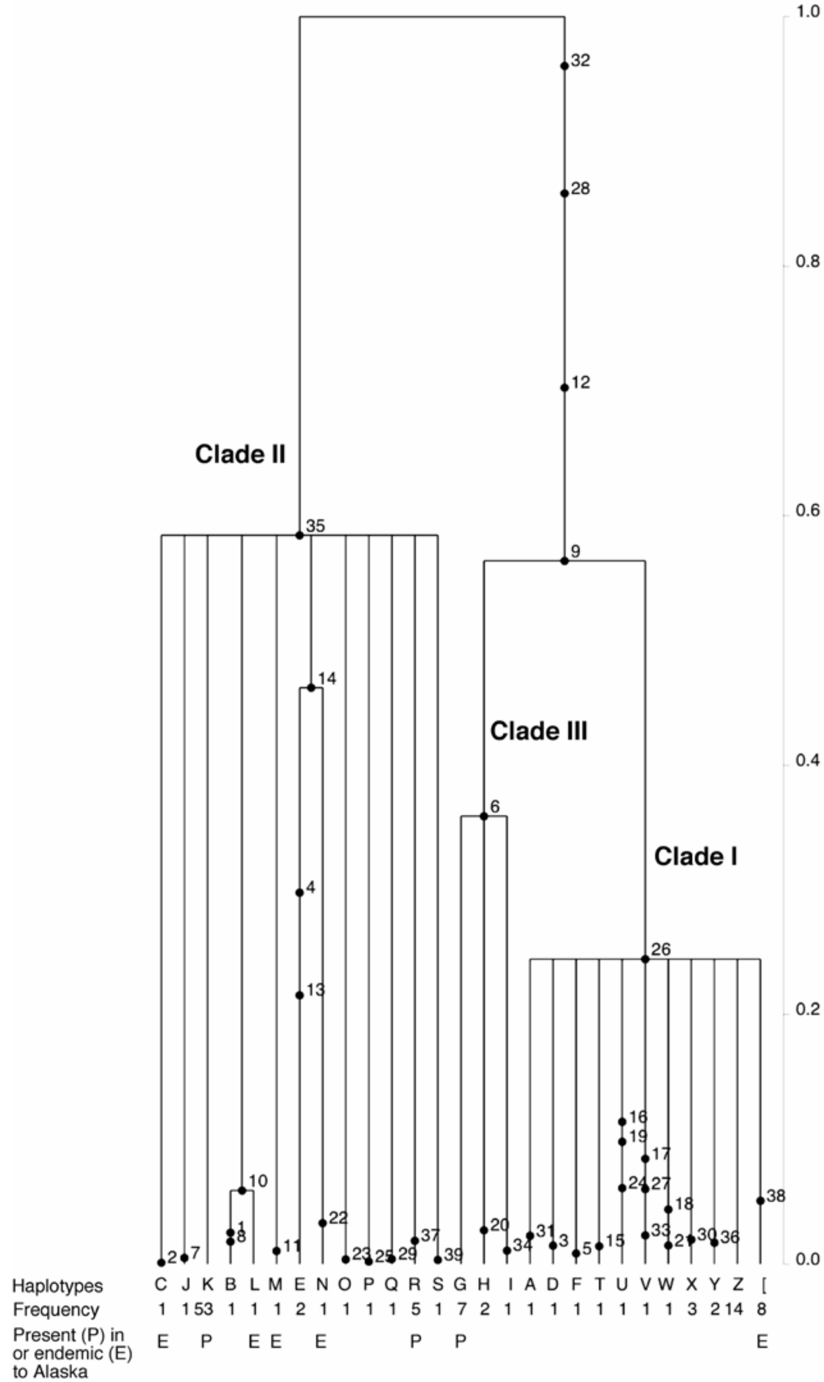

Figure 3. (Right) Coalescent-based genealogy showing the distribution of mutations for the ITS region in the major phylogenetic species clades in *A. muscaria.* The time scale is in coalescent units of 2N, where N is the population size. Mutations and bifurcations are time ordered from the top (past) to the bottom (present). The letters and numbers below the tree designate the distinct haplotypes, their observed frequencies, and their occurrence in Alaska.

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Cultural Vulnerability and Resilience in the Arctic: Preliminary Report on Archeological Fieldwork at Cape Krusenstern, Northwest Alaska

By Shelby Anderson, Adam Freeburg, and Ben Fitzhugh

While natural scientists track environmental change in response to global warming, less attention has been directed towards human interface with long term Arctic environmental dynamics. Current research at Cape Krusenstern, Alaska, seeks to address this deficit through investigation of human-environmental interactions recorded in archeological and paleoenvironmental data spanning the last 4,000-5,000 years at the Cape, building on the pioneering work conducted at Krusenstern by J. Louis Giddings and Douglas D. Anderson. Systematic survey and use of new mapping technology to record cultural and natural features are methods central to addressing these research questions. Discovery of new archeological features indicates occupation of the Cape was more extensive over the last 1,000 years than previously thought, although additional fieldwork and analysis are needed.

Figure 1. Cape Krusenstern beach ridge complex.

Introduction

Global warming is dramatically impacting the Arctic, bringing about fundamental changes in human lifestyles. This is apparent in countless scientific studies and the testimony of life-long arctic residents (*Hassol 2004*, *Krupnik et al. 2002*). While natural scientists strive to track earth systems changes in response to the rapidly evolving environment, less attention has been directed at understanding human interface with long-term dynamics of environmental change in the Arctic. This research seeks to address this deficiency through an investigation of human-environmental interactions recorded in archeological and paleoenvironmental data spanning the mid-to-late Holocene in Northwest Alaska. The goal is to better understand the dynamics linking human and environmental systems in Northwest Alaska and to assess the critical factors that limit or enhance cultural vulnerability and resilience to environmental change in the north.

To achieve these goals, the University of Washington (UW) and the National Park Service (NPS) are currently engaged in a multi-year interdisciplinary research project at Cape Krusenstern National Monument in Northwest Alaska (*Figure 2*). In 2006, the NPS led an archeological field project at Krusenstern, and in 2008 UW carried out the first of three additional field seasons that will continue through the summer of 2010. This research seeks to build on the pioneering work of J.Louis Giddings and Douglas D. Anderson (*1986*) by conducting the first systematic survey of the beach ridge complex and through the use of new mapping technology to precisely record cultural and natural features. Numerous new radiocarbon dates will be obtained as part of this effort to build on and refine existing archeological data sets from Cape Krusenstern. Synthesis of new, high resolution paleoenvironmental and archeological data collected at Krusenstern will help address long-standing questions about the relationship between local and regional environmental change and past human lifeways. Fieldwork is ongoing, but preliminary findings suggest occupation of the Cape was more extensive over the last 1,000 years than previously thought; numerous previously unknown archeological features were identified in 2008 on beach ridges dating to this time period. Additional fieldwork and analysis is necessary to better understand how new data may alter existing understanding of settlement patterns at Krusenstern, but the work conducted to date illustrates the potential of Cape Krusenstern archeology in answering long-standing questions about human-environmental interactions in the Arctic.

A Unique Paleoenvironmental and Archeological Landscape

The beach ridge complex located at Cape Krusenstern is an ideal place to address questions about archeological and paleoenvironmental change over time. The Krusenstern beach ridge complex is the most extensive in Northwest

Alaska, encapsulating over 4,000 years of human occupation as well as a record of past coastal environments (*Mason and Jordan 1993*). Beach ridges at Krusenstern develop during decade- to century-long periods of fair weather and are eroded during periods of coastal storminess. The approximately 9,000-acre complex contains over 70 distinct beach ridges, forming a 'horizontal stratigraphy' with archeological remains progressively older inland (*Figure 1*). The beach ridges themselves are a record of fluctuating sea level, wave energy and wave direction as the beach ridge complex formed during the mid-to-late Holocene. Human occupation of the Cape spans from approximately 4,000 years ago to the present, encapsulating numerous cultural traditions and recording important changes in subsistence, settlement, and socio-economic organization that occurred throughout the region (*Giddings and Anderson 1986, Harritt 1994, Schaaf 1988*). A rich ethnographic and ethnohistoric record (*Burch 1998*) indicates close connection between cultural organization and environmental variability in the more recent past, suggesting that human-environmental dynamics were important throughout prehistory.

Methods

Archeological field methods are directed at systematically collecting samples and spatial data across the beach ridges, as well as precisely mapping relationships between archeological and environmental features for the first time. Use of high precision, high accuracy Global Positioning System (GPS) units to collect spatial data is central to gathering the data needed to address project research questions. GPS technology allows rapid recording of feature size, shape and condition information as field crews survey and test the beach ridge complex (*Figure 3*). Trimble GeoXH and ProXH units used with Zephyr antennas can be accurate to within 8 inches (20 cm) after data postprocessing. The challenge of connecting archeological sites with specific beach ridges is a critical, and until recently, very difficult aspect of conducting fieldwork at Krusenstern. New high resolution orthorectified imagery for the area (*Manley et al. 2007*), along with GPS and Geographic Information System (GIS) technology, make this task much simpler. The project GIS combines GPS spatial data with site condition and collections information, making the GIS a useful research and management tool.

Integrating data from previous archeological work at Krusenstern is an important component of the research. To achieve this, Giddings' original spatial data was collected from two annotated aerial photomosaics, which were imported into the project GIS and georeferenced (*Figure 4*). Archeological features marked on the photos were digitized and the spatial placement of each feature location cross checked with orthographic imagery. While site locations generated through this process are not always precise, this provides the information needed in the field to determine whether or not a feature was recorded previously. Most importantly, it is now possible to connect existing dates and excavation data with specific features, which are in the process of being re-recorded and incorporated into the project GIS along with new archeological data.

2006 and 2008 Field Seasons: Preliminary Findings

It is estimated that over 600 archeological sites and features were identified on the beach ridge complex before 2006. These sites were primarily recorded by Giddings and his students who worked at Krusenstern in the late 1950s to early 1960s. The NPS, however, estimates that before 2006, the beach ridge complex was only approximately 30% surveyed. Considerable potential exists for new archeological discoveries and the results of the first two seasons of field work support this. In addition to previously reported and excavated features, numerous previously undocumented features were recorded in 2006 and 2008 (*Figure 5*). To date, approximately 2,400 acres of the beach ridge complex have been systematically surveyed and over 1,280 archeological features have been recorded by the current project. Many of these newly recorded features are smaller house or storage features that are not as densely clustered as the large settlements that were the focus of previous investigations. Although new features were recorded in survey areas across the beach ridge complex, many of these features date to the last 1,000 years.

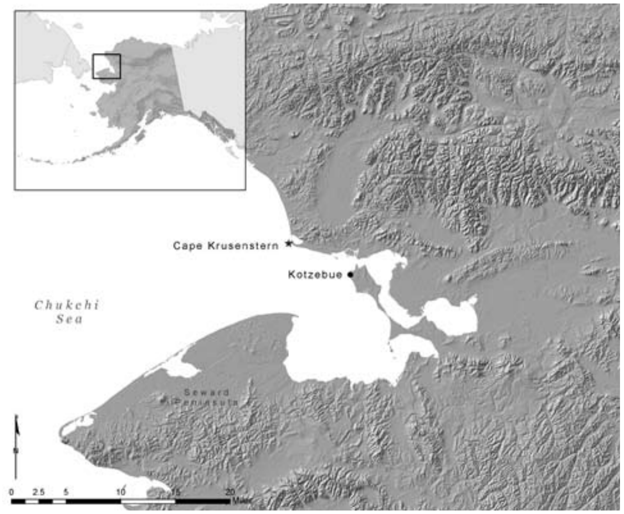

Figure 2. Cape Krusenstern study area.

Photograph courtesy of Shelby Anderson

Figure 3. Recording feature with GPS unit.

Photograph courtesy of Shelby Anderson

Figure 4. Documenting Giddings' site location information.

In addition to survey and mapping activities, several site areas were tested in 2006 and 2008 (*Figure 6*) in order to collect well-provenienced samples for dating and other analyses (*Figure 7*). A total of 19 radiocarbon dates were obtained in 2006, and dating yielded ages from 6420 BP to 280 BP (before present). The 6420 BP date is likely due to accidental sampling of old wood, as the beach ridges themselves did not begin to form until sea level stabilized in the region between 5,000 and 4,500 years ago. Additional samples from the 2008 field season will be submitted for dating in winter 2009.

Discussion

Previous settlement reconstructions indicate that population increased at Krusenstern until about 500 years ago, based on the number and density of house features, and then decreased after this time as people dispersed, perhaps to focus on different resources (*Anderson 1984*). This pattern at Krusenstern is in contrast to that known for other large settlements around Kotzebue Sound, such as Point Hope and Wales, where population continued to increase over the last 500 years (*Mason 1998*). Perhaps this is because people continued to have access to whales and other large marine mammals in these other locations while people living at Krusenstern did not (*Anderson 1984*). New survey information, particularly for the last 1,000 years, will be important in re-evaluating existing settlement models and population estimates for Krusenstern. Reconsidering Krusenstern's place in the regional socio-political sphere in light of this settlement data may also yield interesting results. Additional survey data and radiocarbon dating will provide information on the timing and nature of changes in settlement densities, as well as data on house size and configuration that may indicate changes in social organization at Krusenstern.

In addition to addressing our research questions, the data generated by this project is important for NPS resource management purposes. The integration of old and new archeological data into a GIS will make it easier for NPS archeologists to fully utilize project findings and share information with other park staff. The incorporation of legacy data into the project GIS means that as fieldwork continues, current feature condition can be compared to that recorded by Giddings 50 years ago. Long-term data on site condition is important for understanding future potential impacts to archeological sites at the Cape.

Summary and Conclusions

At Cape Krusenstern we have the opportunity to undertake a comprehensive study of past human and environment interactions in a place where human occupation appears to be nearly continuous over the last 4,000+ years. Previous research at Krusenstern has provided a strong framework for integrating archeological and paleoenvironmental research through this new study. With new tools like high resolution GPS, the beach ridge complex can be systematically surveyed, mapped, and sampled for the first time. Findings to date show interesting patterns in settlement size and density, and illustrate how questions about changing settlement, demography, and mobility will be addressed through additional fieldwork and analysis. An improved chronology for the occupation at Krusenstern will also have regional level implications.

In the 2009 and 2010 field seasons, fieldwork will be focused on testing to gather more samples for dating and analysis from features across the beach ridge complex, although the survey and mapping effort will continue as well. Given the important place of Krusenstern in our understanding of regional cultural evolution, the new archeological and paleoenvironmental research carried out at Krusenstern will be relevant to research in both fields across greater Beringia. More information about the project is available on the website: http://students.washington.edu/shelbya/CAKR_Project.shtml

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Photograph courtesy of Nicholas Radko

Figure 5. Mapping previously excavated features.

Photograph courtesy of Shelby Anderson

Figure 6. Testing archeological features.

Photograph courtesy of Shelby Anderson

Figure 7. Artifact recovered during testing activities.

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2006-2008 Investigation of the Old Eskimo Settlement Kivak, Providenskiy District, Chukotka Autonomous Region, Russia

By Aleksandr A. Orekhov

In 2006-2008 an archeological team from Northeastern State University (NESU) in Magadan, Russia, conducted emergency rescue work on the archeological monuments near Kivak Lagoon, based on a request from the Department of Culture of Chukotka Autonomous Region. The money from a designated fund financed this research, which was overseen by A. Os'kin and E. Rogozina. The main goal was to research the 65 feet (20 m) stretch of coast that is being destroyed by surf waves.

The remains of a semi-subterranean dwelling with two cultural layers has been partially (50%) preserved here. The first cultural layer was located at a depth of 2.8-3.7 ft (0.85-1.1 m) and 16.3-17.2 ft (4.9-5.15 m) above sea level. Its thickness is 0.7-1.2 ft (0.2-0.35 m). The layer is composed of dark brown sandy loam saturated with fat (of pinnipeds?) and contains the artifacts of the Punuk Culture.

The second layer, which is characteristic of Old Bering Sea Culture, is located at a depth of 5.8-7.3 ft (1.75-2.2 m). It has a thickness of 1.2-1.5 ft (0.35-0.45 m), and is 14.7-15.8 ft (4.4-4.75 m) above sea level. This layer is composed of dark brown sandy loam, which includes a large number of baleen strips of different sizes that are located at the same depth. These strips seem to have been used as a floor covering for thermal and hydro-insulation, and, perhaps, for hygiene purposes. The unearthed covering stretches for 173 ft (52 m) and corresponds, not just to the footprint of the dwelling, but, possibly to the household chore area (dressing of animal carcasses?).

A large number of household items, marine mammal hunting and fishing tools, as well as tundra and coastal gathering tools, and pieces of ceramic were found in the talus of the cultural layers near the dwelling and at the dwelling excavation site. The found items are mainly made of marine mammal bone, reindeer bone and antler, walrus tusk, skin, wood, stone (siliceous schist is prevalent), whale baleen, and clay.

This article will characterize the complex of dwelling #1 of Kival Settlement. The tool assembly for winter household activities, such as pinniped hunting near ice holes, under ice fishing, winter transportation of catch, moving across the frozen snow crust and ice, and clearing the ice holes of ice attest that this was a winter dwelling.

The large number of the ivory items are covered with carved decoration. Judging from the straight lines and the edges of the cuts, the artifacts were carved with iron gravers. The blade of one graver and two whole gravers attached to bone composite handles were discovered in the Old Bering Sea cultural layer. The tools mainly made out of the walrus tusk with characteristic delicate complex Old Bering Sea ornamentation are the most interesting. The linear geomentrical motifs are characteristic. The main elements of the ornamentation are parallel lines (from two to five) that often form various figures (with different configurations) such as oval, half oval, circle, triangle, lines connecting different elements, lines with short perpendicular lines, teeth, and dots. Complex compositions accordingly fill out and organize the surface of the object with consideration for its shape. As a rule the ornamentation covers the whole surface of the tool.

The toggling harpoon points with the side inserts are the most characteristic feature of the Old Bering Sea culture. Many different sizes of the decorated toggling harpoon points (28 whole points and 5 fragments) of the Old Bering Sea type were found. The harpoon points have single (sometimes double or triple) prongs, one hole for the rope [lin'], and grooves for the two side flint retouched inserts. In ten cases, the center of the circles and ovals were marked with round convexity. Tools with such micro-relief are characteristic for the Old Bering Sea Culture. One harpoon point has a slit at the tip for the spike insert and a small hole on a prong (for poison?). Punuk toggling harpoon points (including the whale ones) with one prong and one hole for the rope, have a slit for the spike insert.

Other elements of the harpoon assembly are present in the tool assemblages. The spiked base of the harpoon shaft, made of walrus ivory, in their form and function resemble the analogical ice pick (called *peshnya* in old Russian) with a groove and notches for the fastening according to the Old Bering Sea type, and with a prominent stem with the Punuk type notching. The base-support of the harpoon shaft with an opening for the insert made out of walrus ivory and wooden nozzles with plugs for the floats (Punuk) were discovered as well.

The stabilizers (the "winged object" of the Old Bering Sea Culture) of the harpoon shaft bases (6 whole objects and 2 fragments), the most important elements of the harpoon complex, were also found. Three were decorated on two sides with complex linear ornament in combination with ovals, circles, dashes, dots, triangles, cogs. The Punuk stablilizer ("trident") was decorated with floral ornamentation. The gaffs made out of walrus ivory were used for bringing the bodies of the pinnepeds closer to the boats.

The eight sewed on badges or buttons are especially interesting. Seven are made of walrus ivory and one of wood. Five ivory badges are decorated. Each badge has on its lower surface a special hole so it is possible to sew them onto hide clothing. One badge had a number of through holes along its perimeter which possible were used for fastening. The badges vary in sizes from 10 x 4 cm to 5 x 3 cm. The four badges have an oval form and one has a lens-like form. On one of the badges, along the edge of the artifact are two parallel lines that form an oval with a combination of "eye-lashed" and dashed ornamentation. Two of the badges have a more complex composition that covers the whole surface. In one case, there are concentric ovals, dots, and "eye-lashed" ornamentation, and in the other case, the triangles, lenses, cogs and punched holes are used in the composition.

Currently there are two analogical artifacts made out of walrus ivory that were noted in Russian publications on archeology; however, they are not decorated. Nikolay Dikov defines one as a button; he found it in one of the Old Bering Sea Culture dwellings right next to Kozhevnikova cliff near Cape Shmidt. Kirill Dneprovskiy denotes an analogical artifact as an unidentified object. The badge with 15 indentations grouped in three rows was discovered for the first time, and the diameter of the indentations of the central row is bigger than the one of the side rows. Such a counting system perhaps presents a calendar (half month/half moon cycle), considering Eskimo tradition of counting by fives. The wooden badge is not decorated; its main decoration is the beautifully selected natural wood grain.

Seven ornamented plates, four of which have the whole surface on one side covered with decoration, were discovered in the complex of dwellings. Two were perhaps used for protection of the wrist (during shooting bow and arrow). One was decorated with a net design in combination with an oval that is formed by triple and double parallel lines; the other one was decorated with a more complex composition made of diamonds and circles formed by double parallel lines. Two ornamented plates with one and three holes were hung or, possibly, sewed on hide clothing (head dress?). The similar ornamented plates (fragments) discovered during the excavation of dwelling #25, late East Thule Culture on Cape Kruzenstern, were interpreted by Louis Giddings and Douglas Anderson as sewed on decorations for the foreheads (*Giddings and Anderson 1986*). The first plate was decorated with a net motif formed by parallel lines. The second plate was compositionally complex that included ovals, triangles, and circles formed by double parallel lines. The parallel lines are scratched on the back surface of the first plate, and the indentations were formed on the second one from multiple scratching. Possibly this is a reflection of certain rituals.

A multitude of fishing tools is present. The summer fishing tools are represented by the nets made out of baleen (*nygakhpak*) and sinkers. A large number of walrus ivory central and side points, part of the harpoon assembly, are present. The winter ice fishing tools are represented by scoop-nets made of baleen (*kalyu*) (3 objects), sinkers

Figure 1. Top Row (left to right): fishing tools, toggling harpoon heads, hunting tools. Middle row (left to right): carved toggling harpoon head, stone point, sea mammal hunting tool. Bottom Row (left to right): remains of dwellings.

Photograph courtesy of A. Orekhov

(45 objects), wooden floaters and composite hooks (5 objects) for the winter fishing pole (*manan*).

On one of the fishing sinkers, three dots mark the mouth and eyes of an animal (seal?). This depiction may have assured good luck. Multitude of fish figurines (also interpreted as whale figurines) are made out of baleen and have marked fins and tail. According to existing interpretation, they were used for ritual purposes. It is possible that these figurines were used as fish bait as well.

The hunting tools consist of fragments of simple wooden bows, composite bows (two halves connected with a bone plate) made of baleen, and arrow points. The arrow points with awl shaped bases (23 artifacts), with grooves and cogs are predominant. The points with a wedge-shaped base are also present. The large number of bird hunting tools are bolas made mainly from walrus teeth.

For moving across the ice the people of the Old Bering Sea Culture used ice grippers: a piece of baleen with inserted spikes made of walrus ivory (3 artifacts) or a bone plate made of whale rib (1 artifact) that were tied to the footwear. To move across snow crusted with ice and to break the ice, ice spires were used.

The seals harvested at the ice edge or near the ice holes were transported in hand pulled sleds, the runners of which are found in large numbers in the complexes of both cultures. However, the Old Bering Sea Culture runners are more complex. The ice from the ice hole was removed with net scoops made from baleen.

The tools of tundra gathering (digging of roots) and dwelling construction (loosening of earth and digging for semi subterranean dwellings) are hoes and picks made of walrus ivory as well as from walrus and whale ribs.

Utensils are represented by fragments of ceramic with linear stamped decoration, applied by both impressing method and dragging method, and the fragments of coil constructed ceramics. Fragments of ceramic without ornamentation are present in large numbers as well. Analyses of the fragments show the predominance of vessels with a round bottom; however, there were also three small vessels of truncated-conical form, with a strait or tapered bottom that were probably used as oil lamps. Two of these artifacts do not have traces of soot deposits and perhaps belonged to children. Also 12 vessels and 8 fragments of vessels made of baleen with wooden bottoms and lids were found. Two have ivory/bone bottoms and lids.

The assemblage of children's' tools (Punuk culture) includes wooden and wooden-baleen bows, spear points made from baleen and walrus ivory, arrows made of one piece of wood with bone/ivory points, miniature toggle harpoon points, boys' "male" polished slate knifes, and girls' bone combs. All children's inventory mirror the "adult" objects, but are simpler and are denoted by small sizes.

The religious objects were also discovered in the dwelling. A figurine of a six-clawed bear is unique. The entire surface of the figurine on two sides is covered with a very complex decoration. The artifact side opposite to the bear's head depicts a whale head. An anthropomorphic figurine-pendant made of walrus ivory was exposed in the Punuk layer . The three duck figurines with a hole for hanging and apparently religious in nature were discovered as well.

Dwellings and constructions from different time periods are present in the settlement. The preserved remains two ancient dwellings, in the form of depressions on high ground, are located in the mouth of an un-named creek, on both of its shores. The Punuk dwelling #1 was a semi-subterranean hut of roundish shape with a long corridor-access-hole, with walls reinforced by rocks, whale vertebrae, and walrus skulls.

The dwelling interior was divided (almost in the center) by the whale vertebrae (three vertebrae high) and walrus skulls combined with large rocks. Wood, ribs, skulls, scapulas and lower jaw bones of whales were used to construct the roof. Judging from the small size of the bone, these may be the bones of a gray whale. Such dwelling complexes are characteristic for the dwelling construction tradition of the Old Bering Sea Culture.

One hundred feet (30 m) to the west of dwelling #1 the well-preserved remains of 11 meat storage caches are located. Their side walls and roofs are made of whale skulls and ribs and covered with sod on the top.

The extremely interesting artifacts, some of which are unique, discovered during the excavation of the site as well as threat of its destruction, warrant the necessary excavation and continuation of research. The new materials not only add to the characteristics of two very interesting Old Bering Sea cultures (ancestral for modern Eskimo), but the presence of clear stratigraphy change between Old Bering Sea and Punuk cultures, perhaps will help to clear the genesis, correlation and interaction of these maritime cultures.

Photograph courtesy of A. Orekhov

Figure 2. Old Eskimo settlement at Kivak.

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Pathways: An Archeological Predictive Model Using Geographic Information Systems

By Dael A. Devenport

Introduction

Anyone who has traveled by foot in the backcountry of Interior Alaska knows what the term 'bushwhacking' means. Notoriously difficult to travel in, the interior of Alaska is riddled with dense black spruce forests and wetlands. Frozen rivers make convenient travel routes in the winter, but the fast-flowing glacial rivers can be difficult and dangerous in the summers. In addition, the banks are often lined with impenetrable willow and alder thickets. This creates quite a challenge for archeologists whose job it is to search the landscape for archeological sites.

Archeological survey can be time consuming and expensive, especially in Alaska where three-quarters of the land is inaccessible via roads. Archeological reconnaissance requires transporting a crew into the backcountry, usually by costly means such as a helicopter or small airplane, or a time-consuming method such as boat or foot travel. To help decrease the time and expense involved in surveys, the use of computer technology is rising in popularity. Increasingly sophisticated techniques are being used to locate archeological sites. But for the most part, when planning a survey in Alaska, archeologists still look at a map, take an educated guess, and start searching. Because the areas picked for survey usually depend on access and ground visibility, we may not obtain an accurate representation of the distribution of sites across the landscape. We know that the vegetation frequently was much different several thousand years ago, and if we are only looking in places that currently have easy access and ground visibility, we may not find all the sites that actually exist. In addition, because of time and staff limitations not all ground can be surveyed, so there is always a compromise between how completely the ground is surveyed and the total area covered by the survey. Any technique that will increase the likelihood of locating sites will decrease the expense and time involved, and increase the productivity of survey.

Geographic Information Systems (GIS)-based predictive modeling is a fairly young technique. Yet it has enormous potential to boost the efficacy of archeological field work and is increasingly being used to predict possible locations of archeological sites. Not every location that a computer program predicts as an archeological site will have one. By using an additional technique for this project, I am attempting to increase the productivity of the model.

The foothills of mountain ranges, esker ridges and other elevated features are often composed of a firmer substrate, are better drained and have less vegetation than the lowlands. They provide faster, more efficient travel routes with fewer obstructions and ancient people may have used them for traveling between sites (*Figure 2*). These are areas that have received little archeological attention. The purpose of this project is to determine where travel and trade routes of prehistoric people existed on these elevated features in order to predict the possible locations of unknown sites along these routes. With the assistance of GIS technology, this model will hopefully make our archeological field expeditions more efficient and effective as far as time, money and productivity are concerned.

Procedure

I am using GIS technology to predict possible locations of archeological sites in order to increase the likelihood of finding new sites during archeological survey. Engineers have found that using GIS to predict the best routes for roads can provide a savings of 5-15% (*Yildirim et al. 2006*). Using GIS may also help archeologists be more efficient regarding time and effort when surveying for new sites. Finding more sites will also provide us with a better understanding of past human use of the landscape.

This project was broken into four main parts. The first part consisted of using a control group to determine what influences peoples' decision making process when they are choosing how to travel across a landscape. The second part was using that information to figure out possible routes that prehistoric people were using to travel between sites in the Yukon-Charley Rivers National Preserve. The third step was to look for the possible locations of unknown sites along those routes. Looking in the locations suggested by the GIS program as possible site locations will be the fourth step.

NPS photograph by Phoebe Gilbert

Figure 1. View along the Yukon River.

Step 1: Control Group

Before the potential pathways between prehistoric sites could be modeled, a control group was needed to determine the factors influencing pathway decisions. The control group was our archeological field crew, whose travel routes while surveying were tracked with Garmin Map 76 GPS units (*Figure 3*).

I loaded the track logs from the field crew into the ArcMap program and ran numerous tests to determine which factors carried the most weight in pathway decision making: vegetation carries more weight than slope, with a 60% to 40% ratio (*Figure 4*). In other words, a person traveling in the backcountry would be more willing to climb a steep slope than scramble through an alder thicket on flat ground.

Step 2: Least-cost pathway analysis

A least-cost pathway analysis is based on the idea that ancient people would want to conserve energy and would pick the easiest route to travel, avoiding steep terrain and thick vegetation. So I programmed the computer to look for the easiest routes between sites that were occupied during the same time period. The analysis took into consideration not only minimum distance, but also the ease of movement across the landscape. Therefore, prohibitive vegetation and slope were considered.

Imagine that a net is put over the ground and in each cell of the net, a number is assigned to the type of terrain: if it is flat, it gets a low number; if it is steep, it gets a high number. The same technique is used for other information such as vegetation. A lower number would be given to vegetation that is easy to walk through, such as grass, and a higher number to vegetation that is hard to walk through, such as an alder thicket. Then, the grids, or nets, can be placed on top of each other and the numbers added together to identify where there is flat ground with vegetation that is easy to walk through. To determine the potential pathways, I used the weighted vegetation and slope grids from the previous step. Starting at a known site, I had the computer look for the cell next to the site with the lowest number, then the cell next to that cell with the lowest number and so on until reaching my destination, another site (*Figure 5*).

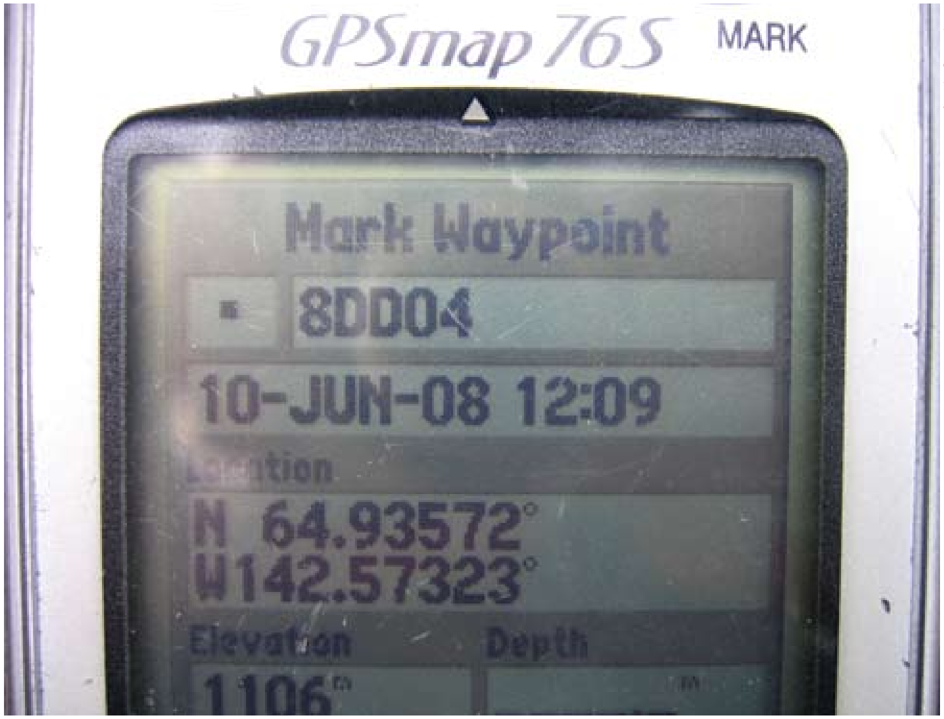
The sites chosen as destinations are late-prehistoric age villages that represent substantial, long term settlements. Villages are assumed to be more permanent and have higher populations than hunting camps. Village sites usually have fixed features such as house pits and are usually located at lower elevations. A village is more likely to be repeatedly occupied than a transient hunting camp and more likely to be a destination for travelers. The sites chosen as sources were stone tool scatters that are assumed to be representative of more transient, briefly occupied sites such as hunting camps. Hunting camps are often found at higher elevations with no fixed features.

Step 3: Predicting Possible Site Locations

Looking for the possible locations of unknown sites


NPS photograph by D. Devenport

Figure 2. Elevated ridge that may have been a possible travel route for prehistoric people. Notice how far you can travel along the top of the ridge.



NPS photograph by Phoebe Gilbert

Figure 3. A Garmin Map 76 GPS unit used to track where archaeologists have surveyed.

along the pathways determined in Step 2 is the third part of the project. This is done with the creation of a predictive model using the GIS program. First, we look at the characteristics of known sites. We know that sites are usually located on flat ground, close to water, with a southern exposure in a well-drained area. Knowing that sites share certain similarities, we can look for other locations that share the same characteristics along the pathways. When the computer program finds areas that share those attributes, we can survey to see if there is a site.

To illustrate this idea, in order to find areas of level ground close to water, I took the slope grid used in the previous steps and looked for cells with low values. Then I drew a buffer around the cell. The buffer is a specified distance away from the cell. For example, supposing people would not want to carry water more than 1,000 feet (300 m) to their campsite, I can create buffers of 1,000 feet (300 m) around the areas with level ground. Then I can do the same thing for water sources and the previously calculated pathways. Where buffers around a water source, level ground, and the pathway overlap would be good places to look for new sites since people would not want to travel too far off the path to get to a site or to get water (*Figure 6*).

Step 4: Testing/Validation

The next step will be to validate the model. There are two ways to validate this model. The first way is to test the model without spending large amounts of time and money. This can be done by excluding a number of known sites from the model construction, and after the model is completed, running the model to see if it predicts the location of the excluded known sites. If not, the model will need to be adjusted until it accurately predicts known sites.

The second way to validate the model is by finding new sites in the areas predicted through the GIS modeling. This will be done during the next field season by our archeological field crew surveying a random sample of the high probability areas indicated by the model.

Conclusions

Once this technique is perfected, it can be used in other areas and by other parks to focus archeological surveys. This predictive model has the potential to be valuable for archeologists, historians and land managers not only by predicting possible site locations, but by also providing new insight into prehistoric populations' movements throughout Interior Alaska. This becomes important when analyzing subsistence resource use, communication networks, disease pathways and trade routes. In addition, this model can be beneficial to other professionals since similar techniques can be used by them to predict things such as invasive plant pathways and animal migration routes.

Acknowledgements

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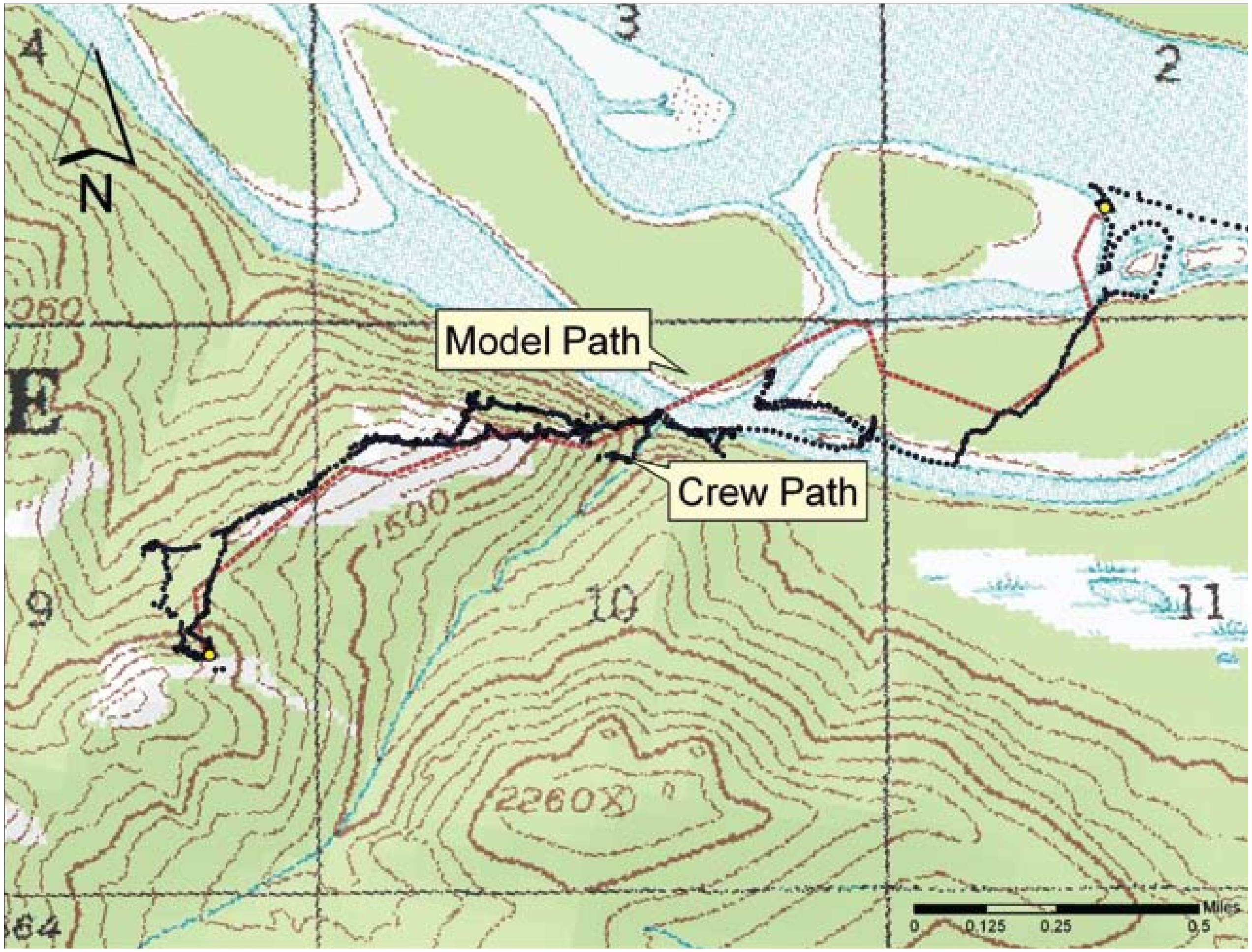

Figure 4. Illustration of archaeological crew's actual path, and the computer program's closest match.

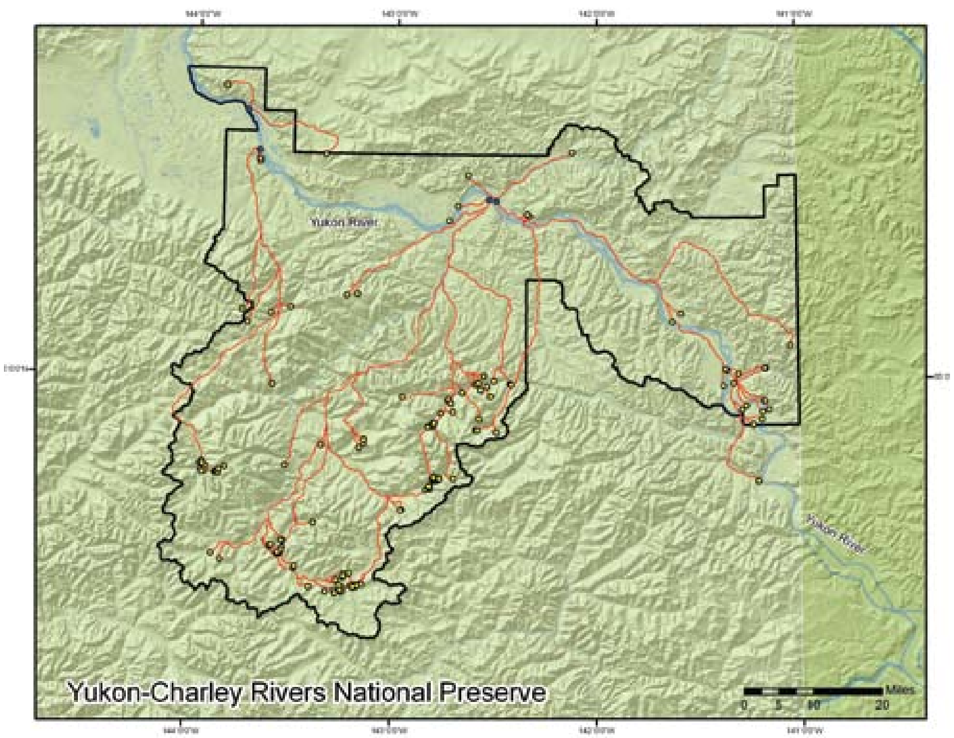

Figure 5. Potential travel routes between prehistoric sites in red. Villages are represented by blue dots and less substantial sites by yellow dots.

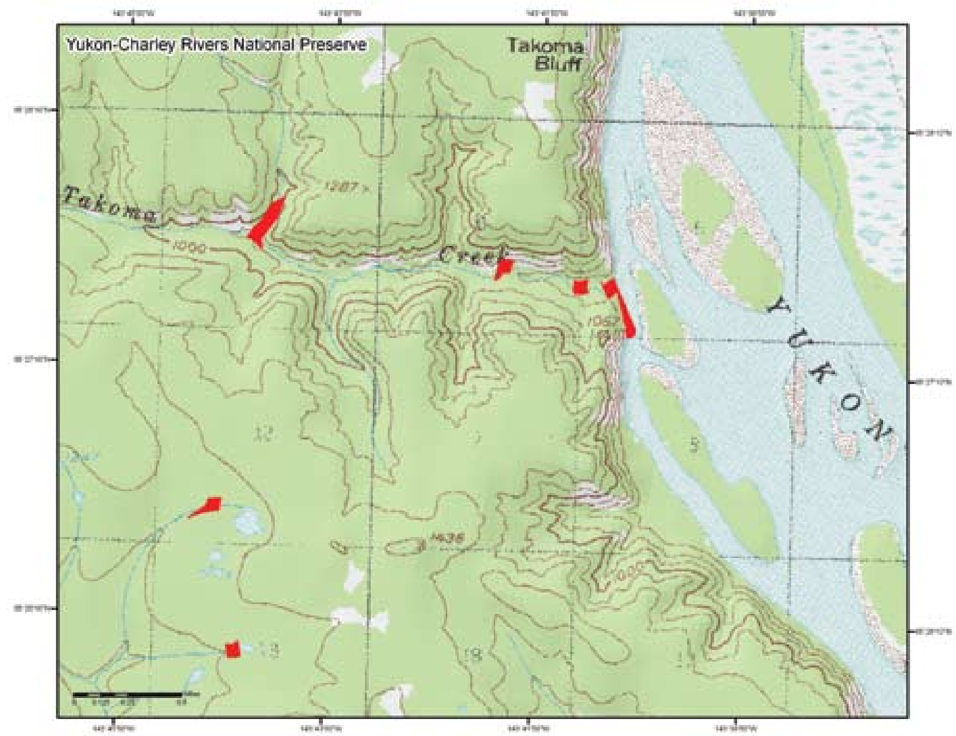

Figure 6. Possible site locations as predicted by model in red.

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Environmental Sustainability and Change

Photograph courtesy of Vladimir Zhuravkov

Transboundary Protected Natural Areas and Their Role In Nature Conservation of Northeast Asia

By Anatoliy Kachur

International relationships in the sphere of environmental protection and ecosystem preservation in transboundary areas such as Northeast Asia have followed a complicated path in their development. These relationships went along the path from distrust and suspicion to growing mutual understanding. Through their interactions, scientists exposed many global and regional ecological problems that require immediate resolution by neighboring countries.

At the end of the twentieth century it became obvious that current models of nature use must be replaced because of numerous ecological crises and the intensification of global problems connected with climate change—alteration of the atmosphere composition, pollution, the loss of biological diversity, the degradation of ecosystems, the exhaustion of the natural resource base, and the continual growth of demographic and social problems. A new system of common priorities based on the realization to transition to a sustainable development concept began to emerge. Recently the term "sustainable nature use", which is the Russian analog of "sustainable development", had started being used in Russia.

The most important task that lies at the base of carrying out the concept of sustainable development is the development of principles and methods to optimize mutual relations between humans and the environment. The most important component is the creation of prerequisites for the preservation of nature and its restoration. The primary method for this is the creation of an ecological framework consisting of a system of protected natural territories.

A separate question is the issue of a strategy for sustainable development in territories or marine areas that belong to two or more countries. In the framework of transboundary protected units, we noted a huge variation in the impact on ecosystems, which in turn causes the appearance of multiple ecological (geo-ecological) problems.

Transboundary territories on the borders between Far East of the Russian Federation, Democratic People's Republic of Korea, and the People's Republic of China are very typical example of such units. Here the significant ecosystem variables cause the occurrence of multiple transboundary ecological problems. Also very important are the differences in the types of nature use. For example, the uneven forestation level on both sides of the borders range 3-4 times. An even higher difference is observed in the animal population, and the difference in economic activities is also high. For example about 270,000 people (average population density is is 39.6 persons per mi^2/15.3 per km^2) inhabit the Russian part of Khanka Lake basin while about 1.9 million people (population density exceeds 130 persons per mi^2/50 per km^2) inhabit the border area of the People's Republic of China that directly influences ecosystems of the Khanka lake basin. The protected area ratio is inverse to the population ratio. All these factors result in sharp landscape contrasts at the border crossing (*Kachur 2005b, 2007*).

Unfortunately despite of the recognition of these facts, the necessary coordination of nature use in the border regions advances very slowly. Along with the recognition that some violation exists (pollution, destruction of ecosystems), an important element of nature use coordination is to determine the reasons of these violations. Forecasting future development considering revealed or forecasted ecological problems and restrictions is also important (*Kachur 2005a*).

The ecological restrictions can be divided into two large groups: 1) restrictions imposed by the characteristics of the natural conditions, and the resources' potential; and 2) restrictions caused by the characteristics of or a result of the existing economy system. The major elements of environmental restrictions are the ones directed towards preservation and towards the restoration of natural biodiversity. They are the most important guarantee of preservation of the natural habitat and acceptable ecological conditions.

Figure 3. (Left) Penkigney Bay. Chukotka, Russia.

The preservation of biodiversity is especially important in the areas that hold the key position in regards to the world's gene pool. Due to the characteristics of its geographical location, its topography, and history of development, Northeast Asia has had favorable conditions for the development of a large number of nature complexes that are unique not just for Asia but also for the whole world (*Baklanov et al. 2003, Kachur 2005a*). An exceptional richness of fauna and flora, dynamic poly-climatic structure, combination of the intense processes of species formation and preservation of the ancient communities, high biological productivity, and evolution of diverse complex forests are very characteristic for the region.

The active economic activity significantly changed the look of the area as well as many biosphere processes here. The shift to a concept of sustainable development is impossible without preservation and, unfortunately as the results of the latest research have shown, without rehabilitation of the natural biodiversity (*Zheleznov 1999*).

The assessment of the existing system of protected areas to ensure sustainable nature use in the transboundary regions of Northeast Asia showed that the existing systems can not carry out the necessary function of providing sustainable development of these regions. That is because these systems do not provide for biodiversity preservation in the transboundary ecosystems, and also can not form the corridors for the rehabilitation of the lost biodiversity in the adjacent areas of transboundary ecosystems.

Overall the countries have developed specially protected natural area (SPNA) systems. For example in Russia, the system of state natural *zapovedniks* (strict preserve) and national parks includes 100 *zapovedniks* with a total area of 129,000 mi²/33.5 million hectares (ha) (1.56% of the area of Russia) and 35 national parks covering 27,000 mi²/7 million ha (0.41 % of Russia) (*Figure 2*). In January 2008, 1,275 SPNA with a total area of 492,000 mi²/127.5 million ha existed in the Russian Far East. Of these, 50 protected areas had federal status, 888 had regional status, and 337 had local status. Data on the SPNA system in China are in Figure 3.

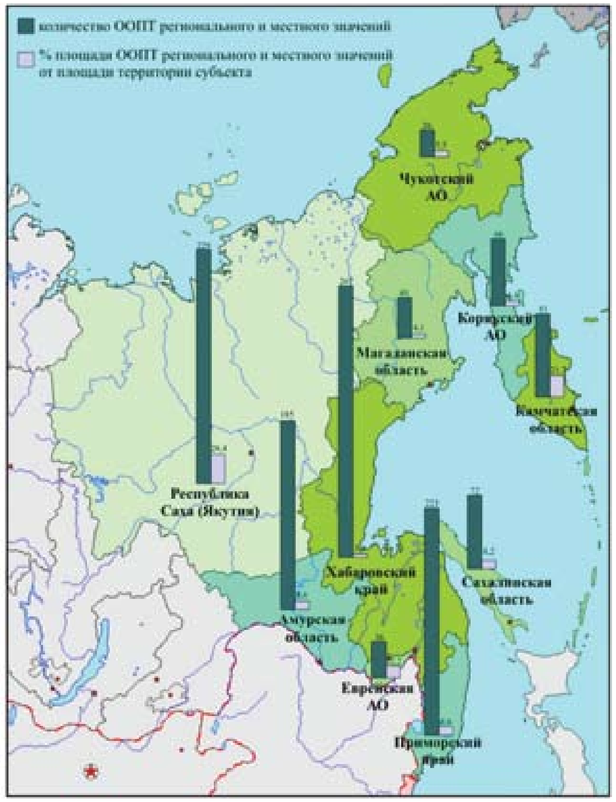


Figure 2. Comparison of the number of specially protected natural areas in the Russian Far East, of all categories and their ratio to the area of the region.

Based on international experience, the best approach to the restoration of biodiversity, when biodiversity and environment conditions are unequal, is the creation of transboundary protected areas that can become a connecting link for natural restoration of biodiversity (*Figure 4*). The transnationalization of protected natural areas is in the initial stage of development (*Kopylova 2003, Hamilton et al. 1996*). These processes are complex and characterized by a number of serious problems of economic, political and ethical origin. It is still too early to talk about the active cooperation of SPNA of different countries; however, even today the role of transboundary specially protected natural areas (TSPNA) is noticeable. In combination with the development of regional environmental networks, it marks the beginning of a new stage in the evolution of territorial nature preservation—transition from local and regional level to global.

It is necessary to consider the whole ecosystem in order to manage sustainable nature use and subsistence. That in turn will allow the creation of an ecological frame based on the principle of self-complementation. This means that theoretically the main part of the ecological frame can be located in one country and work as a core for support and, if necessary, for the restoration of biodiversity for the whole ecosystem. At the same time it provides a system of ecological corridors that will support the whole ecosystem.

An important component of the TSPNA system is the network of maritime, island and coastal SPNA (*Baklanov et al. 2003*). So far such a system has not been created in Eastern Asia, however, its establishment would be timely. Russia has three approved international natural preserves (*Figure 4*) (*Kopylova 2003*).

The first established TSPNA was the Russian-Finnish *zapovednik* Druzhba (Friendship). It was established on the basis of the agreement between the governments of Finland and Soviet Union in October 1989. It includes the Russian *zapovednik* Kostomukshsky (185 mi²/480 km²), and some smaller Finnish units which in total cover about 85 mi² (220 km²). Each country is responsible for financing the preservation of the protected units, though both countries have a joint coordination council for regulation of scientific work and ecological education.

The second TSPNA was established on March 29th, 1994, on the basis of the agreement between the Russian Federation, Mongolia, and the People's Republic of China. The TSPNA encompasses the Russian National Nature Biospheric Daursky (total area 173 mi²/44,752 ha and protection zone 367 mi²/95,000 ha), the Mongolian reserve Mongol Daguur (total area 405mi²/105,000 hectares), and the Chinese preserve Dalai Nor (total area 2,860mi²/740,000 ha, including specially protected sections of 63mi²/16,300 ha). In the future it is planned to expand all three preserves with the goal of converging their boundaries and establishing a joint protected network of Dauria steppes, obtaining biosphere wildlife reserve status for the Mongolian and Chinese preserves, and creating an international biosphere wildlife reserve on the basis of the transboundary protected area.

The third TSPNA is the international preserve in the Khanka Lake basin. The preserve stretches along the coast of Khanka Lake. It was established on the basis of the agreement signed on April 25th, 1996, between the Russian Federation and the People's Republic of China. The reserve includes the Russian *zapovednik* Khankaisky (total area 146 mi^2/37,989 ha and protection zone 284 mi^2/73,743 ha) and the Chinese preserve Sinkai-Hu (total area 222 mi^2/57,700 ha). The significant part of Khankaisky is located in a closed border zone with strict admission rules. In 1975 this area received the status of wetlands of international significance mainly because of its waterfowl habitat (*Bocharnikov et al. 2001*). The protection status in Sinkai-Hu is similar to the status of Russian preserves and their protection zones. The joint Russian-Chinese commission coordinates the transboundary cooperation.

The establishment of several new TSPNA in the Russian Far East is currently under discussion or in the planning stage: 1) international biosphere in the lower reaches of Tumen River; 2) TSPNA that will include the Russian Bolshekhekhtsirsky *zapovednik* and the Chinese Sanjiang preserve; 3) TSPNA that will include the Russian Khingansky *zapovednik* and the Chinese Hunhe biosphere preserve; and 4) Beringia International Natural Park (Russia, USA). The most likely projects to be implemented in the near future are the International Biosphere Preserve in the lower reaches of Tumen River and Beringia International Natural Park.

The Tumen River basin and adjoining marine areas form the central zone of the international waters and biodiversity of the region, which in turn are key to the river

SPNA types	Number	Area in hectares (x10,000)	% ratio of the total number of SPNA	% ratio of the total area of SPNA
Total in the country	2395	15153.50	100	100
National level	265	9169.7	11.06	60.51
Local level	2130	5983.8	88.94	39.49
Local: Provincial level	793	4441.80	33.11	29.31
Local: Urban level	422	522.44	17.62	3.45
Local: District level	915	1019.56	38.20	6.73

Figure 3. The system of specially protected natural areas in People's Republic of China.

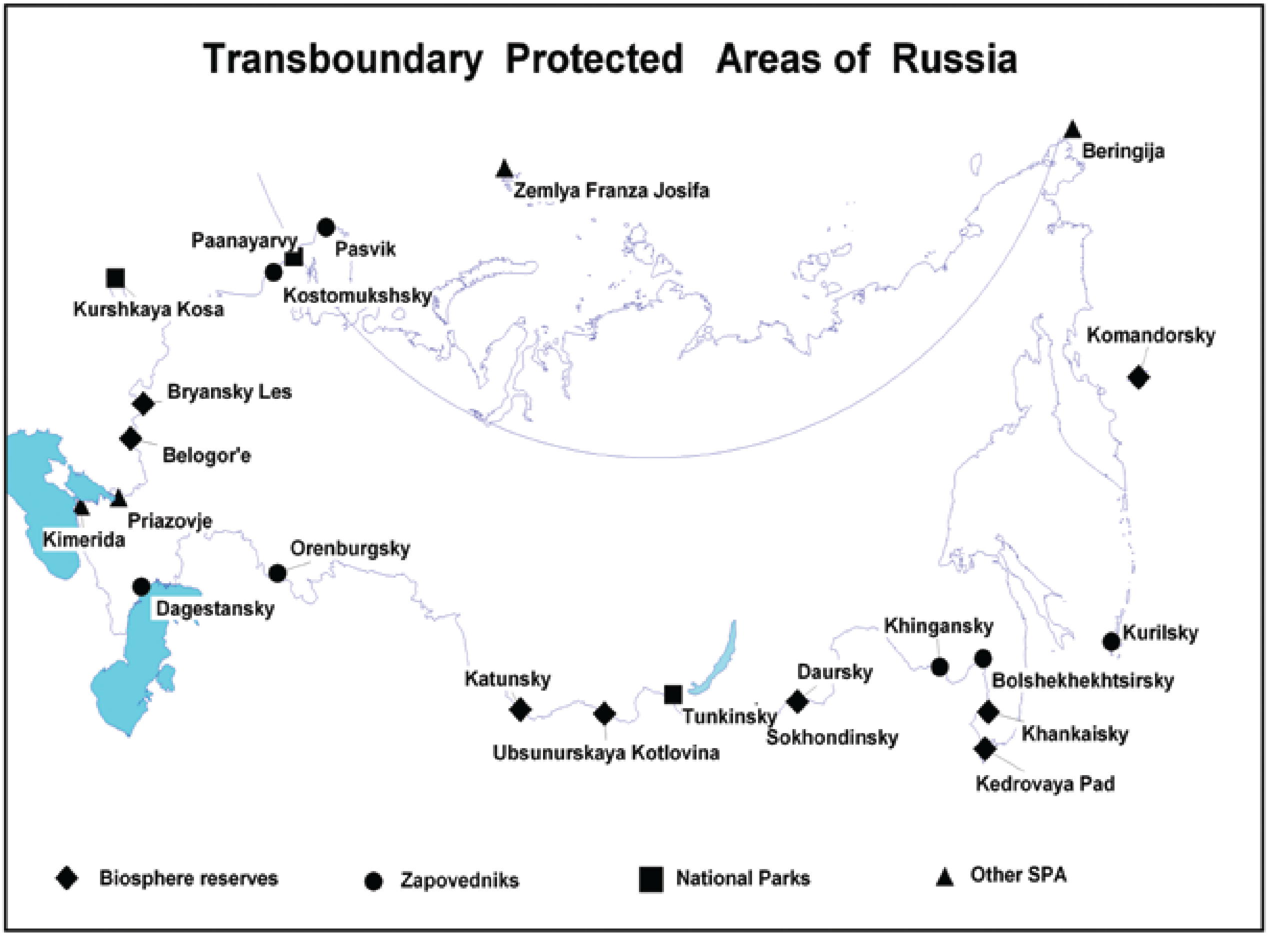
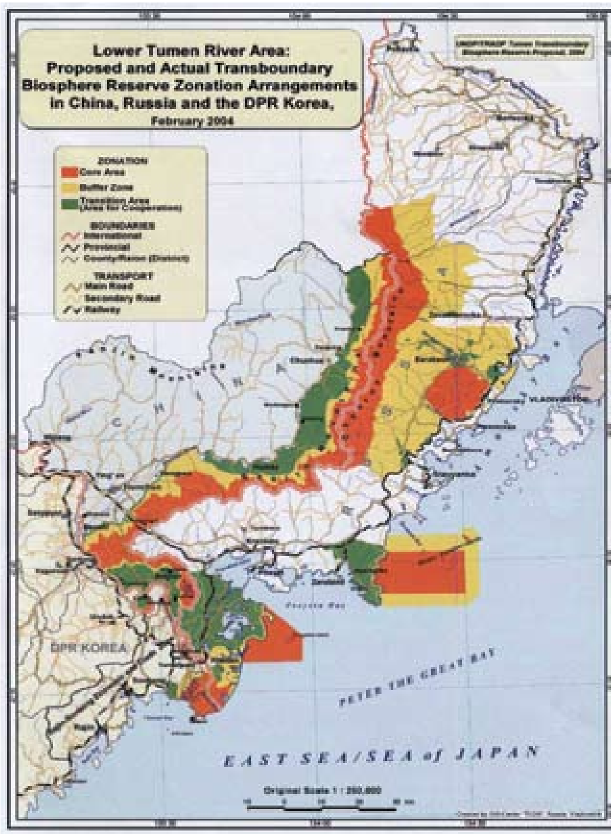
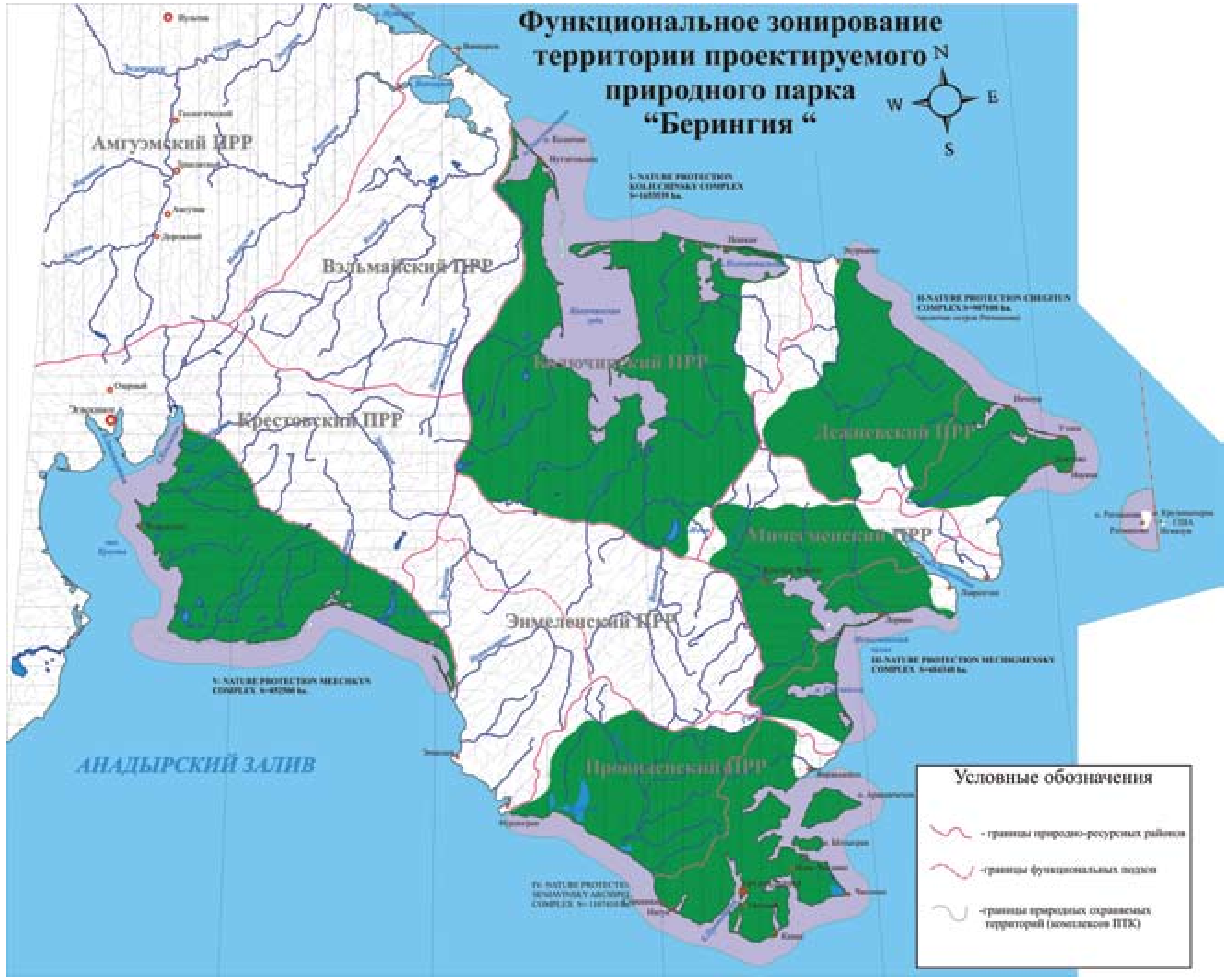


Figure 4. (Right) Existing and potential transboundary protected natural areas of Russia.

Figure 5. (Below) Project of an International Biosphere *Zapovednik* in the lower reachers of Tumen River.

Figure 6. (Right) A sample version of the organization of the Russian part of the Beringia International Natural Park.





basin's environmental protection. A great variety of birds are present in the coastal and marine areas, and a large number of marine and terrestrial animals use the area for their migrations. The wetlands are an important part of the East Asian migration route between Siberia and Australia. A number of transboundary problems in the region are related to the influence of local and regional air pollution and pollution of land and coastal waters. The most important resources of this territory and adjoining water areas of Asia are wetlands, bird population, marine ecosystems, forest and steppe ecosystems, wildlife populations, and air quality.

In order to preserve these valuable water resources and biodiversity, it is necessary to strengthen the measures against environmental threats. For this purpose the world community has conducted a series of actions towards establishment of an international biosphere reserve in the lower reachers of Tumen River (*Figure 5*) (*Kachur 2007, UNDP 2004*).

To protect the unique ecosystems of Northern Asia and America it is planned to organize an international park under the tentative name Beringia that will include the eastern part of Chukotsky Peninsula (*Figure 6*) and the northwestern part of Seward Peninsula in Alaska (*Baklanov et al. 2000, Zheleznov 1995, 1999*). The park is based on the unity of ecosystem, its genesis, historical similarity in exploration, and uniqueness of ethnic relations and culture of people inhabiting Chukotka and Alaska.

The northern part of the Pacific Ocean is an unique ecosystem of global value with a varied biodiversity of animal species including large sea mammals. Closer to the Bering Strait, the biodiversity and density of marine animals increases slightly because of the narrowing of the strait and the changing marine ecological conditions. During the last decade the habitat, number, and density of terrestrial vertebrate animals that reside along these coasts drastically decreased.

Considering the social specifics of the population inhabiting the park area and the specifics of their economy, the preservation of the traditional forms of nature use and subsistence and the preservation of the lifestyle of Beringia Native peoples becomes one of the park's most important functions and, perhaps its main goal.

In the conclusion, it is necessary to note that the main positive aspects in establishing transboundary protected natural areas that give them advantage over national specially protected natural areas are the following:

- Expansion of the total reserve area, due to merging of separate national SPNA, results in weakening of the "island effect" – greater and more vital populations become protected, and conditions for animal migrations improve.
- By merging several SPNA stability of an ecosystem increases, life expectancy of organisms grows, and the protection regime becomes more effective.
- The process of animal reintroduction becomes simpler.
- The greater area, especially in the case of large predators, strengthens the control over the numbers of animals that endanger the preservation of an ecosystem.
- The control over spreading of pathogenic and parasitic organisms and occurrence of hotbeds of diseases becomes easier.
- International cooperation in science allows standardizing research methods, sharing of expensive equipment and excluding techniques of data gathering that lead to difficulties in subsequent analysis and comparison of results.
- The international natural reserve territories can join their efforts in rescues and in fighting fires, poaching, and illicit trade.
- There are advantages in the joint development of tourism, ecological education, and dissemination of information.
- The image of the international units is higher, and it is easier to receive the status of biosphere reserve or an area of world significance.

At the same time, the process of establishing and operating a TSPNA also has a number of the significant problems, which makes the work more complex than that of a national SPNA:

- There are differences in legislation, religious and cultural practices of peoples, languages, and attitudes towards nature (for example towards pests or introduced species).
- There is the potential to have an unequal partnership – political, financial distinctions, different professional

Photograph courtesy of Vladimir Zhuravkov

Figure 7. This road from Provedeniya leads to Novoe Chaplino in Chukotka, Russia, an area of exceptional scenic, natural and cultural importance. Residents of several smaller coastal villages were resettled here during the Soviet era (including Kivak (see Orekhov, this issue) and some also compete in the annual dog race *Nadezhda* (see cover). More information about this and other areas of the Nature-ethnic Park "Beringia" is available at: http://www.beringiapark.ru/indexen.php

level of the personnel, different rights of the units within their countries, etc.

- Sometimes the partners have different goals – one aspires to develop tourism and the other strives for strict protection.
- There is the potential for poor communication between the preserves and difficulties in crossing the borders.
- The unequal value or absences of the scientific personnel on staff have a negative influence on scientific cooperation.

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The Lost Fleets of the Western Arctic: Preserving a Significant Element of the Maritime and Cultural Heritage of Alaska and the United States

By Bradley W. Barr

Abstract

In 1848, Yankee whalers first entered the Chukchi Sea. The ensuing 66 years of commercial whaling in the western Arctic had a profound impact on the history and culture of the Beringia region, its resources, and its people. In this period, more than 160 whaling ships were lost. The stories from these journies are compelling, filled with tales of danger, heroism, sacrifice, and loss so common in arctic adventures, and of great interest to a broad audience of the American public. These are highlighted by: the exploits of the Confederate Sea Raider *Shenandoah*, seizing 24 and burning 22 whalers in the Bering Strait, months after the Civil War had been lost; the 32 whalers sunk by the ice and more than 1,200 crew stranded in the disaster of 1871, where all survived; the dozen whaling ships lost in the same location five years later, with more dire consequences; and the events of 1897-98 that compelled the U.S. Government to drive more than 400 reindeer over 700 miles through the deep arctic winter in an attempt to bring food to whaling crews stranded in Barrow. Few if any of these shipwrecks of the "Lost Fleets" of the western Arctic have even been discovered, despite a rather richly documented history. The NOAA Office of National Marine Sanctuaries has initiated a project to search for and document what remains of the "Lost Fleets". The re-telling of these stories is intended to not only engage and inform the public about this very significant place and time in the maritime history of the nation, but also of the people and cultures of the Beringia region whose lives we so profoundly changed by these events.

Introduction

During the latter half of the nineteenth and into the twentieth centuries, whaling fleets from a variety of nations concentrated their efforts far to the North, among the bergs and ice pack of Alaska's north slope. This was one of the last refuges of the oil-rich bowhead whale. The harsh extremes found in the Arctic made the hunt particularly hazardous, and on two occasions, 1871 and 1876, whole fleets were trapped by the ice and crushed. These losses marked the downfall of the American whaling effort, already in decline due to the impacts on marine mammal populations and the American Civil War (*Bockstoce 1986*).

From Captain Thomas Roys first passage through the Bering Strait in 1848, in the whaling bark *Superior*, until the last whales were taken by the commercial whaling fleet around 1914, the western Arctic was one of the most important places in American whaling. This intense human activity in the region changed the face of the Arctic both ecologically and culturally (*Bocktose 1986*).

According to Chaffin (*2006*), between October 1864 and November of 1865, during a desperate campaign to strike a blow to the economy of the North, the Confederate sea raider *Shenandoah* seized a total of 38 ships of commerce, and burned 32 to the waterline. Prowling the western Arctic, over a period of less than a week in late June of 1865, the *Shenandoah* captured 24 whaling ships and sunk 20 in the waters near the Bering Strait. The *Shenandoah*'s captain, James Waddell, and his officers did not believe reports from the vessels they were destroying that the war had already ended, some three months earlier. All ships' personnel from these captured vessels, numbering over 1,000 according to the ship's records, were released unharmed, and only two of the crew of the *Shenandoah* lost their lives during the epic voyage. The total loss to the whaling industry was estimated at $1.4 million ($19.7 million in 2000 dollars).

Photograph courtesy of Robert Schwemmer

Figure 1. Shipwreck timbers.

Figure 2. A) Abandoning the barks 'George,' 'Gayhead,' and 'Concordia' in the ice off Point Belcher; B) Barks 'Arctic' and 'Progress' receiving the crews of the wrecked and abandoned ships south of Icy Cape; and C) The barks at Icy Cape - the boats effecting a landing.

As chronicled by Bockstoce (*1986*), in August 1871, 32 whaling ships from Hawaii, New England, and California had come to the icy waters of the Arctic in the pursuit of the bowhead whale. The pack ice being close to shore that year left little room for maneuvering of the fleet but whales were relatively plentiful, and while there are whales to catch, the whaleboats go off to hunt. The whaling captains counted on a wind shift from the east to drive the pack out to sea as it had always done in years past. Instead of moving offshore, the ice pack suddenly and unexpectedly trapped all 32 ships between ice and shore in a constantly and quickly diminishing lead in the ice with no chance to escape to open water. The captains conferred, crafted a joint declaration describing the reasons for the abandonment, unanimously approved and signed the declaration, then began the very treacherous process to evacuate all 1,219 men, women and children by way of the ships' whaleboats. In these frail craft, the ships' crews rowed 90 miles south past Icy Cape where they were rescued by seven other whaling ships whose captains and crews gave up what was likely to be their own very lucrative whaling season to ferry the survivors to safety. Although the journey in the whaleboats required them to row through ice-choked and heavy seas, not one life was lost. Of all the ships abandoned to the Arctic winter of 1871, only one ever sailed again. The remaining 31 vessels were crushed by the ice and sunk or burned after they were abandoned. The economic blow to the whaling industry was staggering. Loss of the ships and cargoes was estimated at $1.6 million ($22.5 million in 2000 dollars). This loss was most keenly felt in New Bedford, which was home port for 22 of the ships lost that year. Interestingly, however, few of these ships were replaced in the fleet, and most of the insurance paid to the whaling companies was reportedly invested in other industries, evidence of the beginning of the end of Yankee whaling.

These are compelling and historically significant stories from our whaling heritage, and there has been a recent surge of interest in these events. A number of historical volumes have been published in the popular press over the last few years. While interest in these events continues, much research remains to be done. The prizes left in the wake of the *Shenandoah*, the subsequent losses of 1871 and 1876, combined with other whalers abandoned and sunk by ice and gale in this region, left a legacy of shipwrecks and artifacts scattered throughout the Bering Strait and along the shore and nearshore waters of the Chukchi and Beaufort Seas. Over the past several years, researchers associated with the Barrow Arctic Science Consortium have been conducting an archaeological and historical survey of some of these coastal and submerged sites related to the 1871 event in the Chukchi Sea (*Beebe 2007*). Regarding the prizes sunk by the *Shenandoah*, very little field work has been undertaken thus far. Of what has been reported to be more than 160 whaling ships lost in these waters of the western Arctic, none, except those that were beached, have been identified and documented. This is a story of our whaling heritage without a final chapter…what remains of these lost fleets and what we can learn from these artifacts.

Discussion

As mandated in the National Marine Sanctuary Act, NOAA's Office of National Marine Sanctuaries (ONMS) is responsible for effective stewardship of America's maritime heritage resources. Working in collaboration with the State of Alaska Office of History and Archaeology and others, the ONMS Maritime Heritage Program is bringing additional resources and assets to support this fascinating and important work. Maritime archaeologists and historians employed by NOAA are already involved in whaling heritage survey and preservation efforts across the nation. For NOAA, the "Lost Whaling Fleets" of the western Arctic represent a partnership project in the context of our larger national whaling narrative. As regards to the 1871 and 1876 disasters, NOAA seeks to work in collaboration with local researchers in Alaska, bringing new platforms and advanced underwater technologies to the ongoing investigation. Ships conducting offshore magnetometer and side scan sonar surveys, and aerial Light Detection and Ranging (LIDAR) flights will provide essential information on what remains of these lost whaling vessels. Also, NOAA will help interpret and communicate these events to a national audience, bringing the considerable experience and expertise of the NOAA National Marine Sanctuary education, outreach and communication staff with web-based education and outreach, video production and telepresence to help tell the story.

As to the brightly-burning American whaling vessels the *Shenandoah* left in its wake, background research is being conducted, potential partners being identified, and preliminary planning for what field surveys might be undertaken in coming years—perhaps linked to the upcoming Sesquicentennial of the Civil War—is in the very early stages of development. This research continues and expands NOAA's long involvement with Civil War history and heritage at the Monitor National Marine Sanctuary.

Conclusion

Through this work in some of the most remote places on Earth, the NOAA's Marine Sanctuary Program will tie together places emblematic of our whaling heritage—New Bedford, Nantucket, Hawaii and California—through national marine sanctuaries associated with these stories from our whaling past. NOAA will weave together these compelling accounts of the icebound whaling fleets of the 1870s and the epic story of the *Shenandoah* with what is learned from field research conducted by NOAA and its partners to enhance and expand the American public's understanding and appreciation of this historically significant chapter in America's maritime history.

Placed in the larger national context of beginning to develop a national system of marine protected areas focused on maritime heritage, part of the ongoing work of the joint NOAA/DOI Marine Protected Areas Center, it will be initiatives like "Lost Fleets" that will be needed to help define and construct this mandated national system of marine protected areas. By confronting questions such as what the criteria might be for sites comprising the maritime heritage element of the national system, and how places like the western Arctic might fit in that system, we help to move toward the sort of robust and comprehensive national MPA system envisioned by the framers of the Executive Order that created the Center and the vision for this national system.

Acknowledgements

Mike Overfield, Bob Schwemmer, Hans Van Tilburg of the ONMS Staff comprise, with the author, the core team behind the Lost Fleets Project at NOAA. For additional information regarding the Lost Fleets Project, go to http://sanctuaries.noaa.gov

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Teshekpuk Caribou Herd Movement through Narrow Corridors around Teshekpuk Lake, Alaska

By Dave Yokel, Alex Prichard, Geoff Carroll, Lincoln Parrett, Brian Person, and Caryn Rea.

Abstract

We used 17 years of satellite and GPS collar location data from the Teshekpuk Caribou Herd in northern Alaska to investigate use of two narrow land areas constricting caribou movement around Teshekpuk Lake. In the future, oil pipelines may be built in either area. We need pre-development data to mitigate impacts of pipelines on caribou movement. Caribou used the areas most during early July, when more than 73% of collared caribou entered the areas. During July, caribou movements were more rapid within the constricted zones than outside.

Photograph courtesy of authors

Figure 1. Author Lincoln Parrett restrains a female caribou while her calf looks on.

Introduction

Caribou (*Rangifer tarandus*) of the Teshekpuk Caribou Herd (TCH) calve near Teshekpuk Lake in northern Alaska (*Carroll et al. 2005, Parrett 2007, Person et al. 2007*). On the northwestern and eastern sides of the lake are narrow strips of land extending from the lake 7 mi (11 km) to the Smith Bay and 8 mi (13 km) to the Kogru River, respectively (hereafter the Smith and Kogru areas). These create constricted zones through which caribou must pass to access the area north of Teshekpuk Lake (*Figure 2*). On warm, summer days, mosquito harassment of TCH caribou can be severe; however, the area north of the lake has reduced mosquito activity, for the Beaufort Sea generally keeps temperatures lower and wind-speeds higher than in areas farther inland (*Parrett 2007*). The two constricted zones are heavily used by caribou during midsummer for travel to and from mosquito-relief habitat north of the lake (*Person et al. 2007*).

As early as 2018, the Bureau of Land Management (BLM) may hold oil and gas lease sales for the area north of Teshekpuk Lake (*USDOI BLM 2008*). Any subsequent development would include pipelines through the constricted zones; pipelines have the potential to impede or deflect caribou movements (*Lawhead et al. 2006*). If caribou cannot achieve an optimal spatial and temporal pattern of insect avoidance and foraging, the negative impact on caribou energy balance could lower survival or productivity (*Murphy and Lawhead 2000*). Baseline data on patterns of constricted zone use by caribou will be crucial for mitigating impacts through pipeline design, and testing the efficacy of mitigations following development.

Methods

Satellite Collars

We analyzed telemetry data to better understand caribou distributions and movements near Teshekpuk Lake. Over 17 years (July 1990 through August 2007), we outfitted 102 caribou (81 females, 21 males) with satellite collars (*Figure 1*). Although satellite-telemetry locations are considered accurate to within 0.3-0.6 mi (0.5-1 km), the data also require screening (*Prichard and Murphy 2004*) to remove spurious locations, e.g. duplicates, locations obtained after caribou mortality, and those for which location quality scores indicated unreliability. We also removed locations that appeared incorrect because they were far from others or were offshore.

To determine the proportion of satellite collared caribou using the constricted zones and the area north of Teshekpuk Lake, we analyzed locations to assess which caribou movements crossed each constricted zone and recorded the direction of movement (north-to-south or south-to-north). We did this for each half-month time period (e.g., 1-15 January, 16-31 January). We included only animals with six or more locations per time period to ensure we had a good record of an animal's movement for that period.

GPS Collars

In recent years, we fitted some TCH caribou with geospatial positioning system (GPS) collars, which provide more frequent locations with increased accuracy. We deployed GPS collars on 10 female caribou in July 2004, and 12 in July 2006. GPS collars remained on for one year. They recorded locations every three hours in 2004-2005 and every two hours in 2006-2007.

These data were screened and filtered as were satellite collar data. We analyzed movements of the 22 female caribou to determine how often they traveled through the two constricted zones. The high spatial and temporal resolution of these data provided relatively accurate estimates of movement paths.

We divided distance between consecutive locations by time to calculate movement rates. We also calculated the average movement rate while caribou were in constricted zones. Because movement rates are sensitive to time between locations (fix-interval), we analyzed changes in movement rate estimates with changing fix-interval. Based on the results, we increased rates estimated from three-hour fix-intervals by 5.6% to approximate rates from two-hour fix-intervals.

Weather Data

Parrett (*2007*) collected temperatures and wind speeds at two locations during summer 2004 (*Figure 2*). One was located 9 mi (15 km) south of Teshekpuk Lake and one on the Beaufort Sea coast north of Teshekpuk Lake. We obtained additional data from Barrow.

Results

Satellite Collars

The proportion of satellite-collared caribou in the area north of Teshekpuk Lake peaked at 73% during early July (*Figure 3*). This proportion dropped sharply during other periods to nearly zero in winter. The proportion of caribou in the Kogru Area was higher than in the Smith Area. A similar pattern was observed for GPS-collared caribou traversing across constricted zones. An

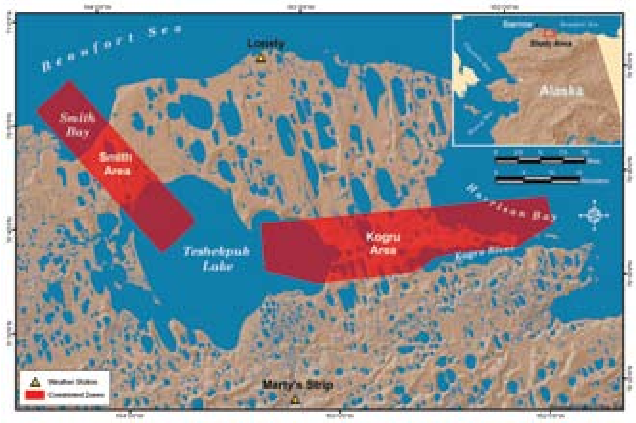

Figure 2. The locations of constricted zones around Teshekpuk Lake, Alaska, and two weather stations recording temperature and wind-speed during summer, 2004.

estimated 38% and 50% crossed the Smith and Kogru areas, respectively, during early July. More moved north than south across the Smith Area, whereas the opposite occurred in the Kogru Area. The proportion of satellite-collared caribou moving across the constricted zones varied widely among years, ranging from 14-83% and 17-77% for the Smith and Kogru areas, respectively.

GPS Collars

GPS-collared caribou frequently used the two constricted zones during mid-summer, especially during 2004 (*Figure 4*). In July 2004, eight of 10 GPS-collared caribou made a circular movement around Teshekpuk Lake, moving south through the Kogru Area during 6–8 July, north through the Smith Area during 20–22 July, and south again through the Kogru Area on 27 July.

The apparent reasons for these movement patterns were supported by weather observations (*Figure 5*). Lonely was generally cooler than Marty's Strip. High temperatures (as seen for Barrow) occurred during the first days of July, and caribou moved north of Teshekpuk Lake where GPS collaring took place. It was cooler July 6-8 when eight of 10 GPS-collared caribou moved south through the Kogru Area, and generally remained cooler and windier until July 20. Then a period of warm weather and less wind followed during 21–26 July, and the eight returned north of the lake. After temperatures dropped and wind speed increased on 27 July, all 10 caribou moved south.

In 2006, five of 12 caribou traveled north and three south through the Kogru Area, and three traveled north and four south through the Smith Area. Only two caribou used the corridors in August and none between September 2006 and May 2007. Only two caribou moved through the corridors in June 2007.

Caribou moved fastest in July and slowest in June (*Figure 6*). They generally moved slower north of Teshekpuk Lake than in either constricted zone. In 2004, movement rates were slower north of Teshekpuk Lake than in the Kogru or Smith area, but there was no significant difference between the latter two. In 2006, movement rates were higher in the Smith Area than north of Teshekpuk Lake or in the Kogru Area, with no significant difference between the Kogru and north areas.

Discussion

As previously reported (*Person et al. 2007*), the constricted zones around Teshekpuk Lake are important movement corridors for caribou moving north of Teshekpuk Lake for insect relief. Satellite collar data show these areas may be used throughout the year (*Prichard and Murphy 2004*), but most movement across the constricted zones occurs in July. These patterns were generally known from field observations prior to the use of satellite collars (*Davis and Valkenburg 1979, Silva et al. 1985*), but our data quantify both use and variation among years.

Both satellite and GPS collar data show a tendency for TCH caribou to move in a clockwise pattern around the lake, although caribou do move both directions through both corridors. Temperature and wind speed may explain the timing of movements to the north of Teshekpuk Lake, and wind may also influence this clockwise pattern. We hypothesize that during low insect activity, caribou tend to move with the prevailing northeasterly winds as

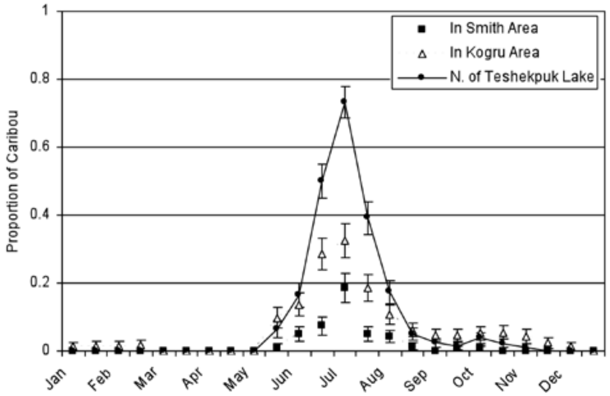

Figure 3. The mean proportion (+/- 1 standard error) of satellite-collared caribou with at least one location in the constricted zones or north of Teshekpuk Lake, during each 2-week time period, 1990-2007.

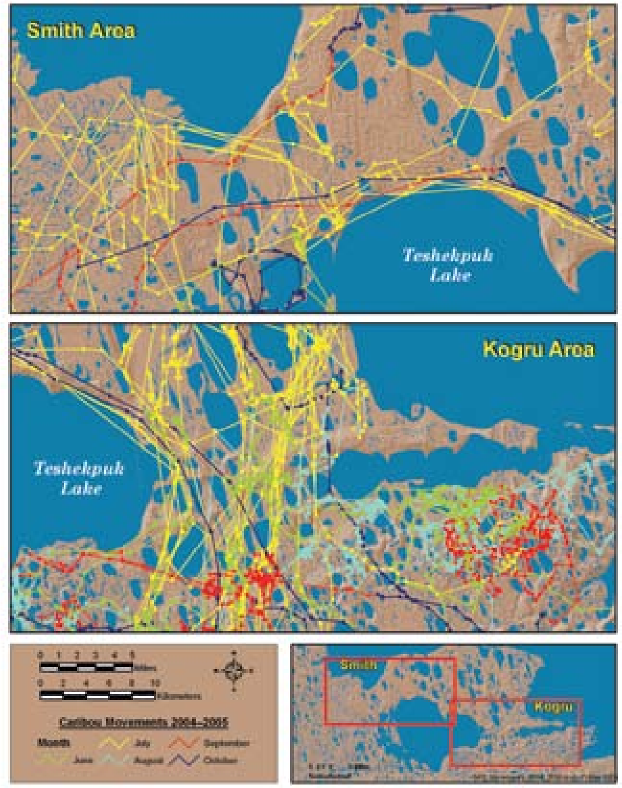

Figure 4. The locations (dots) and estimated movement paths (line segments) of 10 GPS-collared caribou (fix interval of 3 h) around constricted zones near Teshekpuk Lake, Alaska, July 2004-June 2005.

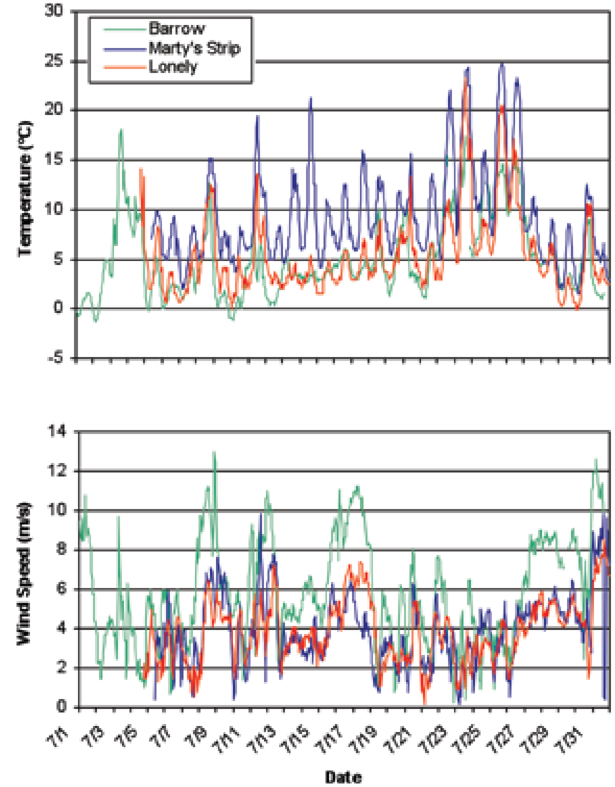

Figure 5. Temperatures (°C) and wind-speeds (m/s) at Barrow, Lonely and Marty's Strip, Alaska, during July 2004.

they forage and head away from insect relief areas. When insects increase, caribou return to relief areas heading upwind. Headwinds decrease insect harassment during the return trip to insect relief areas.

GPS collar data best describe specific movement paths and rates of movement. Observed variation in movement rates is consistent with use of the area north of Teshekpuk Lake for insect relief. Movement rates are fastest during July, when mosquito activity is greatest. During July, movements are slower north of the lake, where mosquito activity is lower, than inland where greater mosquito harassment occurs.

Management Implications

The BLM has acknowledged the importance of the two constricted zones to the TCH (*USDOI BLM 2008*) by allowing only pipelines, not roads, within them. Traffic on nearby roads is the most important factor affecting pipeline crossing success by caribou (*Lawhead et al. 2006*). Our GPS collar data suggest that caribou do not consistently favor specific paths through the constricted zones, so there may not be a "best" pipeline route. However, these results are based on a relatively small sample of 22 caribou, and our larger, satellite collar dataset displays variability among years but longer-term trends. We require additional years of GPS data collection to discern any real trends in caribou routes.

Acknowledgements

Many biologists, pilots and students have helped with collaring operations, and several from the authors' agencies or corporations have contributed to project planning and implementation, funding, and data analysis. An attempt to name all would likely result in omissions, but we express our gratitude.

		North of Teshekpuk Lake		Kogru Area		Smith Area	
Year	Month	Average	*n*	Average	*n*	Average	*n*
2004	July	0.70	612	1.45	123	1.16	57
	August	0.52	25	0.40	56	-	-
2005	June	0.17	3	0.21	164	1.14	1
2006	July	0.88	430	1.02	169	1.63	38
	August	0.60	58	0.75	17	-	-
2007	June	0.18	218	0.43	52	-	-

Figure 6. Movement rates (km/h) of GPS-collared caribou north of Teshekpuk Lake and in constricted zones on either side of Teshekpuk Lake, 2004-2007. Sample size (n) is number of movement segments, i.e. pairs of consecutive locations.

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Fire in the range of the Western Arctic Caribou Herd

By Kyle Joly, T. Scott Rupp, Randi R. Jandt, and F. Stuart Chapin, III

Abstract

Wildfire is the dominant ecological driver in boreal forest ecosystems. Although much less is known, it also affects tundra ecosystems. Fires effectively consume fruticose lichens, the primary winter forage for caribou, in both boreal and tundra ecosystems. We summarize 1950-2007 fire regime data for northwestern Alaska and subregions. We also identified meteorological factors that help explain the variability in fire extent across this landscape. We review information and inferences from recent studies on tundra fire regimes for managing caribou winter range. Climate warming may increase fire size and frequency in this region, which may substantially impact the vegetation, wildlife, and people of this region.

Introduction

Although much attention has been focused on the role of wildfire in boreal forest ecosystems, its role in tundra ecosystems has largely been overlooked (*but see Miller 1985, Racine et al. 1985*). Wildfires effectively consume ground-dwelling lichens that are the primary winter forage for Western Arctic Herd (WAH) caribou. These lichens can take decades to recover to pre-fire levels in northwestern Alaska (*Jandt et al. 2008*). Wildfires potentially limit caribou winter range by destroying preferred forage (*Rupp et al. 2006*). The WAH has undergone a population expansion starting in 1976 until reaching a high of 490,000 caribou in 2003 (*Dau 2005*). The herd has expanded and shifted its primary winter range to the Nulato Hills and the Seward Peninsula from its historic winter range in the Buckland Valley and Selawik National Wildlife Refuge (*Figure 2*). Both density dependent (i.e., increasing herd size leading to reduced lichen biomass) and density-independent (i.e., increasing area burned by wildfires leading to less mature habitat) may factor into the changes in winter range distribution exhibited by the WAH.

Temperatures, in Alaska, including northwestern Alaska, have been rising and the rate of climate warming is predicted to increase (*Stafford et al. 2000, ACIA 2005*). Summer precipitation has decreased at many locations throughout Alaska, and Barrow has seen declines in annual precipitation as well (*Stafford et al. 2000*). Warmer and drier summers are associated with greater area burned in Alaska (*Duffy et al. 2005*). In the tundra ecosystem, wildfires are also predicted to increase (*Higuera et al. 2008*). Regional temperature and precipitation are correlated with large scale climatic regimes, such as the Pacific Decadal Oscillation (PDO) (*Hartmann and Wendler 2005*). Our goals were to 1) elucidate the fire regime in northwestern Alaska and in tundra ecosystems, 2) test whether wildfires are increasing in extent and frequency in the range of the WAH and 3) identify meteorological variables that correlate with annual area burned.

Methods

We summarized the data contained in the Alaska Fire Service's geodatabase, which catalogs the extent, number and location of large fires mapped from 1950-2007 (*Figure 3; data at http://agdc.usgs.gov/data/fire/index.html*). Kasischke et al. (*2002*) performed similar analyses for Interior Alaska, but we calculated them for northwestern Alaska and various subsets including the WAH core winter range, outer range, and potential future winter range - defined as a 30-mile (50-km) wide buffer around the outer range (*Figure 2A*). We also summarized burn area by conservation unit, ecoregion, tundra ecosystem, boreal forest ecosystem and also the area north of the 68th latitude (*Figures 2 and 3*). Tundra ecosystems were differentiated from forested areas using the 33-yard (30-m) National Land Cover Database − Alaska 2001 coverage (http://www.epa.gov/mrlc/nlcd-2001.html).

For all of these areas, we also calculated the percentage of burned area that burned two or more times during the 58-year study period. Similarly, we calculated the fire cycle (i.e., the number of years required to burn over an area) (*Kasischke et al. 2002*) for these areas. We calculated this by dividing 1 by the proportion of area burned and multi-

Figure 1. Grazing caribou.

plied the dividend by the duration of the study period (58 years). We used linear regression to test whether annual area burned and number of wildfires were increasing over time and for correlation among variables. We used average monthly temperature and total monthly precipitation data (Western Region Climate Center, http://www.wrcc.dri.edu/summary/climsmak.html) from 1950-2005 to develop climatic models to explain the variance in the amount of area that burned annually. Sets of station averages were compared to find the grouping that provided the most predictive power. We also transformed these data, by exponentiation, and included measures of the strength (average of January and February as per *Duffy et al. 2005*) of the PDO (University Of Washington, http://jisao.washington.edu/pdo/PDO.latest) to develop alternative models. The best models were chosen based on predictive ability and parsimoniousness using Akaike's Information Criterion (AICc).

Results

More than 10.5 million acres (4.3 million hectares) burned in northwestern Alaska between 1950 and 2007, covering approximately 10.9% of the region. Of these burned acres, 7.9% have re-burned during this time period. We determined the fire cycle for the region to be 535 years. The range of the WAH covers this entire region, excluding the western most extremes of the Seward Peninsula. The percent area burned and re-burned, and fire cycle for other portions of the WAH's range, conservations units, and ecoregions are shown in Figure 4. Ecoregion fire cycles were similar to those reported by Kasischke et al. (*2002*). North of 68° latitude, only 1.1% of the area had burned with no re-burning at all. More than half of the burned area was attributed to the 2007 Anaktuvuk River fire. In the boreal forest ecosystem, 24.1% had burned but only 1.5% of those burned areas had re-burned during the past 58 years. The fire cycle for forested areas was 240 years. Burns only covered 9.2% of the tundra ecosystem, but 7.0% of that area had re-burned in the past 58 years. The fire cycle for tundra areas was 630 years.

The average of the seven weather stations (Bettles, Big Delta, Fairbanks, McGrath, Nome, Northway and Tanana) that Duffy et al. (*2005*) used to model area burned in Interior Alaska provided the most explanatory power versus various subsets or the inclusion of the Barrow and Kotzebue station data. Average June and July temperatures have increased over time in northwestern Alaska (*Figure 5;* $F_{1,55} = 18.67$, $P = 0.001$, $F_{1,55} = 10.99$, $P = 0.002$), though average August temperature and precipitation from June through August did not show a significant relationship. The average August temperature for Barrow, Kotzebue and Nome was 46.7°F (8.2°C) +/- 2.6°F (1.4°C).

There was no significant relationship with time and area burned (i.e., there was no evidence that burned area is increasing over time; $F_{1,57} = 0.61$, $P = 0.439$). However, when we omitted years with more than 200,000 acres (81,000 hectares) burned, the amount of burned area did

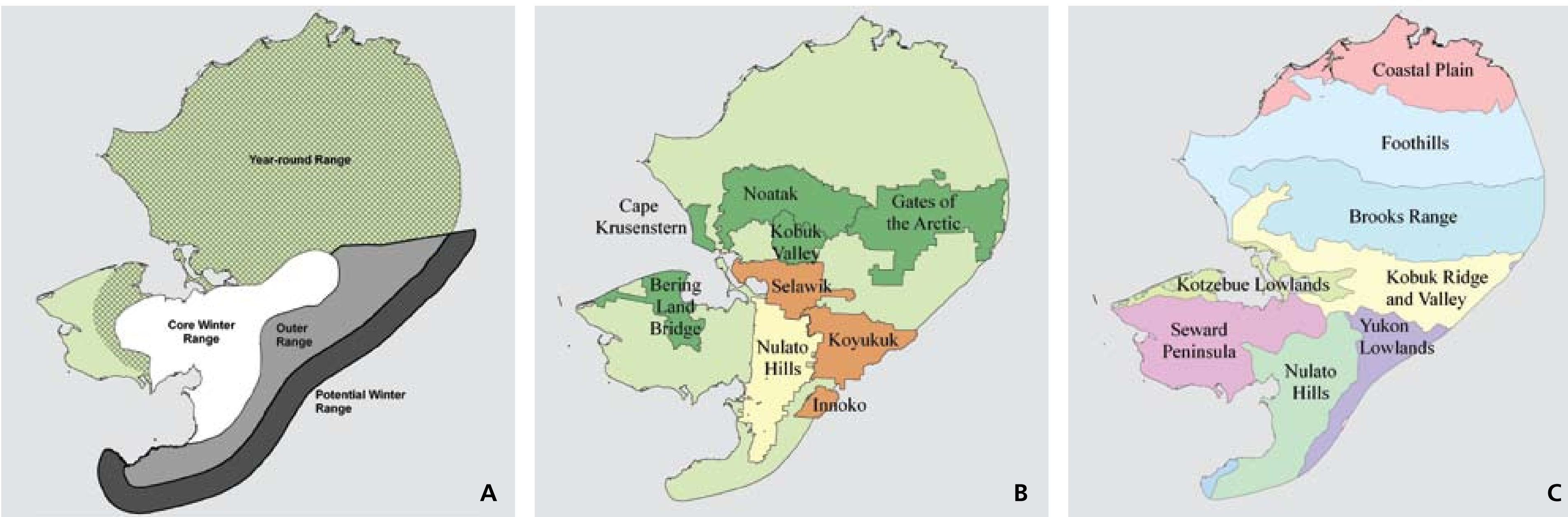

Figure 2. Study Area. A) Range of the Western Arctic Herd caribou. B) Conservation system units of northwestern Alaska: dark green, brown, and pale yellow are managed by NPS, USFWS, and BLM respectively. C) Ecoregions of northwestern Alaska.

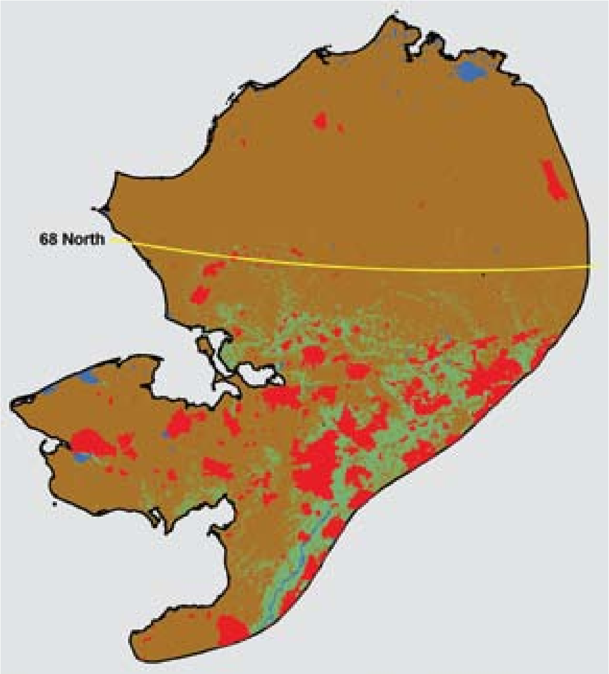

Figure 3. Wildfires on the landscape of northwestern Alaska, 1950-2007. Red polygons are burned areas, brown areas are dominated by tundra (non-forested) habitats, green is boreal forest ecosystems and blue depicts water.

Region	% Area Burned	% Area Re-burned	Fire Cycle (years)
Caribou			
Core winter range	19.6	8.7	296
Outer range	34.9	6.8	166
Potential winter range	42.8	13.2	136
Conservation Units			
Cape Krusenstern (NPS)	0.1	0.0	53349
Gates of the Arctic (NPS)	2.7	5.0	2173
Noatak (NPS)	4.7	5.2	1237
Bering Land Bridge (NPS)	4.9	0.0	1188
Kobuk Valley (NPS)	6.9	3.5	844
Nulato Hills (BLM)	19.9	1.3	292
Selawik (FWS)	28.0	15.7	207
Koyukuk (FWS)	45.1	11.0	129
Innoko (FWS)	57.6	12.7	101
Ecoregions			
Coastal Plain	0.0	0.0	n/a
Brooks Range	1.0	3.3	5917
Foothills	1.7	0.0	3467
Kotzebue Lowlands	6.8	2.9	859
Seward Peninsula	13.9	15.1	418
Nulato Hills	20.5	2.0	283
Kobuk Ridge and Valley	30.0	8.6	193
Yukon Lowlands	42.2	10.0	137

Figure 4. Percent area burned and re-burned from 1950-2007 and fire cycle for various regions within northwest Alaska.

increase over time ($F_{1,42} = 9.95$, $P = 0.003$). There were 15 years where the annual burn area was greater than 200,000 acres (81,000 hectares) and they were clustered into 4 groups – each group contained three to five years of high burn area, spanned four to nine years and were temporally separated by an average of 16.3 years (sd = 0.72). All but 1 (i.e., 14 of 15) of these high fire years were associated with average August temperatures exceeding 53°F (11.7°C). The exception occurred in 1969, which had the lowest June precipitation on record – well less than half the normal for the month. Although burned area was more than double in years with average August temperatures > 53°F (11.7°C), 226,000 versus 96,000 acres (91,000 versus 39,000 hectares), the difference was not statistically significant ($P > 0.1$).

The number of wildfires in northwestern Alaska and in the tundra ecosystem significantly increased from 1950 to 2007 ($F_{1,57} = 11.50$, $P = 0.001$, $F_{1,57} = 11.40$, $P = 0.001$, respectively). These trends disappeared when the analysis was limited to 1988-2007 ($F_{1,18} = 0.73$, $P = 0.404$, $F_{1,18} = 0.72$, $P = 0.406$, respectively). Dry weather in August was significantly associated with high August temperatures ($F_{1,55} = 7.42$, $P = 0.009$). A 6-factor (June-September precipitation and July-August temperature) model explained the most variation, approximately 31%, in annual burn area in northwestern Alaska. Explanatory power was increased when non-linear factors were added; a 5-factor model (June and August precipitation, exponential of June precipitation, exponential of August temperature and PDO) explained 55% of the variance in annual burned area. This model plus the exponential of June temperature explained 67% of the variance of average annual burned area within tundra ecosystems. The single factor of the exponential of August temperature explained 28% of the variance in burned area for northwestern Alaska and 47% for tundra fires in this region. For more on models, see Figure 6.

Discussion and Conclusions

We found that wildfire is a common occurrence in

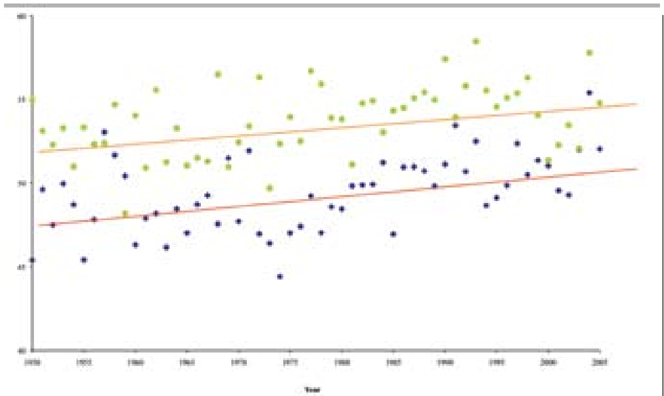

Figure 5. Significant increases in average June (blue diamonds) and July (green circles) temperatures from 1950-2005 in northwestern Alaska. Corresponding regression lines are depicted in red (lower line) and orange (upper line). Temperatures represent an average for the Barrow, Bettles, Kotzebue, McGrath, Nome and Tanana weather stations.

northwestern Alaska, in the range of the WAH and in tundra ecosystems. Burn acreage tended to decrease with latitude and longitude as, historically, fires have been rare events north of the Brooks Range and in maritime climates. Nearly 20% of the WAH core winter range has burned during the past 58 years. With current high population densities and declining lichen cover, the herd may seek out additional winter ranges (*Joly et al. 2007b*). We found that the WAH's outer range has burned even more extensively than its core winter range. Potential future winter range, further to the east, was one of the most extensively burned areas in the region and also appeared to have one of the highest incidences of re-burning - likely because it is in the warmer and drier continental Interior climate zone. We believe this level of burning may prove to be an impediment for the herd to expand its winter range possibilities as extensive, mature lichen mats are unlikely to be found in these areas.

The extent of burned area within Selawik National Wildlife Refuge (28%) came as a surprise, as well as the fact that this area had the highest percentage of re-burned area of any sub-region within northwestern Alaska. These facts may help explain why the herd has largely abandoned its historic winter range in the refuge, though density-dependant factors are likely to have also played an important role. The Seward Peninsula ecoregion had the second highest re-burn percentage, but is still utilized by the herd (*Joly et al. 2007a*). One possible reason for the continued use of this region as winter range is that it contains > 4 times more area that has not burned in the past 58 years than the Selawik. Re-burn estimates need to be cautiously interpreted, however, as fire perimeters in the AFS database do not account for unburned inclusions and in earlier years were often based on rough maps produced by firefighting crews.

As we expected, wildfire affected a greater percentage (~ 25%) of forested areas than tundra areas (< 10%) in northwestern Alaska during the past 58 years. We found that burned tundra was 4.5 times more likely to re-burn than burned forest during our 58-year study period. This finding is intuitive because grasses and sedges that dominate tundra ecosystems recover very quickly (*Jandt et al. 2008*), and produce an important surface fuel (dead leaf litter) to carry new fires. Conversely, surface fuel loads (dominated by feather mosses) in the boreal forest can take decades to return (*Kasischke and Stocks 2000*, *Camp et al. 2007*). The fire cycle for tundra areas was more than 2.5 times longer than for forested areas. We did not find any examples of forested areas being re-burned more than once, while we found 11 cases in the tundra where a patch had re-burned more than once and one location on the central Seward Peninsula was mapped as burned in 1971, 1990, 1997 and 2002.

Using the large fire database, we were unable to detect a trend of increased annual burn area over time. This may be because climate warming is not yet strong enough to impact northwestern Alaska's fire regime or is intertwined with other factors that may suppress wildfires. However, when we omitted large fire seasons, we found a strong increasing trend (*Figure 7*). This may be explained in at least two ways. First, changes in the accuracy of fire maps and in fire suppression capability and management over the period of record may affect apparent burn acreage trends. Alternatively, climate warming may indeed be increasing annual area burned, but some other factor may induce pulses of large fire seasons that mask this overall trend when included in the regression analysis. The number of wild and tundra fires in northwestern Alaska appear to have significantly increased during the past 58 years. This, however, may also be an artifact of the fact that fires less than 1,000 acres (405 hectares) were not regularly mapped prior to 1988. We did not find evidence that the number of wild and tundra fires have increased since 1988 – a time period when all of these factors should be equivalent in the database. Increases in both the area burned and number of fires in the boreal forest

A. All of northwest Alaska

Model Variables	△	Adj.
June and August precipitation, exp August temperature, exp June precipitation, PDO	0.00	0.547
June precipitation, exp August temperature, exp June precipitation, PDO	0.40	0.532
exp August temperature	20.12	0.284

B. Tundra

Model Variables	△	Adj.
June and August precipitation, exp June and August temperature, exp June precipitation, PDO	0.00	0.667
June precipitation, exp June and August temperature, exp June precipitation, PDO	0.16	0.656
June precipitation, exp August temperature, exp June precipitation, PDO	0.47	0.645
exp August temperature	19.10	0.467

Figure 6. Models for explaining the annual amount of area burned for (A) all of northwestern Alaska and (B) just for tundra (non-forested) ecosystems in northwestern Alaska, 1950-2005. The term "exp" means the exponential of that variable was used. The term "PDO" is the average of the January and February values of the strength of the Pacific Decadal Oscillation.

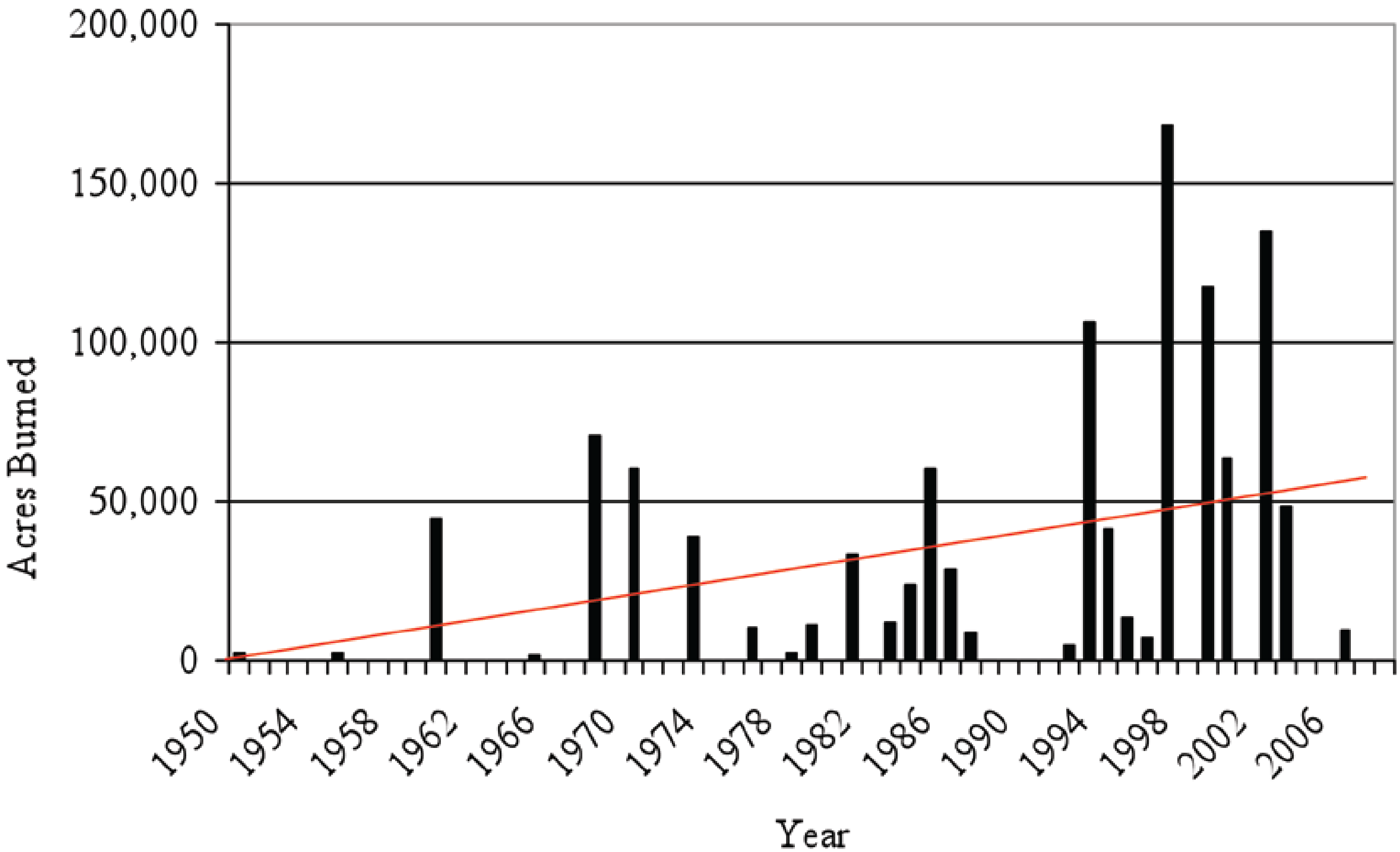

Figure 7. Amount of burned area in northwestern Alaska, 1950-2007, excluding years with very high acreages (> 200,000, n = 15). Red line is the regression line showing a significant increasing trend in burned area. This trend may be real or an artifact of the large fire database due to varying fire suppression and mapping efforts over the years.

have been identified (*Kasischke and Turetsky 2006*).

Our addition of non-linear and Pacific Decadal Oscillation factors greatly improved our model's ability to predict annual burned area. The model was even stronger at predicting the amount of burned tundra. The effects of climate change, potentially warmer and drier summer weather, may have non-linear effects on the fire regime of northwestern Alaska. For northwestern Alaska and tundra, the exponential of August temperature had the greatest explanatory power. For Interior boreal forests, June temperature was the single most important factor explaining variance in burned area (*Duffy et al. 2005*). Part of this difference may be explained by phenology differences between the ecosystems – in other words, summer simply comes later to northwestern Alaska than it does to the Interior, therefore temperatures later in the year are more important in determining annual burn area. Additionally, August is on average the coolest of the summer months but has the greatest variability. Warm temperatures in August were correlated with dry weather and thus it is not surprising that they are associated with increased annual burned area in northwestern Alaska (*Miller 1985*).

Management Implications

The management of wildfires is a contentious issue, not least of all because of its implications for caribou winter range. Our findings are based on the large fire database maintained by the Alaska Fire Service and thus should be viewed carefully. We believe our preliminary findings provide a starting point for understanding the importance of wildfire in northwestern Alaska and tundra ecosystems in general. While fires are less common in tundra ecosystems than in boreal forests, tundra ecosystems are capable of burning much more frequently. Understanding the fire regime of this region and its impacts on the WAH will be critical information utilized in the development of a fire management plan for the winter range of the herd.

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Ecological Land Classification and Mapping of the Wrangell-St. Elias National Park and Preserve

By Torre Jorgenson, Ken Stumpf, Joanna Roth, Trish Miller, Eric Pullman, Tim Cater, Michael Duffy, Wendy Davis, Matt Macander, and Jess Grunblatt

Introduction

Ecosystems of the Wrangell-St. Elias National Park and Preserve (WRST) are highly diverse owing to extremely variable geologic terrain and to the large climate gradient that ranges from the wet Gulf of Alaska coast to the cold and dry continental climate of Interior Alaska. At 13.2 million acres, it is the largest park in the NPS system. Its national and global significance was recognized by its designation as a national park and preserve under the Alaska National Lands Conservation Act in 1980 and as a "World Heritage" site by the United Nations in 1979 that includes the Canadian Kluane National Park.

Ecological field surveys and landcover mapping are essential for evaluating land resources and developing management strategies that are appropriate to the varying conditions of the landscape. Land classification and mapping can be used to efficiently allocate inventory and monitoring efforts, to partition ecological information for analysis of ecological relationships, to develop predictive ecological models, and to improve techniques for assessing and mitigating impacts. To satisfy this wide range of needs, we used an integrated approach of inventorying and classifying ecological characteristics from the "bottom up" and used satellite image processing and environmental modeling to map landcover from the "top down." This integrated effort also required a team with diverse skills—ABR, Inc. conducted the intensive field inventory, ecological analysis and classification work, Geographic Resource Solutions (GRS) performed aerial surveys and satellite image processing, and NPS provided logistical support, data management, and product review.

The structure and function of natural ecosystems are regulated largely along gradients of energy, moisture, nutrients, which disturbance. These gradients are affected by climate, physiography, geomorphology, soils, hydrology, vegetation, and fauna, which are referred to as ecological components or 'state factors' (*Bailey 1996*). An ecological land classification also involves organizing ecological components in a hierarchy of spatial and temporal scales, where local-scale features (e.g., vegetation) are nested in regional-scale components (e.g., climate and physiography).

Methods

We used a multi-step process to sample and assess the variability in vegetation and other ecological characteristics in order to implement the ecological land classification segment of the overall mapping effort (*Jorgenson et al. 2008*). These included: (1) an integrated ecological land survey to characterize vegetation, soils, and other ecological characteristics; (2) classification of plant communities (floristic associations), soils, and local-scale ecosystems (termed "ecotypes") that integrate co-varying ecological

Photograph courtesy of T. Jorgenson

Photograph courtesy of T. Jorgenson

Figure 1. Field surveys were done in teams of two with a botanist and a soil scientist to document geomorphology, hydrology, soil stratigraphy, site chemistry, and vegetation structure and composition. Each plot required about an hour to complete.

properties; and (3) analysis of relationships among ecological components. Relationships among ecological components then were used in map development by incorporating a simplified integrated-terrain-unit approach based on climate zone, physiography, surface form, and vegetation. These are features which can be readily mapped or modeled. Physiographic units were derived from the existing landscape-level ecological maps (subsections) for WRST (*Swanson and Anderson 2001*) and are closely related to geology and geomorphology (*Winkler 2000*). Surface forms (primarily slope-related features) were derived from a digital elevation model (DEM). Vegetation classes were obtained from the landcover types developed by the spectral classification performed by GRS. This integrated-terrain-unit (ITU) approach, along with the landscape relationships developed from the analysis of the field survey information, allowed us to develop a set of map classes from remote sensing that better differentiated ecosystems and their floristic and pedologic characteristics.

We conducted ecological field surveys in WRST during 2004-2006 using a gradient-directed sampling scheme across climatic, geologic, and topographic gradients to sample the range of ecological conditions and to provide the spatially-related data needed to interpret ecosystem development. Intensive sampling was done along transects located in climatic subzones and major physiographic units, including coastal, glacial, riverine, lacustrine, lowland, upland, subalpine and alpine areas. Data were collected at 569 plots along 77 transects. Along each transect, four to 14 plots were sampled, each in a distinct vegetation type or spectral signature identifiable on aerial photographs. At each plot (~33 ft/10 m radius), descriptions or measurements were made of GPS location, geology, surface form (micro- and macrotopography), hydrology, soil stratigraphy, and vegetation cover (*Figures 1-3*).

Photograph courtesy of T. Jorgenson

Figure 2. Visual estimates of percent cover were made of all vascular plant species and the dominant nonvascular plants.

Photograph courtesy of T. Jorgenson

Figure 3. Soil profiles were described at each plot. Relationships among soil, vegetation, and other landscape components were used to develop rules to model the landcover map into a soils landscapes map.

Results and Discussion

For ecological classification, individual ecological components (e.g., geomorphic unit, Alaska Vegetation Classification) were classified using standard classification schemes for Alaska, but modified when necessary to differentiate unique characteristics in the study area. We identified 67 plant associations through multivariate classification techniques (*Figure 4*). Soils described at 423 plots were classified into 53 soil types (subgroup level), of which 15 were rare occurrences and not used in the analysis of soil-vegetation relationships. We used the hierarchical relationships among ecological components to develop 68 ecotypes that best partition the variation in ecological characteristics across the entire range of aquatic and terrestrial environments. Thirty-nine ecotypes were described from the boreal climatic zone, 23 from the maritime zone, and an additional six water and snow/ice classes. The most prevalent ecotypes included: Snow and Glacier (42.6%), Boreal Alpine Barrens (21.4% of area), Boreal Subalpine Willow and Birch Scrub (7.1%), Boreal Alpine Sedge-Dwarf Willow Meadow (4.1%), Boreal Alpine Dryas Dwarf Scrub (4.0%), Boreal Glaciated Barrens (3.7%), Boreal Upland White Spruce Forest (2.9%), Boreal Subalpine Spruce Woodland (2.8%), Maritime Glaciated Barrens (2.8%), and Boreal Lowland White Spruce Forest (2.6%).

Soil landscape classes, were developed by cross-tabulating soils with the ecotypes assigned for each plot. The cross-tabulation revealed that two to five closely related soil types usually were associated with two to three ecotypes. These groupings were used to identify 21 terrestrial and five water and glacier landscapes, which provide a set of 26 classes with broad application for resource management.

Multiple environmental site factors contributed to the distribution of ecotypes and their associated plant species, resulting in large differences among ecotypes. Mean surface organic-horizon thickness (an indicator of land surface age), anaerobic soil conditions, and distur-

Photographs courtesy of T. Jorgenson

Figure 4. Views of some of the wide range of ecosystem types in WRST. Photos left to right, in rows top to bottom: Boreal Alpine Dryas Dwarf Shrub, Boreal Glaciated Barrens, Boreal Subalpine Forb Meadow, Boreal Upland Aspen Forest, Boreal Lowland Black Spruce Bog, Boreal Riverine Dryas Dwarf Shrub and Barrens, Boreal Lacustrine Pondlilly, Maritime Upland Sitka Spruce Forest, and Maritime Coastal Angelica Meadow.

bance, ranged from 0 inches (0 cm) in alpine, coastal and riverine barrens to 5 feet (150 cm) in boreal lowland sedge-shrub fens and boreal lacustrine sedge meadows (*Figure 5*). Mean depth to rock, an indicator of surficial deposit depth and drainage, ranged from 0 inches (0 cm) in alpine barrens to >6.5 feet (>200 cm) in numerous ecotypes that occurred on thick, eolian surficial deposits. Permafrost presence varied in the boreal zone. Areas where permafrost was at >5 ft (>1.5 m) depth or was absent, included upland, subalpine, younger riverine, and lacustrine fens. In other lacustrine, lowland and alpine areas, permafrost was usually present at 1.6-3.3 ft (50-100 cm) depth, with a minimum depth of 6 in (15 cm). Permafrost was absent in the maritime zone, except for high elevation mountainous areas and areas underlain by glacial ice. Mean water depth (negative when below ground) for terrestrial ecotypes ranged from >-6.5 ft (>-200 cm) in Boreal Upland Sagebrush Meadow to 4 in (10 cm) in Maritime Coastal Sedge Meadow. Mean pH, which affects nutrient availability, ranged from 3.4 in Maritime Upland Tall Alder Shrub to 8.3 in Maritime Coastal Barrens. Mean electrical conductivity (EC), important for osmotic regulation in plants, ranged from 30 µS/cm in Alpine Lake to 37,500 µS/cm in Nearshore Water in aquatic ecosystems, and from 33 µS/cm in Maritime Alpine Barrens to 613 µS/cm in Maritime Coastal Sedge Meadow in terrestrial ecosystems.

Two types of map products were developed: landcover maps produced by GRS (*Stumpf 2007*) that use vegetation classes similar to the AVC classification, and ecosystem maps derived from landcover maps through rule-based modeling with ancillary maps. A landcover map was developed through classification of spectral characteristics of 11 Landsat scenes that covered the area. The process involved: (1) compiling and preprocessing 11 Landsat ETM scenes; (2) developing an unsupervised classification of the scenes to guide field surveys; (3) developing spectral training areas by sampling spectrally homogenous patches by helicopter; (4) developing a spectral database that included both spectral and vegetation characteristics; (5) evaluating similarities and differences among spectral signatures; (6) classifying the vegetation type of each spectral signature using cut-point rules from the AVC and the quantitative vegetation data; (7) performing a supervised classification of all the scenes using the classified signatures; and (8) reducing errors in the resulting scenes through rule-based modeling with ancillary data. These data included a DEM, winter Landsat scenes, and an ecosection map to help with regional differences. The resulting landcover map has four levels of aggregation from 123 calculated vegetation types to 11 major physiognomic classes.

We developed a set of three ecosystem maps from

Figure 5. Mean thickness (± SD) of surface organic layer, depth to rock (>15% coarse fragments) and depth of thaw for boreal ecotypes in Wrangell-St. Elias National Park and Preserve, 2004-2006. Sample sizes are in parentheses.

the GRS landcover maps, based on rule-based modeling. First, a map of integrated terrain units (ITUs) for WRST was developed by overlaying and combining the detailed 123 classes from the GRS landcover map and four terrain layers: climatic subregions (7 classes), physiography (floodplains, glaciers, coastal, and other), elevation (<800m, 800–1000 m, and >1000 m), and slope (< 7° and ≥7°). This initial set of 6,465 combinations, or ITUs, was aggregated into a reduced set of 66 ecotype map classes (two ground classes could not be mapped) based in large part on terrain relationships developed from analysis of field data (*Figure 6*). Third, we developed a soil-landscapes map with 25 classes derived from aggregating similar ecotypes with similar soils (*Figure 7*).

Ecotype distribution was affected by numerous landscape-level factors. Tectonics and regional mountain building have created barriers to atmospheric movement and topographic climate gradients, resulting in strong differences between boreal and maritime ecotypes. Oceanographic conditions have lead to salt-affected ecotypes along the coast and the prevalence of lowland ecotypes on the coastal plain. Soil pH and nutrient status are strongly affected by underlying bedrock types and geomorphology. Geomorphic environments associated with active sediment erosion and deposition create a wide range of soil conditions and disturbance regimes (*Figure 8*). Areas underlain by permafrost have impeded subsurface drainage, and the varying volumes of ground ice affect the magnitude of permafrost degradation. Fires are a strong modifier of ecosystem dynamics, particularly in interior areas vegetated by black spruce. Finally, recent spruce beetle infestations have severely damaged large areas of spruce forest.

Conclusions

This integrated ecological land survey approach has

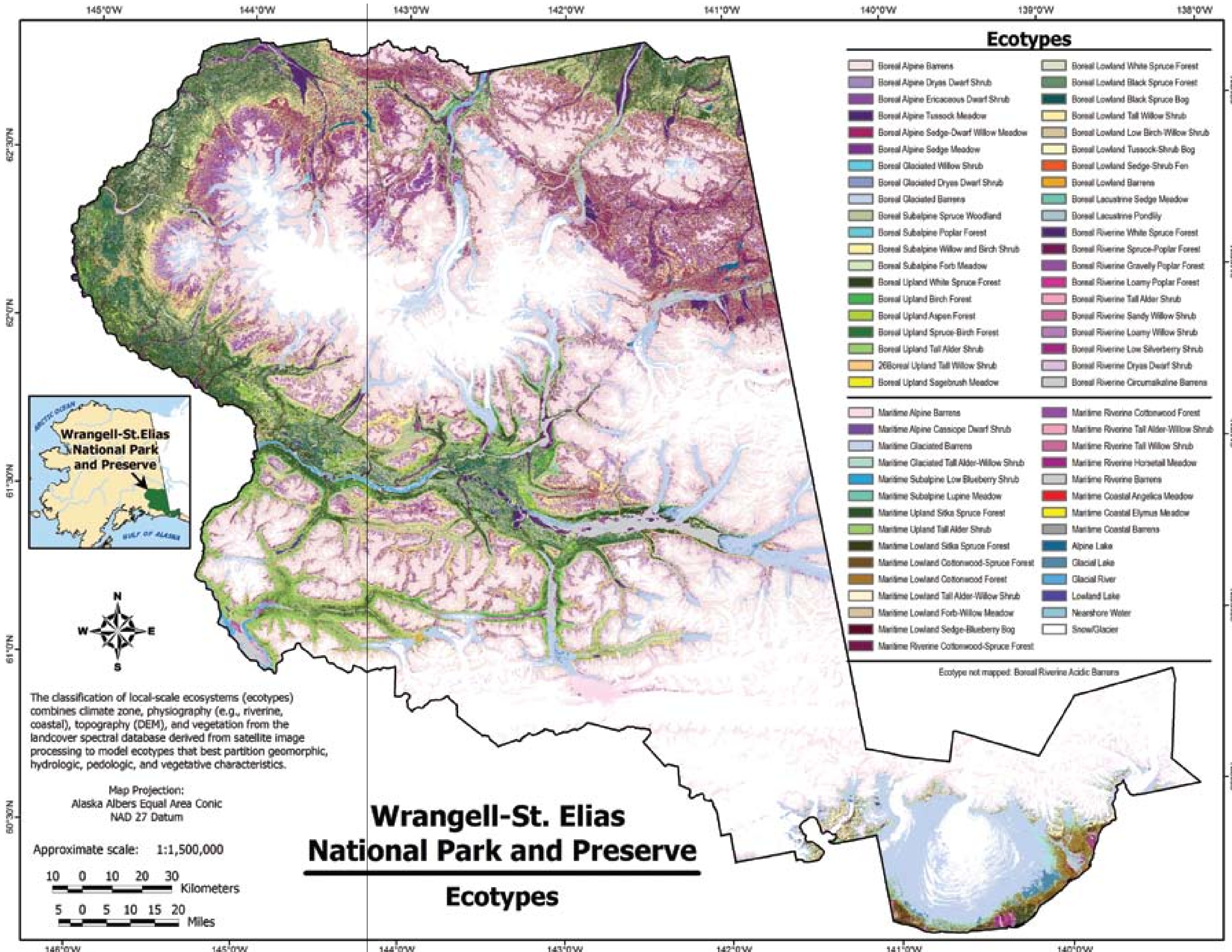

Figure 6. Map of ecotypes of the Wrangell-St. Elias National Park and Preserve.

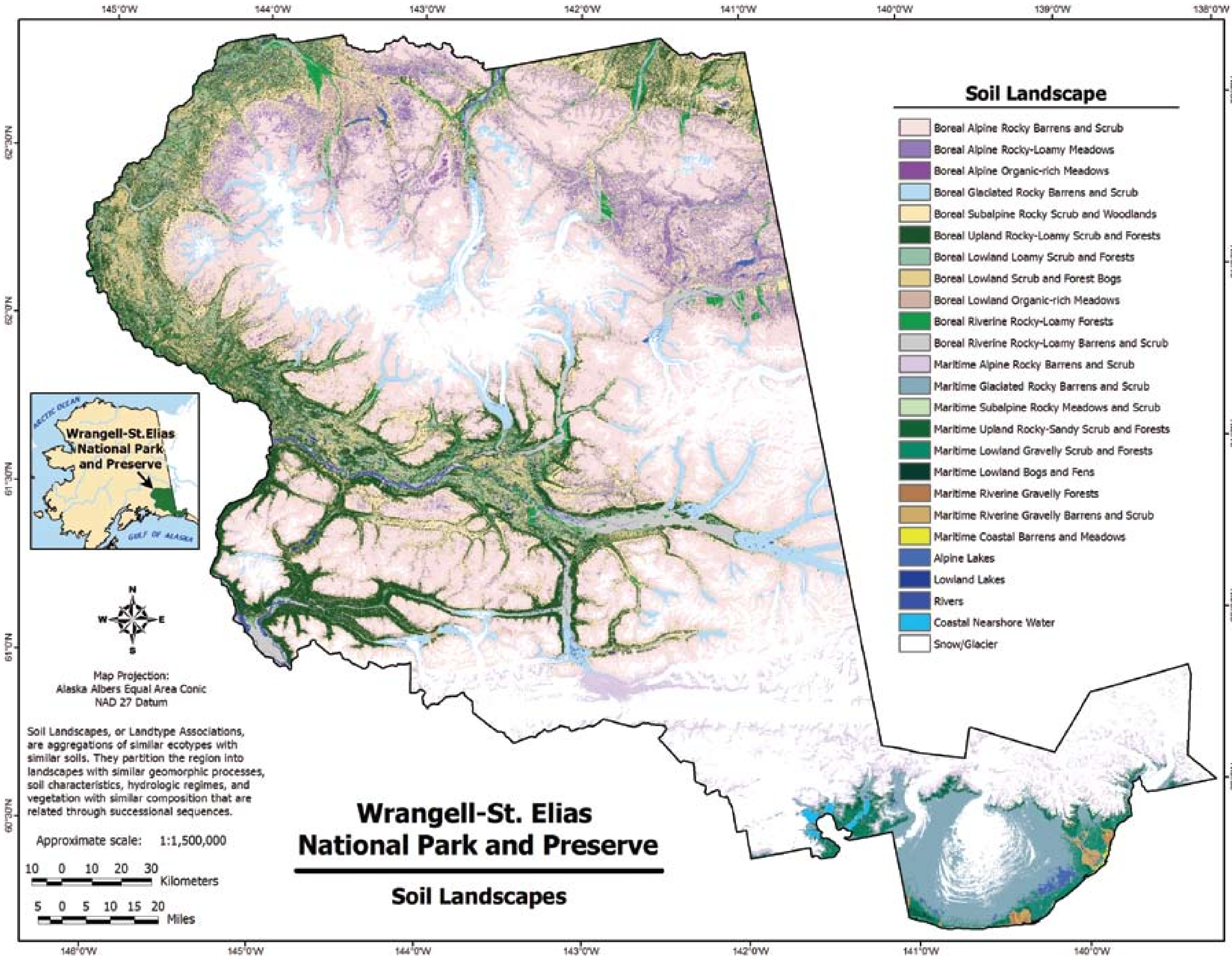

Figure 7. Map of soil landscapes of the Wrangell-St. Elias National Park and Preserve.

several benefits for understanding landscape processes and their influence on ecosystem functions. First, it analyzes landscapes as ecological systems with functionally related parts. This hierarchical approach, which incorporates numerous ecological components into ecotypes with co-varying properties, allows users to partition the variability of a wide range of ecological characteristics. Second, it recognizes the importance that geomorphic and hydrologic processes have on disturbance regimes, the flow of energy and material, and ecosystem development. Third, development of a spectral database for landcover mapping, which integrates spectral and field vegetation information for use in satellite image processing, facilitates the analysis of vegetation distribution across the landscape. Finally, the linkage of landcover maps to climatic, physiographic, and topographic variables in the development of ecosystem maps serves as a spatial database with differing ecological components. Construction of a map as a spatial database can help resource managers evaluate ecological impacts and develop land management strategies appropriate for a diversity of landscape conditions.

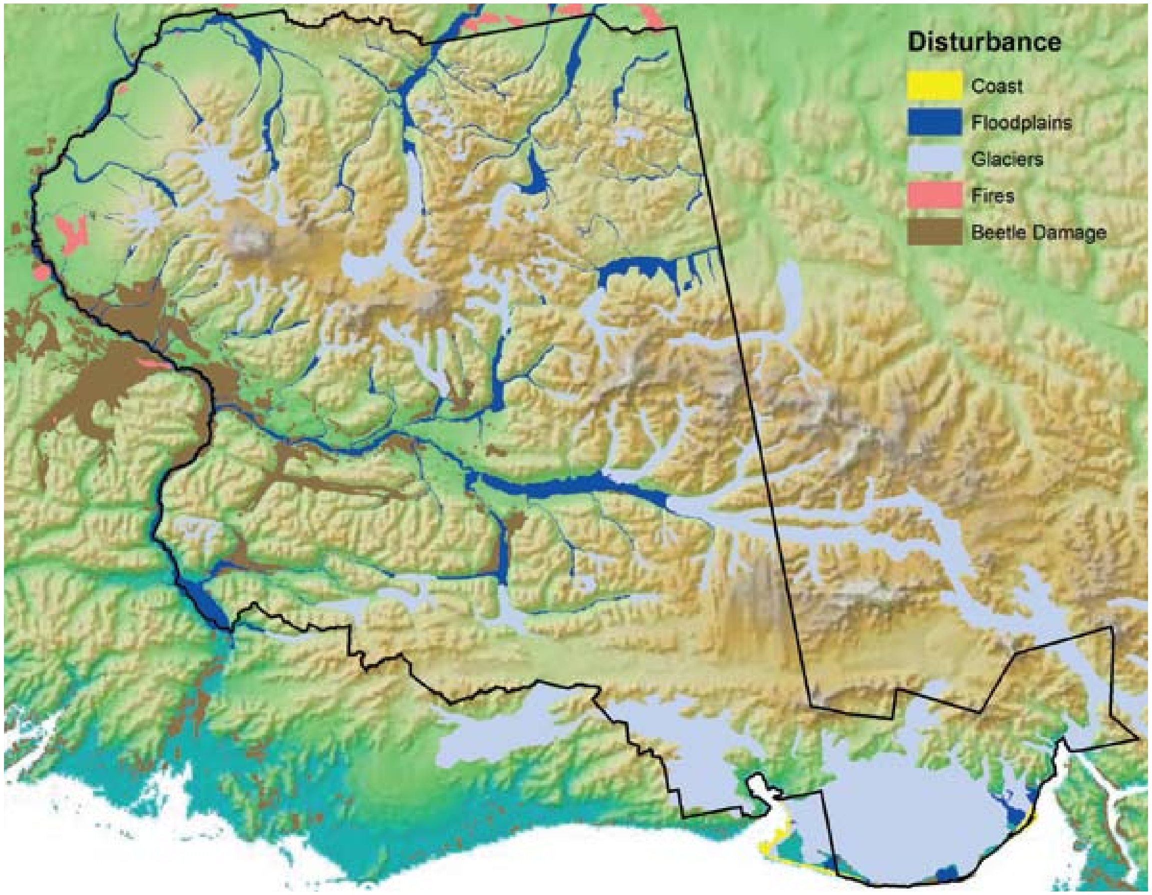

Figure 8. Distribution of large-scale disturbances associated with geomorphic processes, fires, and insects.

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Natural and Cultural Healing Places Within Publicly Managed Lands

Carl M. Hild, Victoria Hykes Steere, and Natalie Novik

Abstract

Understanding the history of land ownership in Alaska and the cultural use of places of ancient traditional healing becomes a critical aspect of public land management. National and international agreements have been reviewed for the legal status and options for management. The identified attributes of the site that contribute to improved well-being may also have been desired for other activities. Producing an inventory of culturally important sites along with their written and oral histories is being achieved through the process of Multicultural Engagement for Learning and Understanding. Computer-based mapping is being used to organize the materials.

Introduction

In 2002 the eight-nation Arctic Council's working group on the Conservation of Arctic Flora and Fauna (CAFF) produced its report "The Conservation Value of Sacred Sites of Indigenous Peoples of the Arctic: A Case Study in Northern Russia" (*CAFF 2002*). In 2004 during a National Institutes of Health program exploring the research requests of the Maniilaq Association's Tribal Doctor Program, it was learned that the protection of and access to a place of ancient traditional healing (PATH) needed to be investigated (*Hild 2006*). These two reports were taken into consideration and an inquiry was made into the factors that contribute to the healing aspects of this PATH. This work was initiated in collaboration with the Tribal Doctors, the Regional Elders' Council of northwestern Alaska, the Shishmaref Indian Reorganization Act Council, the National Park Service, the National Parks Conservation Association, and a number of other organizations. The method applied was one of "Action Research" with the use of "Appreciative Inquiry", which yielded a collaborative process identified as Multicultural Engagement for Learning and Understanding (MELU)(*Hild 2007*).

The PATH currently being investigated is considered of extreme cultural relevance, and its natural factors need to be protected for future generations of Inupiat through a process of recognizing traditional healing places. The health and well-being of the Inupiat is intricately bound to the concept of oneness with the land. This worldview, embedded in their recognition of the healing power of the land, cannot survive where ownership is the primary manner in which the land is viewed.

Investigations

Historically, Russia did not lay claim to Inupiaq lands or try to colonize them (*Case 1995, Edwardsen 1993, Okun 1979, Price 1982*). The United States wrote to Russia to ask for additional clarification on the specifics of the sale. According to Sergei Kostlivtzov's Memorandum and subsequent clarifying documents, only 117,600 square feet of Russian-American Company land was included in the transfer under the 1867 Treaty of Cession (*Clay 1867, Okun 1979, Price 1982*). The sale only included what the Russians considered as the extent of their colony: i.e. the stockades, buildings, and the right to trade with the indigenous populations that were considered "allies." The U.S. agreed to the language of the Treaty in that: "uncivilized tribes" (i.e. all tribes outside of the sphere of influence of the Russians, and therefore not subjected to tribute payments or considered allies) "will be subject to such laws and regulations as the United States may, from time to time adopt in regard to aboriginal tribes of that country" (*Price 1982*). When the U.S. took over the territory they assumed claim to all of the lands and soon mining and reindeer claims were recognized, while indigenous claims were not addressed.

A century later requests for identification and protection of sites were made under the 1971 Alaska Native Claims Settlement Act (ANCSA) and specifically its 14(h)1. Some selections conflicted with the federal goal of public management for natural resources. In 1978 under Public Land Orders 5653 and 5654, the lands surrounding Serpentine Hot Springs, including the site itself, were withdrawn from

NPS photograph by Zachary Babb

Figure 1. Serpentine Hot Springs

possible selection under the clause of "reserving public lands to protect their resource value." (*BIA 1984*).

In the process of reviewing the legal tools that may be implemented by indigenous peoples, the question of original claims to the land surfaced (*Edwardsen 1993, Price 1982*). Investigating international doctrines, charters, declarations, and covenants along with U.S. decisions, Executive Orders, and Acts has revealed that there has been no legal act that would remove indigenous claims to water rights throughout Alaska. Because many of the PATH of interest deal with water sources, these sites may hold additional value to indigenous peoples.

The Territory of Alaska was listed by the United Nations General Assembly Resolution 66(j) of 14 December 1946 as a "Non-Self-Governing Territory" with the "Right of Nationhood" under Article 73 of the United Nations Charter. Under the Charter, the U.S. agreed to conditions for how the Territory of Alaska would be administered, how its citizens would be treated and how the process of decolonization would take place. One of the requirements was for the original inhabitants of the territory to be brought from their preliterate state to be educated and fully informed of their status prior to a vote of the original inhabitants to determine their political status and future. The U.N. provided a process for decolonization within its legal and institutional framework, and provided money for the political discussions to take place once the original inhabitants had become literate and were deemed by a vote of the U.N. General Assembly to be literate, fully informed of their status, and acting accordingly free of political interference by the governing nation.

This special status of the Territory's indigenous peoples is reflected in the Alaska State Constitution, Article 12, Section 12 that states: "The State and its people further disclaim all right or title in or to any property, including fishing rights, the right or title to which may be held by or for any Indian, Eskimo, or Aleut, or community thereof, as that right or title is defined in the act of admission." Therefore, as of statehood the indigenous claims were not extinguished.

NPS photograph by Zachary Babb

Figure 2. Bath houses at Serpentine Hot Springs.

The Territory of Alaska's original inhabitants had, and still have, the right under the U.N. Charter Chapter XI, Declaration Regarding Non-Self-Governing Territories, to vote to either remain a protectorate of the United States or to become an independent nation. This process has not been pursued.

Discussions with traditional healers led to the identification and the need to understand the natural attributes of culturally used lands, as well as what requirements there may be by public land managers about the sustained utilization of such sites (*Hild 2006*). ANCSA Section 14(h)1 allows for special site selections due to cultural

U.S. National Archives

U.S. National Archives

Figure 3. (Top) Copy of the check from the Treasury Department of the U.S. to Russia for the 1867 Treaty of Cession. (Bottom) Cover page of Russion version of the Treaty of Cession.

use and sensitivity. An inventory of PATH and other important sites is being developed from the 2,200 reports with the materials being placed in a standardize data form (*Hild 2005*).

Results

The subsequent and desired action from the investigation was the submission in January 2008 by the Shishmaref IRA Council of a National Historic Preservation Act (NHPA) Section 106 request to the NPS to enter into a Memorandum of Agreement "to foster an on-going relationship to discuss the planning and management options that will address all of our cultural sites that are now considered public lands." In addition, an effort to conduct cultural-use computer-based mapping of the site has been initiated through the National Parks Conservation Association to document the knowledge of the members of the Shishmaref Elders' Council.

A project was completed to digitize the BIA 14(h)1 reports so that the 2,200 site files may be word searched. What is being learned about these other ancient cultural sites will enable more appropriate management plans and access utilization schemes to be prepared for continued healing purposes.

Discussion and Conclusion

The MELU process of partnering to achieve practical knowledge that can be applied to generate solutions, is a positive approach to dealing with issues. It brings together multiple world views so that additional perspectives can be considered and utilized in the discussions and decision making processes.

Even after ANCSA and while passing Alaska National Interest Lands Conservation Act in 1980, Congress had a clear interest in protecting the rights of Alaska's indigenous peoples. Although ANCSA extinguished hunting and fishing rights, no act of Congress has extinguished indigenous water rights. As Serpentine Hot Springs is one of the most sacred sites for the Inupiat, and as a water source, the aboriginal rights to its use have not been extinguished.

In 1992 the U.S. Congress ratified the International Covenant of Civil and Political Rights. Within this U.N. document 171, Article 1, Section 1 states: "All people have the right of self-determination. By virtue of that Right they freely determine their political status and freely pursue their economic, social and cultural development." As an international treaty that has been ratified this commitment has the same standing as the U.S. Constitution.

Management Implications

The crux of the discussion regarding Serpentine Hot Springs is that the tribal bodies were not allowed to claim these sites during ANCSA or under ANILCA processes, because the PATH sites were designated as being on public lands. Moving beyond the legal implications discussed above, what needs to be decided now is how to plan to manage Serpentine Hot Springs and other similar sites? What role can traditional use of the natural resources play? Can there be a determination that it is a ceremonial site important to the Inupiaq culture? What natural resources have been traditionally used for healing, for which continued access is necessary? What priorities can the NPS put on the cultural heritage of the site and allow for the interpretation and experiential applications to be considered "outdoor recreation and environmental education"?

The NPS effort to preserve and protect historic properties and cultural traditions of American Indians needs expansion. The NPS assists tribes to manage, research, interpret, protect and develop historic properties on Indian lands in national parks under various authorities. In order to meet the critical level of resource management and protection needs, ethnographic and archeological surveys, interpretive facilities, collection management, site stabilization and preservation planning programs should be expanded significantly (*NPS 1990*).

The Inupiat offer the NPS a unique opportunity to forge a new relationship with Alaska's indigenous peoples that recognizes and honors that sometimes doing what is morally right allows for all of us to become more than we were, and advances civilization forward in a just and honorable way. Such engagement may inform everyone on sustainable practices that contribute to the greater well-being of all.

NPS photograph by Zachary Babb

Figure 4. Near Serpentine Hot Springs, 2008.

Acknowledgements

Thanks to Cody Alf, Helen Bolen, Ernest S. Burch, Jr., Ken L. Pratt, Jim Stratton, Bureau of Indian Affairs, Maniilaq Tribal Doctors, National Institutes of Health, National Park Service, National Parks Conservation Association, Rasmuson Foundation, Regional Elders' Council for northwestern Alaska, Shishmaref Elders Council, Shishmaref IRA Council.

NPS photograph by Zachary Babb

Figure 5. Near Serpentine Hot Springs, 2008.

NPS photograph by Zachary Babb

Figure 6. Musk oxen near Serpentine Hot Springs, 2008.

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Contribution of Russian Specialists to the Study of the Bering Strait Region

By L.S. Bogoslovskaya

The Bering Strait region includes Bering Strait as well as adjacent lands and waters that are united together by the commonality of natural and ethno-cultural processes, which encompass terrestrial and marine areas of various size. Therefore, it is rather difficult to determine the outer boundaries of the region. Their location depends on the phenomenon or process being examined.

The natural complexes of the Bering Strait region form a unique biosphere that is connected with all the continents of our planet and represents the key eco-systematic component of the North Pacific and the adjacent sector of the Arctic. The Asian component is usually called Russian Beringia. Its main region, Chukotskiy Peninsula (*Figures 1-2*), is noted for its high level of biological diversity and productivity of marine and coastal ecosystems, unusual for the Arctic.

The Bering Strait region is an area of multiple migrations for ancient peoples. It is thought that this was the area where, about 15,000 years ago, the ancestors of the North American peoples crossed over from Asia. Thanks to its unique geographical location, Chukotka and Western Alaska played an important role in the history of Asiatic-American contacts for more than 10,000 years. Ancient and modern peoples left a gigantic complex of archeological monuments, from Paleolithic sites to much more recent dwelling and ritual constructions made of whale bone, as well as beautiful walrus tusk artifacts.

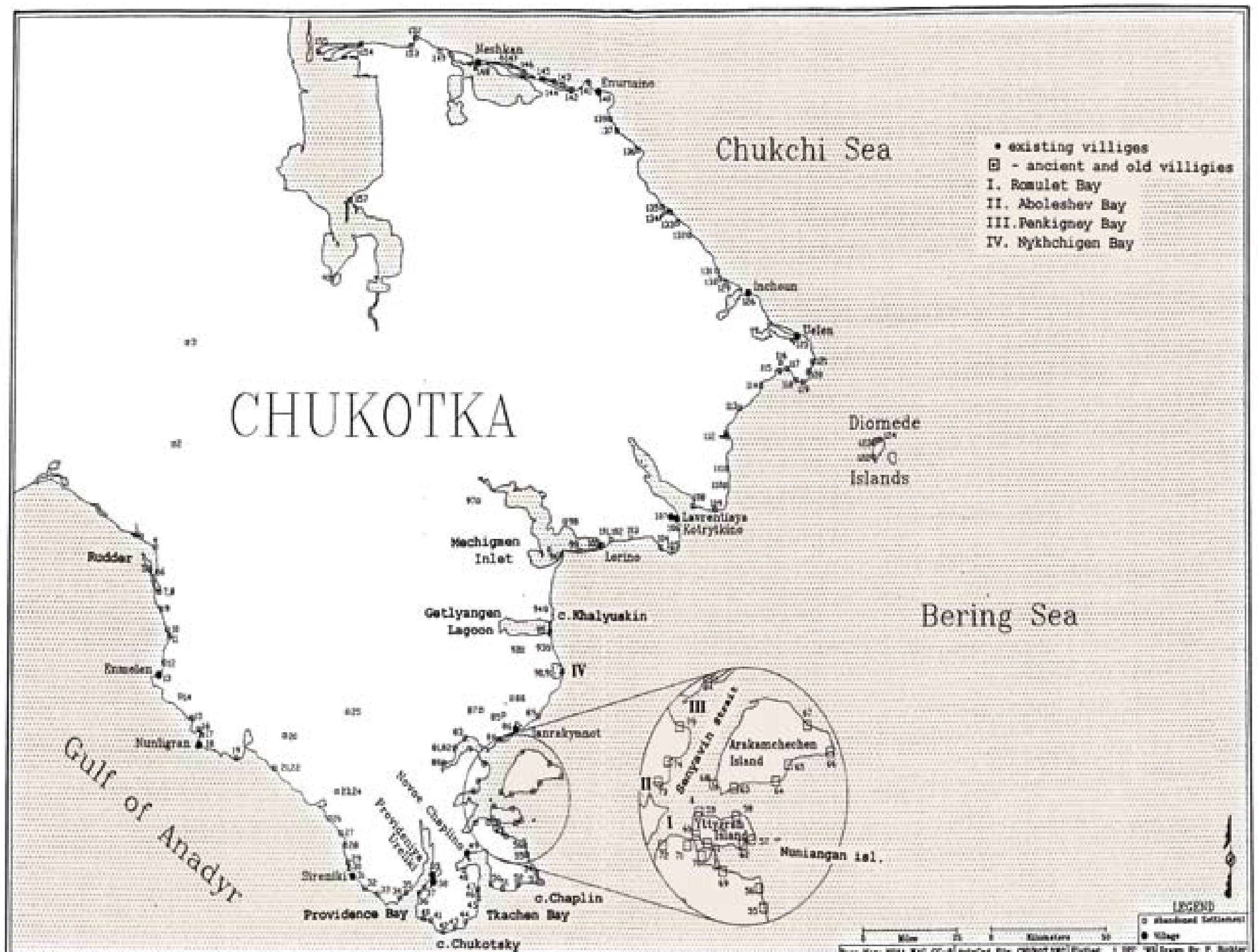

Figure 1. Map of Chukotka, the eastern end of Russia.

During the course of the eighteenth and to the beginning of the twentieth centuries, the scientific achievements of Russia in the Bering Strait region are associated with the names of Navy mariners and natural scientists that were included on the crews of the Navy vessels. The first were the two Navy expeditions of Vitus Bering and Aleksey Chirikov in 1741 and Ivan Fedorov and Mikhail Gvozdev in 1732. Fedorov and Gvozdev were the first to delineate the American coast line of the Bering Strait. Then there were a host of famous Russian mariners that studied nature and Native peoples of Chukotka and Alaska, which until the second part of the nineteenth century was called Russian America. This period was capped by the grandiose Navy hydrographical expedition on the vessels *Vaigach* and *Taimyr* in 1910-1915.

In the first part of the twentieth century, multiple expeditions of the USSR Academy of Sciences explored the marine and terrestrial geo-biocenosis of the Eastern Chukotka. In the second part of the twentieth century the work of the Botanical Institute of Russian Academy of Sciences (BI RAS, St. Petersburg) headed by Boris Yurtsev and the staff of the Institute of the Biological Problems of the North of the Far Eastern Branch of Russian Academy of Sciences (IBPN FEB RAS, Magadan) contributed greatly to the study of Chukotka Peninsula biodiversity. In particular the series of scientific publications by BI RAS should be mentioned. They were prepared in the beginning of the twenty-first century with a broad audience in mind: Terrestrial Vertebrates of the North-East Russia; Wetlands of Russia (volume 4); The Life at the Limit; The Red Book of Chukotka Autonomous Region (volumes 1 and 2).

During 1977-1992 the Chukotka zoological expedition headed by Lyudmila Bogoslovskaya and organized by the Institute of Evolutionary Morphology and Ecology Named in Honor of A.N. Severtsev of the Academy of Sciences of USSR (now the Institute of the Problems of Ecology and Evolution Named in Honor of A.N. Severstev of the Russian Academy of Sciences – IPEE RAN, Moscow) studied the biology of marine mammals and birds of Bering Strait

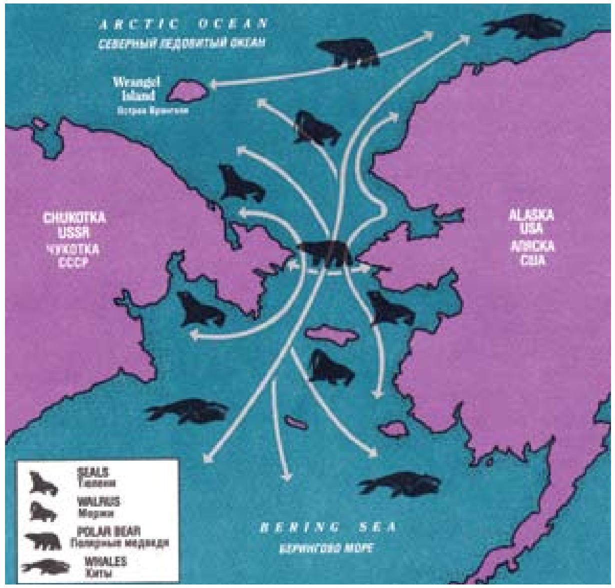

Figure 2. Migratory patterns for Arctic marine mammal subsistence species.

as well as the traditional culture of marine mammal hunting of Asiatic Eskimo and Coastal (Maritime) Chukchi. This work was continued in 1993 by the Center of Traditional Culture of Nature Use of the Russian Institute of Cultural and Natural Heritage Named in Honor of D.S. Likhachev of the Ministry of Culture of Russian Federation (Heritage Institute, Moscow). L. Bogoslovskaya (Heritage Institute) and Igor Krupnik (Arctic Studies Center, Smithsonian National Museum of Natural History) head this project.

As a result of many years of research, the maps of sea bird colonies, rare and especially protected species of orni-fauna, the areas of whale and pinneped concentration, and the map-diagram of ancient, old and modern settlements of Chukotka Peninsula coast (from Rudder Bay to Kolyuchin Bay) were compiled. The articles and books on the biology of marine animals and traditional life style of marine mammal hunters of Eastern Chukotka were published. The most important of them are: Igor I. Krupnik, Let Our Elder Speak. The Stories of Asiatic Yupik Eskimo. Recording of 1975-1987, 2000; Lyudmila S. Bogoslovskaya, The Whales of Chukotka, 2003; Lyudmila S. Bogoslovskaya, I. Slugin, Igor Zagrebin, and Igor I. Krupnik, The Basis of Marine Mammal Hunting, Scientific and Methodological Publication, 2007; Lyudmila S. Bogoslovskaya, V.S. Krivoshchyokov, and Igor I. Krupnik, (eds), Following the Path of Bogoraz, Scientific and Literature Materials, 2008.

The research of Vladimir Bogoraz plays an important role in the study of the peoples of Russian Beringia. In 1900-1901 the world-famous ethnographer worked in Chukotka as a member of the Jesup expedition. For decades, his monograph Chukchi has been an important and invaluable source of information on Chukchi and Asiatic Eskimo traditional life style. Bogoraz's remarkable ability to penetrate the very essence of other cultures and languages in our opinion can be explained by his outstanding talent and high general cultural level that were characteristic of him as well as of the other scientists of old Russia.

Alexander Forshtein and Nikolay Shnakenburg, both students of Bogoraz, continued the ethnographic study of Chukotka peoples and of their languages at the end of the 1920s. Unfortunately, the research materials of these specialists were completely lost or destroyed during the years of Stalin's repressions, with the exception of Forshtein's beautiful photographs that are partially published in the monograph Following the Path of Bogoraz.

From the 1930s to the 1950s, the leading figures in the study of traditional cultures and languages of the Native peoples were also students and colleagues of Bogoraz. Innokentiy S. Vdovin had a significant input in the studies of history and language of Chukchi. Ekaterina Rubtsova and Georgiy Menovshchikov (Institute of Language Studies of the USSR Academy of Sciences, Leningrad branch) determined that during those years Asiatic Eskimo spoke three dialects of Siberian Yupik: Chaplino, Naukan, and Old Sireniki. Today specialists classify these dialects as independent languages. Inupiat Eskimo from Big Diomede (*Ratmanov*) Island had another language that belongs to the Inupiaq language group. Rubtsova's unique research Materials on the Language and Folklore of Eskimo (*1954*) and Eskimo-Russian Dictionary (*1971*) remain invaluable and are significant contributions to science.

In the second part of the twentieth century Nina Emelyanova, Nikolay Vakhtin, and Aleksey Burykin from the same institute (now the Institute of Linguistic Studies of Russian Academy of Sciences) continue to study Chukchi and Eskimo languages.

From the 1970s to the 1990s, the Chukotka Ethnographical expedition from the Ethnography Institute named in honor of N.N. Miklukho-Maklay of the USSR Academy of Sciences (EI AS USSR, Moscow) worked on the coast of Chukotskiy Peninsula between Uelkal and Nutepelmen. The expedition was headed by Mikhail Chlenov who was the first to discover the famous Eskimo religious monument, the Whale Bone Alley.

According to I. Krupnik and M. Chlenov, five large associations of Asiatic Eskimo—Imakligmit (Imakliks, about 100 people), Nyvukagmit (Naukan, about 350 people), Unazigmit (Chaplino, about 550 people), Avatmit (Avan, about 120 people), and Syginygmit (Sireniki, about 150 people) —existed at the end of the nineteenth and beginning of the twentieth centuries. Each association consisted of several related family groups (clans or kinships) with their own historical names. The smaller tribal groups of Eskimo—Kigvagmit (Kivak), Imtugmit (Imtuk), Atkalkhagmit (Atkalkhak), and Napakutagmit (Napakutak) —existed until the end of the twentieth century.

According to the supposition of the authors, the coastal Chukchi also were organized into territorial neighboring groups at the end of the nineteenth and beginning of the twentieth centuries. Similar to the Eskimo tribes, the most ancient of them, such as Uelen, Inchoun, Enurmino, Yandagay, and others, consisted of several patriarchal kin groups with their own particular names.

Thus, less than a century ago, all Chukotka coastline was a continuous chain of Chukchi and Eskimo tribal lands with established boundaries, permanent settlements and seasonal hunting camps, strict rules of nature use and subsistence, and close family and trading ties between neighboring settlements.

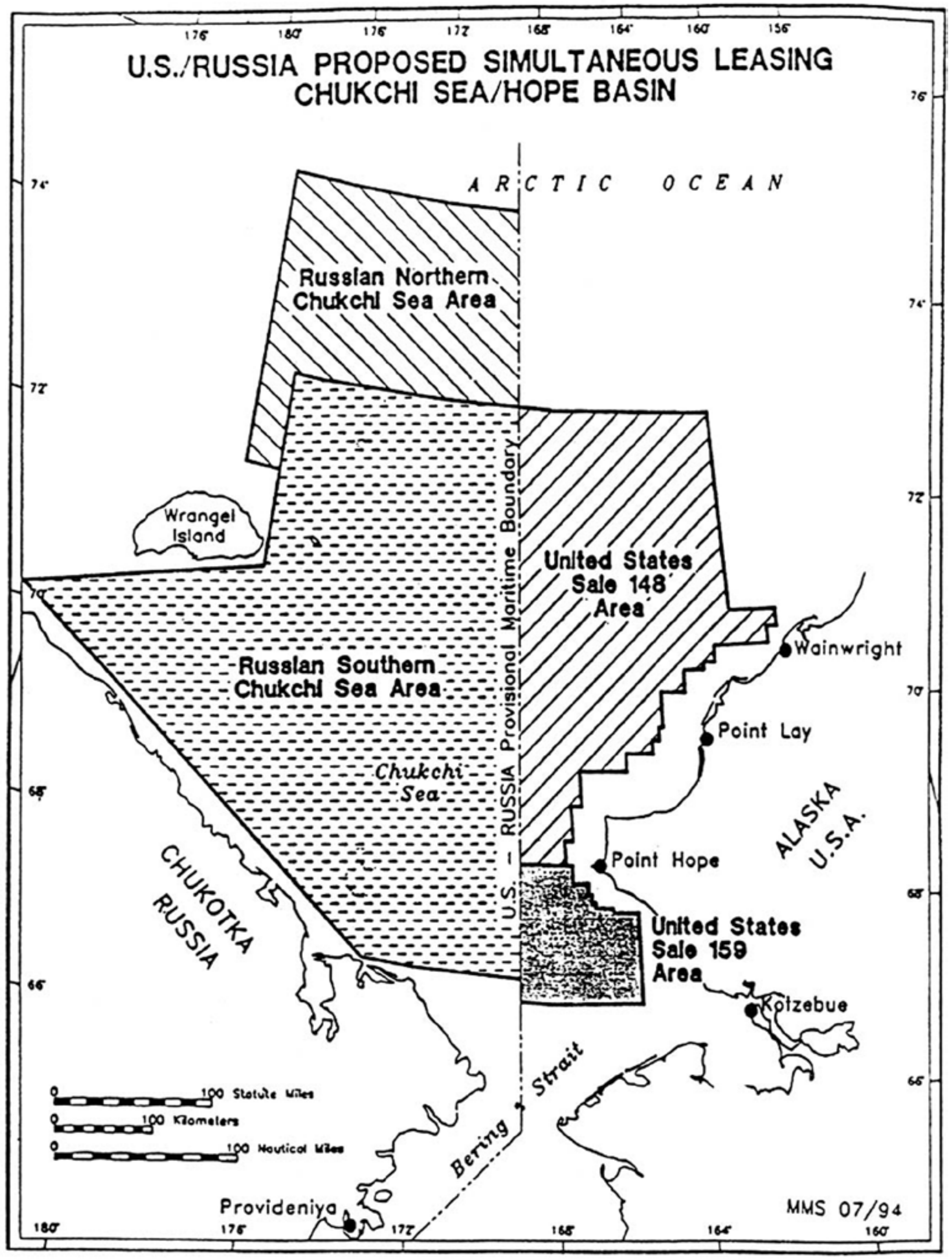

Figure 3. Map of the location of shelf target zones of the Far-eastern Licensing Program for the Potential Oil Development (Russia, Northeastern Oil Operations Agency 1993) and of the shelf areas of Alaska OCS Region for the planned exploration and extraction of hydrocarbons (U.S., Mineral Management Service 1994).

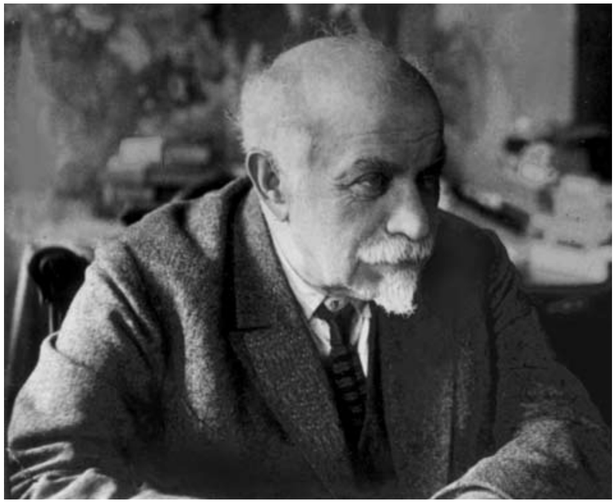
Photograph copyright B.I. Vdovin Archives

Figure 4. Vladmir Germanovich Bogoraz (1865-1936).


Photograph copyright Museum of Archeology and Ethnography Archive, #XXIII-481

Figure 5. Aleksandr Semyonovich Forshtein (1904-1968).

As a result of the relocation, merging and closing of settlements that occured during the Soviet period, only three (Uelkal, Sireniki, and Novoe Chaplino) of the 19 Eskimo settlements that existed at the beginning of the twentieth century remain. Sireniki is the only Eskimo settlement that existed in the same spot for more than 2,000 years. Chukchi underwent similar changes. Thus, in the area between the villages of Vankarem (Chukchi Sea) and Uelkal (Cross Bay) 25 Chukchi villages and reindeer camps were closed. As a result of the disturbance of the traditional settlement system, the cultural heritage of the Native peoples of Russian Beringia suffered irreparable damage.

Sergey Rudenko (1947) conducted the first archeological research on the east coast of the Chukotskiy Peninsula. Sergey Arutyunov and Dorian Sergeev (IA USSR AN, Moscow-Leningrad) continued Rudenko's work in the 1960s-1980s. Archeologists worked together with the outstanding anthropologists Mikhail Levin and Grigoriy Debets, and then Valeriy and Tatyana Alekseeva from the same institute.

The famous archeologist Nikolay Dikov and his employees from the laboratory of the Northeastern Multi-Discipline Scientific Research Institute of the Far Eastern Branch of Academy of Sciences of USSR (NEMDSRI FEB AS USSR, Magadan) started their multi-year research in Chukotka a little bit later. This scientific group paid special attention to the Paleolithic and Mesolithic sites.

Currently the Archeological Expedition of the State Museum of the Art of the Peoples of Orient (SMAPO, Moscow) headed by Kirill Dneprovskiy continues the research of Arutyunov and his colleagues. They are doing this in close collaboration with a group of paleoecologists from the Institute of Ecological and Evolutionary Issues of Russian Academy of Sciences (IEEI RAS) and Chukotka Heritage Museum Center (Anadyr'). An exhibit of ancient Eskimo art took place in 2007 and commemorated the activity of the Archeological Expedition of SMAPO. A wonderful catalog, The World of Arctic Marine Mammal Hunters – Steps into the Unknown authored by M. Bronshtein, K. Dneprovskiy, and E. Sukhorukova, was published for this exhibit.

Yuriy Shirokov and Mikhail Bronshtein, employees of this museum, study the ancient and modern bone carving of Chukotka craftsmen. The scientists' latest research is represented in the following publications: M.M. Bronshtein, I.L. Karakhan, and Yu.A. Shirokov, Uelen's Carved Bone: The Folk Art of Chukotka, 2002; M.M. Bronshtein, and Yu.A. Shirokov, Chukchi and Eskimo Carved Bone: The Artistic Crafts of the 1st – 20th Centuries from the Collections of the Museum of the Orient, 2008.

Archeologist Sergey Gusev (Heritage Institute, Moscow) began his work on the Chukotskiy Peninsula in the 1990s. He investigated many ancient settlements and discovered a Mezolithic site, Naivan, on Cape Chaplina. Recently, archeologist Alexander Orekhov (North-Eastern State University, Magadan) started to conduct test excavations in the area of Kivak Lagoon. Some time ago Orekhov dedicated much of his time to the study of the South Chukotka maritime culture (south portion of Anadyr Bay and the adjacent coast of Koryak Plateau).

During the last 30 years of studying and preserving the natural and cultural heritage of Russian Beringia, the joint work of the specialists and Native people became the most valuable type of research. This was started in 1975-1978 by the ethnographer Igor Krupnik, the whaleboat captain Leonard Botrogov, and the biologist Ludmila Bogoslovskaya. Now the employees of the Nature-Ethnic Park Beringia (Natalya Kalyuzhina, Director) and Beringian Heritage Museum (Tatyana Zagrebina, Director) continue this research. Zoologists Anatoliy Kochnev (Chukotka Branch of the Pacific Scientific Research Fisheries Center, Anadyr) and Andrey Boltunov (WWF – Russia) actively cooperate with the Native people.

During many years of successful cooperation a highly qualified network of observers was established. Over the course of 30 years these observers conducted the monitoring of marine mammals and climate change, recorded many stories told by elders, and compiled specialized

Photograph copyright Bogoslovskaya Archives

Figure 6. Members of the Chukotka zoological expedition and Native Eskimo from the village of Sirenki who in 1985 sailed in baidara (umiaks) along the Chukotka coast. Standing (left to right): zoologist L. Bogoslovskaya, lookout T. Panauge, motorist S. Nanukhtak, ornithologist B. Zvonov. Sitting: ornithologist N. Konyukhov and umiak captain V. Mienkov.

Eskimo and Chukchi dictionaries. These types of projects play a great role in preservation of Native cultures and languages. The aggressive influence of the Russian variant of Western culture and by socio-economic market relations has further endangered not only the ancient marine mammal culture, but the existence of Asiatic Eskimo and Chukchi.

The Native people aspire to strive to contra pose their traditional cultural values to this negative influence and to preserve for future generations the natural and cultural heritage of the region and their Native tongues. Because without them, the transfer of the traditional knowledge, customs and rituals from one generation to the other is impossible.

I would like to name just a few activists in this area: Artur Apalyu and Alexander Borovik (photography series: Whale Hunting, Ringed Seal Hunting, Yanrakynnot and Novoe Chaplino Inhabitants); Tatyana Achirgina, Roman Armayrgin, Tatyana Pechetegina, and Victoria Golbtseva (marine mammals and weather monitoring, compiling of Uelen wind and ice dictionaries); brothers Vladilen and Sergey Kavry (photography of the marine animals of the Arctic coast of Chukotka); and Valentina Leonova (hand written book Memory of Naukan). I especially would like to note an archival photo exhibit and two booklets that T. Achirgina prepared to commemorate the sad anniversary of the closing of the villages Un'azik' and Naukan in 1958-1959.

In conclusion I would like to note that by 1988 more than 100 countries recognized the special status for the Bering Strait region as a repository of world significance, containing answers to many questions about Earth's history. This provision was included in the resolution of the General Assembly of the International Union for the Conservation of Nature and Natural Resources (IUCN). However, currently this whole region is in danger due to development of the oil-containing shelf zone of Bering and Chukchi Seas on both Russian and USA sides (*Figure 3*). This is a source of great concern for the Native peoples of Bering Strait region and the international scientific community that work together to preserve the natural and historic-cultural heritage of Beringia.

Climate Change

Photograph courtesy of Bruce G. Marcot

Modeling Approaches for Predicting Change Under WILDCAST: Making Progress in a Data-Poor World

By Bruce G. Marcot

Abstract

A basic framework is suggested for knitting together models of climate change, vegetation, and wildlife habitats and species, for use in the U.S. Geological Survey, Alaska Science Center's WILDCAST Program. The framework also addresses influence of climate change on key ecological functions of organisms and on ecosystem services of value to people. Many of the linkages among models will require expert interpretation. Tools and approaches to formalizing that expertise are suggested, as are next steps in the modeling process.

Background: The WILDCAST Vision

The U.S. Geological Survey (USGS), Alaska Science Center has initiated a major new program to produce a documented, knowledge-based forecasting tool called the WILDlife Potential Habitat ForeCASTing Framework (WILDCAST). WILDCAST is intended to help predict potential influences on species, communities, wildlife habitats, and ecosystems from climate change over the next century.

WILDCAST is a major undertaking. To be successful, it must span and knit science and models of global and regional climate including effects of climate change on subsurface and exposed water and ice; vegetation response and dynamics; interpretation of vegetation and environmental conditions in terms of habitat and resources for wildlife; interpretation of wildlife species and population responses to changes in habitats and environmental conditions; and how all these changes influence the functions of, and services provided by, ecosystems.

Figure 1. Drained lake in Bering Land Bridge National Preserve.

The tools and models developed under WILDCAST should also provide insight into the types, degrees, and implications of uncertainty in each of these linkages, as well as the expected sensitivity of outcomes to various scenarios of climate change and environmental conditions.

A Framework for WILDCAST

The basic linkages can be depicted as an influence diagram (*Figure 2*). Note the explicit presence of unknown and unmodeled effects, and also, in the bottom right of the diagram, the feedback arrow that represents how ecological functions of organisms can affect the occurrence and distribution of other organisms.

Modeling Questions

There are many possible objectives and purposes for the WILDCAST tool, including: 1) to describe some pattern, 2) to compare a pattern with some goal, 3) to explain the pattern (mechanisms), 4) to predict outcomes in other geographic areas, 5) to predict outcomes in future time periods, 6) to diagnose problems, 7) to identify best parameters for monitoring, 8) to identify best parameters for conservation, and other possible uses. No one modeling system can fully achieve all of these objectives, so it will be critical to clearly define what WILDCAST will be expected to do.

Similarly, it will be helpful to identify the intended audience(s) for the WILDCAST tool. They might include researchers and scientists, managers in land management agencies, politicians, the general public, local communities, the courts, attorneys, and others. Some of these audiences, such as scientists, embrace uncertainty, whereas others want to dispel doubt and desire answers in simple terms. To satisfy all audiences will be a challenge.

The stated purpose of WILDCAST is to forecast climate change and its influence on vegetation, land cover, and wildlife response. But how accurate do forecasts need to be? Accuracy pertains to

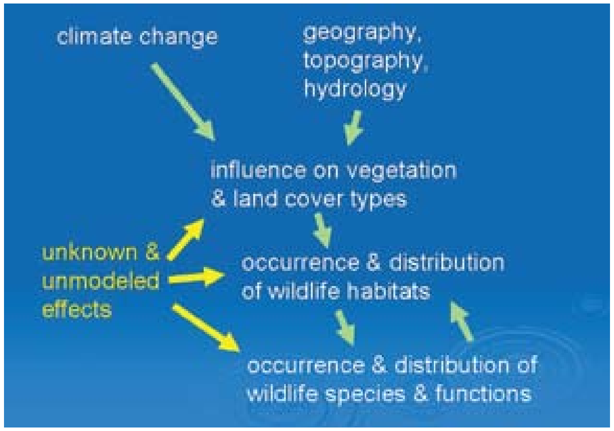

Figure 2. An overall "influence diagram" framework of model linkages for use in U.S. Geological Survey's WILDCAST Program of evaluating climate change.

Figure 3. An example of a "key ecological function" of wildlife. A black bear has dug out this log in search of grubs to eat. The log and woody material now can be readily invaded by fungi, bacteria, and insects that will break down the wood into organic matter and nutrients to be taken into the soil, and the cavity can be occupied by rodents, and other species. In this way, the action of the bear provides ecological services and functions benefitting other species and the ecosystem. How will such functions be affected by the influence of climate change on the bear's habitats and food sources?

correctly forecasting the trajectory of change. Would forecasting just the direction of change be enough? How should uncertainty play a role in forecasting accuracy?

Many forecasting models produce predictions that increase in uncertainty over future time periods; that is, the rangeof possible future conditions spread out over time. The spread represents increasing uncertainty, which can be represented in the models as increasing variance, a widening confidence interval, and other measures of variation. A familiar example is the spread of the potential tracks of hurricanes, where the most likely track is depicted with the most severe forecast of a hurricane warning, and less likely tracks shown, in decreasing severity, as areas of hurricane watch, tropical storm warning, and tropical storm watch. In a similar way, forecasting climate change and its effect on wildlife habitats, species, functions, and ecosystem services may be depicted with increasing uncertainty over time, with various possible outcomes shown with probabilities and various levels of warnings. Combining outcomes with probabilities is the basis for risk analysis, where warnings of "risk" refer to probabilities of not achieving some stated goal or desired outcome.

In addition, how precise do forecasts need to be? Precision pertains to how fine the increments of change can be forecasted and depicted. What are acceptable levels of spatial or temporal resolution in the forecasts? That is, what are acceptable levels of habitat and species occurrence, abundance, and distribution?

Answering questions of objective, purpose, audience, accuracy, and precision – as well as related questions of bias, consistency, and area of application – will help guide development of the WILDCAST tool but will not necessarily eliminate uncertainty and the need to use expert judgment.

Working With Uncertainty

Climate, being inherently variable and often chaotic, is the paragon of uncertainty (*Mitchell 2007*). But uncertainty is information that can be of value to decision-makers who deal with questions of risk management and managing systems that are chaotic or poorly understood.

Thus, WILDCAST is an example of complex ecological interactions and outcomes with no simple analytical solution. There are a number of rules of thumb, or tips and tricks, to solving analytically intractable problems. For example, one approach is to decompose the problem into more tractable and solvable sub-problems, to split the model, so to speak. Then, it can become easier to build, test, and update the submodels. Examples of submodels are functions of individual species-habitat relationships (e.g., resource selection for particular species).

Another approach to tackling difficult problems is to make the best estimates for variables and their relationships, based on expert judgment. Expert panels can be used to provide a range of possible values and functions. Competing models can be evaluated for their specific forecasting ability, and the best one(s) chosen for application.

A third approach is to use a combination of information sources, such as expert panels, statistical methods of combining information and meta-analysis, and use of traditional local knowledge.

Beginning the WILDCAST Modeling Work

A simple but useful approach to framing the models for WILDCAST is to build influence diagrams, also known as concept maps, cognitive maps, mental maps, and mind maps. Figure 2 is an example of an influence diagram. Influence diagrams depict the major components of a system and how they relate functionally or logically. A number of computer software programs are available for creating influence diagrams, including Microsoft's PowerPoint, Mindjet's MindManager, Inspiration, Personal Brain, Norsys' Netica, cMap, and FreeMind (the latter two being freeware).

One step up from an influence diagram is to statistically denote the strength of the connections in the diagram. Strengths can be shown in various ways, including partial correlations as used in path regression models, strengths

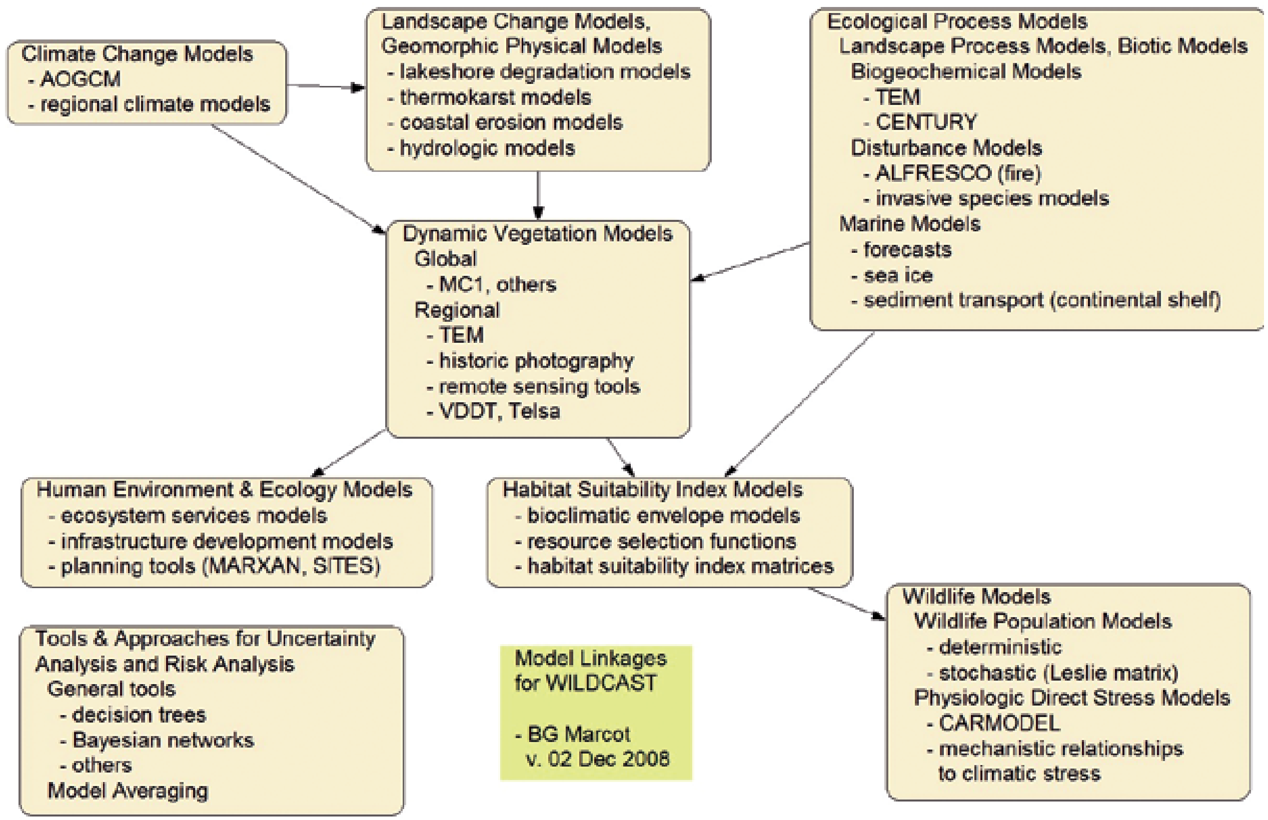

Figure 4. A fuller expression of the WILDCAST influence diagram shown in *Figure 2*, denoted with specific models and topics.

of evidence as used in fuzzy logic models, and transition probabilities as used in Markov chain models. Note that the uncertainty portion in Figure 2 can be included to show the relative influence of uncertainty in the model. Various approaches to estimating strength of connections are available, including structural equation modeling, which is a generalized approach to statistically formalizing relationships among variables such as with regression and factor analysis.

If the connections in an influence diagram are depicted with functions, the system can then be depicted as a process simulation model. One commercially-available modeling shell is the STELLA program which produces time-based projections of values of variables.

The Wildlife Connection

Wildlife-habitat relationships (WHR) models pertain to the bottom two segments of our WILDCAST influence diagram (*Figure 2*) – predicting species from habitats. WHR models typically take the form of a matrix or data table in which species are listed down the rows and various habitat or land cover types are listed across the columns, and cells are filled in according to the presence or strength of relation between the two. WHR models are often created from a variety of information sources including expert judgment and experience, anecdotal observations, field studies, and literature reviews. Examples of WHR models include databases built for terrestrial wildlife species in Oregon and Washington (*Johnson and O'Neil 2001*) and in the interior Columbia River Basin of the inland west U.S. (*Marcot et al. 1997*).

WHR models can extend well beyond simple depictions of habitat types. The Johnson and O'Neil WHR model has been extended as a relational database to include information on wildlife habitats, habitat structures (structural or successional stages of vegetation), key environmental correlates, and influence of management activity on habitats and environmental correlates, as well as categories of key ecological functions and life history attributes of each species. Further extensions can include categories of key cultural values of each species, which depict how local communities and cultures value and use organisms for a variety of needs and purposes. Developing such extensive WHR models for the WILDCAST project should be possible and would provide great value for evaluating climate change effects not just on wildlife but also on human communities.

Key Ecological Functions and Ecosystem Services

The WILDCAST tool could explicitly include the influence of key ecological functions (KEFs) of organisms: the way that ecological roles of wildlife can alter environmental attributes and habitat suitability for other species. Examples of KEFs include primary cavity-excavating birds (e.g., woodpeckers) creating tree hollows occupied by a host of secondary-cavity using species (e.g., some small owls, squirrels); species of insects and some birds (orioles, hummingbirds) that pollinate flowering plants; and organisms (pileated woodpecker, black bear) that strip or tear apart dead trees, thus providing coarse organic matter for incorporation into soils (*Figure 3*). I have developed an extensive, hierarchical classification system of KEFs and used it in various WHR models to evaluate the functional patterns of a variety of wildlife assemblages and communities (*e.g., Marcot and Aubry 2003*), including how conditions of habitat and environment provide one set of species whose KEFs influence habitats and environments for other species.

WILDCAST also could be designed to forecast influence of climate change on ecosystem services. Ecosystem services are those resources and ecological processes that are of value to people and that can serve to sustain a natural ecosystem. Examples include water filtration by wetlands, pollination of crop plants by native bees, carbon sequestration by trees, medicinal uses of native plants, and many other categories. A growing field of environmental economics is beginning to valuate ecosystem services (*e.g., Brown et al. 2006*), and such estimates could be included in the WILDCAST framework.

Where To Next?

The next steps in the WILDCAST program might involve answering questions raised here about scope, purpose, and audience, and then questions of model accuracy, precision, and related attributes.

In October 2008, a workshop was held in Fairbanks to begin the process of identifying the various components and submodels of the WILDCAST influence diagram presented here, and how they might begin to be linked (*Figure 4*). Making linkages among the submodels will likely require expert judgment and interpretation (*Ayyub 2001*). One possible method for identifying linkages is use of formal expert panels or other knowledge engineering approaches to develop probabilistic structures such as Bayesian networks (*Van Allen et al. 2008*). Bayesian networks could depict the degree to which the output of one model, such as a vegetation condition model, would serve as a proxy input variable for another model, such as a wildlife habitat model. I have successfully used this approach in developing Bayesian network models of wildlife-habitat relationships.

With the advent of the National Climate Change and Wildlife Science Center in Lansdowne, Virginia, recently formed by the USGS, modeling effects of climate change will certainly continue to garner great interest and concern from a host of audiences, partners, and stakeholders in natural resources management.

Acknowledgments

My thanks to USGS, particularly Leslie Holland-Bartels, Carl Markon, and Sue Haseltine, for inviting me to work on several modeling projects pertinent to WILDCAST. Thanks to Carl Markon for review of the manuscript. Mention of product names does not necessarily constitute endorsement by the U.S. Government.

Photograph courtesy of Bruce G. Marcot

Figure 5. View of the Schwatka Mountains in Gates of the Arctic National Park and Preserve.

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Changing the Arctic: Adding Immediate Protection to the Equation

By Falk Huettmann and Sue Hazlett

The Arctic represents a region of the globe directly affected by climate change, human disturbance and natural variation. In addition to acting as the global weather machine, it is considered one of the last remaining "wilderness" areas. However, the warming of the Arctic, a prospect of an ice-free maritime route across the top of the world, and the International Polar Year (IPY), have piqued an interest in the Arctic not previously seen. Prospects of shipping routes, tourism, oil and gas development, and new commercial fisheries have started a "land rush" by various nations to claim a piece of the northern oceans. The Arctic is in danger of being given away piecemeal as each nation asserts claims and then rushes to develop or exploit their territory to aid in establishing ownership.

A wider public discussion on the protection and management of this unique zone has not happened, and despite, or perhaps because of, globalization, protection is still difficult to implement. So far, if at all, only haphazard conservation measures have been considered. Most lack either focus, enforcement, or a performance review. The recent listing of polar bears in the U.S. is a prime example, and Alaska is in the process of appealing the listing for fear protection will interfere with oil development and related transportation in the Alaskan Arctic. Other species in decline include the ivory gull, thick-billed murres, Kittlitz's murrelets, some eider duck species, various shorebirds, and Arctic cod.

Many other crucial components of the Arctic biodiversity have not even been assessed, calling for the Precautionary Principle, as promoted by the International Union for Conservation of Nature. Science-based adaptive management, a management method widely suggested to attain sustainability, had not really been applied to the Arctic. In this article we describe and assess the existing protection schema, and the pros and cons of increased protection in the Arctic, as well as how it links with global sustainability in monetary, biodiversity, and other terms. We are in a strong position to do this assessment because we were able to assemble over 45 data sets in a consistent format and as GIS layers for the entire circumpolar Arctic (*see Figure 1*).

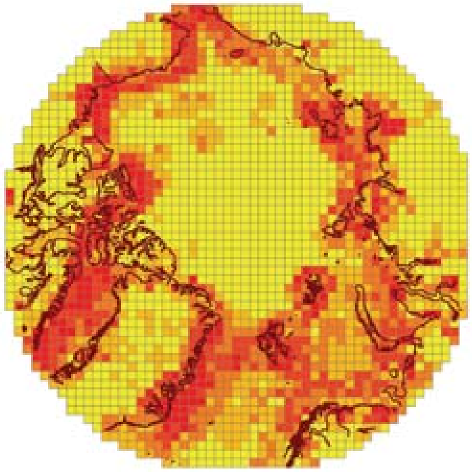
So what would be the best level of protection for the Arctic and how would this be accomplished? With the Antarctic Treaty for instance, half of the polar regions have basically been protected for decades. In contrast, few Arctic conservation zones exist, and they were virtually derived ad hoc, without any relevant principles of global democratic governance and management practices. There has consistently been a history among nations of protecting 'rock and ice', and most current protected areas within the Arctic are of this type. If individual nations are each left to decide the level and area of protected areas, this concept would likely be the case for any future mandated protection. Many decisions were made without proper data and driven by specific agendas. Promotion of economic growth and nationalism have driven management decisions in the Arctic rather than a global consideration of biodiversity, indigenous people and potential ecological services. As more development occurs, protection appears to continue to be an ad hoc process that protects an area with no perceived economic value. This is also true if protection is mandated to a certain percentage of the overall Arctic, or of each country's territory (the Rio Convention figure is a meager 10%). It is known from elsewhere that a small fragmented network of conservation features does not meet protection goals. We would like to put forth the concept of considering the Arctic as an entire ecosystem which takes long-distance migration and energy flows into account, and propose the proper use of Strategic Conservation Planning to implement conservation plans on an international level before wholesale development of the Arctic begins.

As an example of such strategic planning, we propose using a MARXAN optimization modeling analysis (*see Figure 2*). MARXAN has been widely applied in many countries and types of marine ecosystems for creating marine protected areas (MPAs). Using some basic scenarios, the model helps find the best available distributions of protected zones given the specified inputs for each scenario to satisfy the greatest number of stakeholders. Data used in the model were taken from various research publications that mapped ranges of arctic species, oceanic conditions, and human impacts in the Arctic, for a total 45 circumpolar GIS layers.

Number	Data Set Name
1	Coastline
2	Bathymetry
3	Human Settlements
4	Mean Ice Cover
5	Sea surface salinity
6	Sea surface temperature
7	Phosphate concentration on sea surface
8	Silicate concentration on sea surface
9	Ocean currents
10	Bioclimate zones
11	Arctic physiological zones
12	Travel- and Shipping routes
13	Current areas of interest to fishing industry
14	Future areas of interest to fishing industry
15	Predicted distribution of Zooplankton (Calanus glacialis)
16	Predicted distribution of Zooplankton (Calanus hyperboreus)
17	Predicted distribution of Zooplankton (Metridia longa)
18	Predicted distribution of Zooplankton (Metridia pacifica)
19	Treeline
20	Areas of interest to Oil & Gas Exploration
21	Bearded Seal distribution
22	Ringed Seal distribution
23	Known Ringed Seal pup sites
24	Narwhale distribution
25	Walruss distribution
26	Polar Bear distribution
27	Orca distribution
28	Beluga whale distribution
29	Known Beluga autumn concentration sites
30	Known Bluewhale migration corridors
31	Known Finwhale migration corridors
32	Land area
33	Known marine biodiversity hotspots (ArcOD)
34	Known Arctic biodiversity hotspots
35	Large Lakes
36	Major Rivers
37	Muskoxen distribution
38	Ivory Gull distribution
39	Major Thick-billed Murre colonies
40	Protected Areas
41	Known Bird flyways
42	Sites of known nuclear pollution
43	Sites of known Caesium pollution
44	Sites of known PAH pollution
45	Planning Units (100km)

Figure 1. (Left) List of Circumpolar Data Sets compiled by the authors and that inform the Marxan runs of this investigation.

A) 20% Viable Seabirds & Habitats



B) 10% Economy & Ecology Compromise

Figure 2. Scenario results of a MARXAN run for the optimization of (A) protection of seabirds (ivory gulls and thick-billed murres) and their relevant habitats, and (B) 10% compromise between general economy and ecology. Red cells indicate highest priorities to achieve goals.

However, such tools are only a first step and require further fine-tuning, approval and use by various governments, stakeholders and legislation. We would highly welcome a wider public discussion, challenge and update of our modeling work. It is extremely likely that developing the Arctic will involve the loss of species, habitats, and sustainability detrimental to existing legislation. We are proposing that the real legacy of the International Polar Year is indeed a protected circumpolar park that achieves the larger sustainability goals in the framework of adaptive management. Science-based adaptive management of Arctic resources can only be achieved when based on sound and mutually accepted data. Such a database, presented at a central web portal, still needs to be assembled and constantly be improved. It can only go hand-in-hand with high-quality monitoring efforts that feed into such efforts and link directly with policy.

We conclude that an immediate large-scale protection (e.g. over 30%) of Arctic resources is warranted, and that the business as usual outlook in the mid- and long-term future will be devastating for most Arctic resources and playing a role in destroying global resilience. Thus, adding protection to Arctic management is not only a best professional practice, in full agreement with the original sprit of the conservation laws, but an inherent part of a global survival strategy.

'The Ice We Want Our Children to Know': SIKU Project in Alaska and Siberia, 2007-2008

By Igor Krupnik

This paper presents an overview on the origins, structure, and current activities under the Sea Ice Knowledge and Use (SIKU) project, which is a part of the International Polar Year (IPY) 2007-2008 science program. The project's acronym, SIKU, is also the basic word for sea ice (*siku*) in all Eskimo/Inuit languages from Bering Strait to Greenland. The SIKU project was started in 2006 and will continue until 2010. Local experts from more than 20 northern communities in four countries participate in SIKU studies conducted by several teams from five nations: Canada, U.S., Greenland, Russia, and France. The program is run as an alliance of several individually funded activities, including two major core grants from the 'Shared Beringia Heritage' program of the U.S. National Park Service and the Government of Canada Program for IPY for the Canadian component called Inuit Sea Ice Use and Occupancy Project (ISIUOP).

The key goal of the SIKU initiative is to document indigenous knowledge about Arctic ice and polar residents' use of the ice-covered marine environment under the impact of climate warming and rapid social change. SIKU activities include ice and weather monitoring by community observers, interviews with elders and hunters, and compilation of local dictionaries of sea ice terms in indigenous languages. These and other activities exemplify the key mission of the SIKU project, namely, to advance polar residents' participation in IPY and to strengthen their contribution to the scholarly studies of Arctic climate change. By its very nature, the SIKU project embodies the inclusive character of IPY 2007-2008; its reliance on sharing and collaboration; and its appeal to the Arctic people.

The SIKU project originated as a follow-up to several recent efforts in the documentation of local knowledge and use of sea ice (*Gearheard et al. 2006, Laidler 2006, Oozeva et al. 2004*). When the call for the prospective IPY activities was issued in 2005, Dr. Claudio Aporta from Carleton University in Canada and I submitted a joint proposal for the SIKU initiative, for which we agreed to work as Principal Co-coordinators (*see http://gcrc.carleton.ca/siku*).

SIKU-Alaska Activities

SIKU efforts in Alaska were launched in spring 2006, almost a year before the official start of IPY 2007-2008. Eventually, indigenous experts from seven Alaska communities (*Figure 1*) became partners in SIKU-Alaska studies. The main features of the SIKU-Alaska effort are its focus on knowledge and heritage documentation and on the integration of observations by local experts to help introduce these data into science models of sea ice dynamics, marine animal distribution, and ecosystem shift.

Specific SIKU-Alaska activities may be summarized as follows. In the village of Wales, daily sea ice and weather observations by Winton Weyapuk, Jr., have been conducted since winter 2007 (*Figure 2*) under the National Science Foundation (NSF) sponsored SIZONeT (Seasonal Ice Zone Network) project headed by Dr. Hajo Eicken from the University of Alaska Fairbanks (UAF). Work in Wales is very much focused on the integration of local hunters' knowledge with modern geophysical methods, such as the use of coastal ice radar, satellite imagery, and on-ice and air-borne thickness measurements. SIKU studies in Wales also include the compilation of the 112-page Wales Inupiaq Sea-Ice Dictionary of some 120 local sea ice terms (*Weyapuk and Krupnik 2008*) (*Figure 3*) and the analysis of historical photography, specifically, the review of several dozen photographs of sea ice hunting taken in Wales by biologist Alfred Bailey in spring 1922.

In Gambell on St. Lawrence Island (*Figure 4*) daily observations of local ice and weather conditions began in Spring 2006 by Leonard Apangalook, Sr., and will be conducted for three full years. Work in Gambell also includes interviews with hunters and survey of the historical records on local ice and subsistence hunting practices since the late 1800s (*Krupnik 2009*).

In Shishmaref SIKU activities are integrated into Josh Wisniweski's Ph.D. study at UAF that includes daily observations of ice and weather conditions, and subsistence hunting, preparation of a bilingual dictionary of local Iñupiaq ice terms used by Shishmaref hunters, and development of cultural curriculum materials for the local school.

Figure1. SIKU project activities in Alaska and Chukotka.

In Barrow on the arctic shore, studies are focused on the integration of local hunters' observations with the geophysical instrumental records under the NSF SIZONeT project. On Nelson Island in the southeastern Bering Sea, another NSF-sponsored project by Ann Fienup-Riordan, Mark John, and the Calista Elders Council collaborates with SIKU-Alaska in the preparation of local dictionary of the Yup'ik sea ice terms, mapping local use of sea ice, and interviews with Yup'ik elders on hunting and sea ice conditions, both past and present.

During the winter 2008-2009, local ice observations will continue in Gambell, Wales, Barrow, Shaktoolik, and, hopefully, also on Nelson Island, to produce a record for two or even three winters (2006-07, 2007-08, 2008-09). Four local sea ice dictionaries are to be completed in Barrow, Shishmaref, Nelson Island, and Shaktoolik, with the associated educational materials for participating communities.

SIKU-Chukotka Activities

Presently, SIKU-related activities are conducted in five communities in Chukotka, with support from local hub communities Anadyr and Provideniya, and the Russian Institute of Cultural and Natural Heritage in Moscow.

In the village of Uelen in the southern Chukchi Sea, the documentation of local sea ice knowledge is supported by the Chukotka Branch of the Far Eastern Research Institute (SVKNII) in Anadyr. It features daily sea ice observations (since 2006), interviews with elders, a dictionary of sea ice terms in the Chukchi language (*Figure 5*), and collection of historical data on local weather and ice conditions. In the town of Lavrentiya, Boris Alpergen and Elizaveta Dobrieva are working on the documentation of the Naukan Yupik knowledge of sea ice, producing an illustrated bilingual ice dictionary. In Sireniki, a mixed Yupik and Chukchi community in the northern Bering Sea, Aron Nytawyi, one of the few local speakers of the Yupik language, has compiled a dictionary of some 60 Yupik ice terms, with the associated safety rules. Since 2007, the Russian Beringia Park in Provideniya has supported three local ice monitors in the communities of New Chaplino, Yanrakynnot, and Sireniki, as its contribution to the SIKU project. Village monitors supply daily records on ice and weather conditions, subsistence activities, and marine mammals and birds. Russian SIKU researchers from Anadyr, Provideniya, Moscow, and St. Petersburg (Lyudmila Bogoslovskaya, Boris Vdovin, and Igor Zagrebin) participate in the collection of data on sea ice use and marine mammals, and processing of historical records on ice and climate change in Chukotka (*Krupnik and Bogoslovskaya 2008, Vdovin and Evstifeyev 2008*). An important component of the SIKU-Chukotka program is public outreach (*Figure 6*) and education.

Photograph courtesy of Matthew Druckenmiller

Figure 2. Winton Weyapuk, Jr., on the shore-fast ice off Wales, Alaska.

For the second IPY winter of 2008-2009, the Russian SIKU team plans to continue ice observations in three Chukotka communities (Uelen, New Chaplino, Yanrakynnot), complete three sea ice dictionaries in local languages, process historical ice and climate records, and disseminate project results through scholarly publications and community outreach. The SIKU-Chukotka team has already produced five publications in Russian and English, and it envisions a major volume of Russian SIKU contributions in 2011.

Conclusion: Major SIKU Science Issues

The role of the SIKU project in the documentation of local knowledge and use of sea ice and in advancing Arctic residents' participation in IPY 2007-2008 is difficult to overestimate. The key science implications of the SIKU program can be summarized as follows.

Firstly, local SIKU studies have produced massive sets of new data on sea ice, climate, subsistence activities, and other relevant information for over 20 indigenous communities across the Arctic. The data collected by local indigenous observers during three past winters will be an invaluable source of information for future researchers, particularly in the studies of transition from a multi-year to the first-year ice regime, and of the ways of knowing, watching, and using the ice by polar residents during the time of IPY 2007-2008.

Secondly, access to the Arctic residents' knowledge via SIKU data and publications will impact the ways physical scientists view and interpret polar ice. Many ice scientists are now open to the value of indigenous knowledge. They are currently looking into new ice parameters to be added to their models, other than the overall extent or thickness, such as ice age, safety, strength, and local variations, very much as is already described by indigenous ice users.

Thirdly, scientists traditionally concentrate on the long-term ice dynamics as an indicator of climate change. The users' perspective, to the contrary, focuses on the short-term variations in each winter, like the specifics of the freezing and thawing processes, and the occurrence of break-up and freeze-up events. Again, we currently witness much greater interest among ice scientists in the seasonal, monthly, or even daily ice dynamics, which is remarkably close to the indigenous perspective. This convergence may expand the application of local users' vision to the scholarly ice and climate models.

Fourthly, SIKU studies will greatly advance our knowledge of traditional Eskimo/Inuit sea ice terminologies and ice classifications. Under the SIKU project, at least a dozen indigenous sea ice 'dictionaries' and scores of local

Figure 3. Cover page of the *Wales Iñupiaq Sea Ice Dictionary* (Weyapuk and Krupnik 2008).

Photograph courtesy of Igor Krupnik

Figure 4. Ice pressure ridge built of thin winter ice off Gambell, St. Lawrence Island. The ridge was destroyed and washed away shortly by a strong storm.

ice classifications are to be collected from Bering Strait to Greenland. The diversity of the Eskimo/Inuit ice terminology is striking, as only but a handful of basic terms, such as *siku* itself, are common across the Eskimo/Inuit language area. Each regional or dialectal list of ice words also shows strength in a particular type of ice or ice-related phenomena typical to a certain area that are of particular importance to local users.

Last, but not least, in many northern communities indigenous terms and classifications for sea ice are being rapidly replaced by English or Russian terminologies; in some places only a few elderly experts retain the old knowledge. The sea ice is also changing rapidly, so that many types of ice, for which there are terms in local languages, cannot be observed anymore. If these trends continue the documentation of indigenous knowledge may become the last reservoir of detailed information on the former ice regimes that could be swept away by the Arctic warming. In the long-term perspective, this may be the most important outcome of the SIKU project and its lasting contribution to the IPY 2007-2008 program.

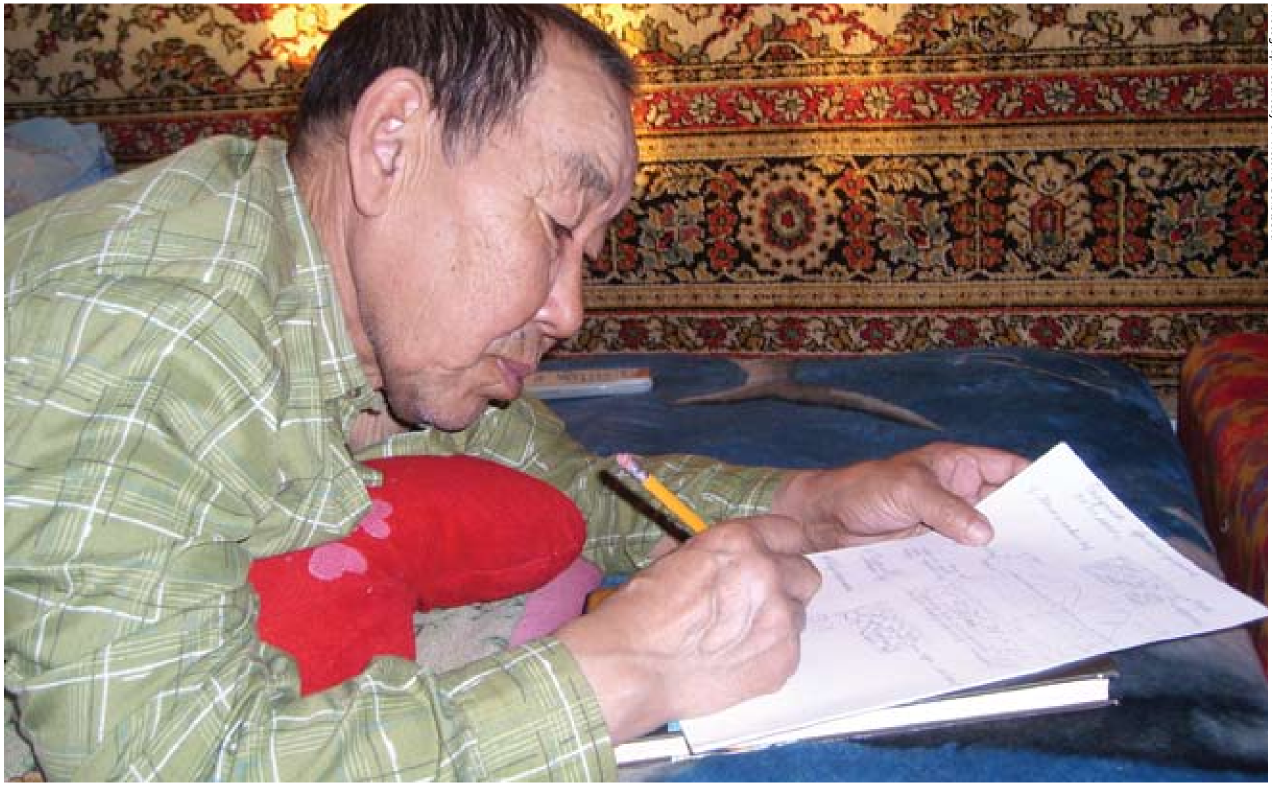


Figure 5. (Left) Roman Armaergen, 69, local hunter from the village of Uelen, makes pencil drawings to illustrate the Uelen Chukchi sea ice dictionary.

Figure 6. SIKU community presentation in Uelen (March 2008). Victoria Golbtseva (to the left) speaks to local elders about the documentation of sea ice knowledge.

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Tourism


NPS photograph by Mark Musitano

Understanding Alaska Public Lands Visitors Through Collaboration: The Alaska Residents Statistics Program

By Peter J. Fix, Linda E. Kruger, Daniel W. McCollum, Susan J. Alexander, Lois Dalle-Molle, William Overbaugh, and Jeffrey J. Brooks

Abstract

The Alaska Residents Statistics Program (ARSP) is a collaborative effort among federal land management agencies to gather information on travel patterns, subsistence and recreation activities, and how public land relates to quality of life. To gather this information, the ARSP study group designed and administered the Alaska Residents Outdoor Activity and Travel Survey to over 2,000 Alaska residents in 2006-2007. Results showing how management decisions might impact subsistence and recreation on public lands will be useful for regional level planning.

Introduction

Alaska's vast acreage of public lands (72 million acres of Fish and Wildlife Service, 70 million acres of Bureau of Land Management, 53 million acres of National Park Service, and 22.5 million acres of U.S. Forest Service lands) provides a diversity of subsistence and recreation opportunities for residents of Alaska and visitors. Understanding those who use public lands is critical for effective management. With respect to non-resident visitors, some studies were conducted in Alaska before statehood (*Stanton 1953*). While the study of non-residents has continued with the Alaska Visitors Statistics Program, there has not been a comprehensive program to study residents.

Studies of residents do exist, but with limitations. For example, the Statewide Comprehensive Outdoor Recreation Plan (*Alaska State Parks 2004*) which gathers information on participation in activities, but not where activities are conducted or settings that may be desired; the National Park Service's Comprehensive Survey of the American Public gathers information related to national parks; the Forest Service's National Survey on Recreation and Environment measures participation in myriad recreation activities, but might not generalize to specific sites in Alaska; and the Fish and Wildlife Service's National Survey on Hunting, Fishing and Wildlife Associated Recreation includes only a limited set of recreation activities. In addition, the above-mentioned studies tend to represent urban areas of Alaska, where the majority of the state's population is concentrated. While many on-site studies, or general population studies related to a specific area have been conducted in Alaska (*e.g., Giruad 2001; Brown and Reed 2000*), the results do not necessarily generalize beyond those sites.

The Alaska Residents Statistics Program (ARSP), a collaborative project among the U.S. Forest Service, National Park Service, Bureau of Land Management, Fish and Wildlife Service, the Alaska Department of Fish and Game, and the Alaska Department of Transportation, was developed to be a complementary program to the Alaska Visitors Statistics Program and gather information regarding Alaskans' recreation patterns and preferences as well as information on how public lands contribute to the quality of life in Alaska. The ARSP recognized that there are not unique USFS visitors, NPS visitors, etc. Rather, residents have preferences that lead them to visit many different types of public lands, and/or avoid certain types of public lands. Thus, it is critical to understand the preferences of Alaskans as a whole, not just focus on visitors to any one particular type of public land.

The ARSP study group developed and administered the Alaska Resident Outdoor Activities and Travel Survey (AROATS) to gather information on Alaska residents. The goal of the AROATS was to gather information on: where residents travel in Alaska; subsistence and recreation activities in areas traveled to, and activities in the area where they reside; areas they avoid; reasons for recreation; and factors contributing to quality of life. An additional goal was to have information that would represent rural areas of Alaska.

Figure 1. Walker Lake in Gates of the Arctic National Park and Preserve.

Methods

Survey Design: A mail survey with a map was designed to gather relatively detailed travel behavior. We first divided the state into five regions, based loosely on borough and conservation unit boundaries and geographic features. The regions represented were: Northern, Interior, Southwest, Southcentral, and Southeast (*Figure 2*). We divided each region into four smaller subregions. The subregions formed the units for which we measured travel to and participation in subsistence and recreation activities. The survey began by asking about travel and outdoor activities. Respondents were presented with a map that showed the subregions and key features in each subregion. Respondents were then asked if they traveled to (or lived in) each subregion and about their participation in 12 activities. The activities were: hiking, camping, wildlife viewing, freshwater fishing, saltwater fishing, food gathering, hunting and trapping, nonmotorized boating, motor boating, ATV/motorbike riding, skiing and snowshoeing, and snowmachining.

Respondents were also asked about visitation to public lands; sites they no longer visit (i.e., changes in visitation or displacement); reasons for participating in their activities; equipment ownership; value orientations towards wildlife; what brought them to Alaska, why they stay, and their plans to stay in Alaska after retirement; quality of life in Alaska; participation in hunting and fishing; and demographics. The demographic section included questions about where respondents lived prior to moving to Alaska, if applicable.

Sampling: To construct the basis for sampling, each city/village in Alaska, as defined by the U.S. Census Bureau, was placed into the appropriate region. Populations of the regions varied from 14,654 to 266,293 (for detailed information on the strata and response rates, see Fix and Tracy 2008). After examining the percentage of the population registered to vote and comparing the Alaska voter registration database (VRD) to commercially purchased samples, the VRD was chosen as the most appropriate sampling frame. For those regions with a high correspondence between the Census cities and the VRD (North, Southwest, Southeast) a proportional sample of approximately 2,000 was randomly selected. For the Interior and Southcentral, which had lower correspondence between the Census and VRD, a random sample of 2,000 was selected for each region. Respondents were mailed a postcard announcing the survey, followed by the survey, a reminder/thank you postcard, and a second survey for those who had not responded. After the second mailing, a third mailing was conducted for those cities/villages that remained underrepresented.

Figure 2. Survey regions for the Alaska Residents Outdoor Activities and Travel Survey.

Results

Response rate varied by geographic strata from 19% to 31%, with an overall response rate of 27%. A nonresponse test, consisting of three questions, was conducted for 146 nonrespondents. No practical differences were found between those who completed the survey and those who did not.

Travel: As expected, the Anchorage subregion of the Southcentral region had the highest visitation rate from each region (ranging from 25% to 49%), followed by the Fairbanks-Ft.Yukon subregion of the Interior region (ranging from 10% to 26%). The North and Southwest regions exhibited low intra-region travel with the average percent of respondents traveling to other subregions 7% and 6%, respectively (adjusted to account for population). Whereas the Southeast region (off the road system with operating ferries) showed higher intra-regional travel, averaging 19%.

Activity participation: Activity participation differed by regions. Food gathering had the highest percent of people participating in the past 12 months for the Northern and Southwest regions, 69% and 77%, respectively; hiking had the highest percent of participants in the Interior, Southcentral and Southeast regions, 57%, 64%, and 75%, respectively.

Displacement: The Kenai and Russian Rivers topped the list of areas people no longer visit, including people who reported a change in visitation patterns. Respondents from each region mentioned these two sites as places they no longer visit from a high of 20% for the Southcentral region to < 1% for the Southeast region. The overwhelming reason reported for displacement was crowding. Second to the Kenai and Russian Rivers was the Denali Park area (Denali National Park, State Park, and just "Denali Park"), also being mentioned by respondents from each region. The range of visitors being displaced was 4% in the Interior region to 1% in the Southeast and North regions. Crowding and commercialization were the most often cited reason for changing visitation patterns to the Denali Park area.

Significant activities and reasons for participating: When asked to identify a significant activity and select from a list of possible reasons for participating, fishing, hiking, and hunting were the top three activities (with 607, 450, and 437 respondents selecting those activities, respectively). However, there were differences in the most often cited activities by region (*Figure 3*). The top reason for fishing and hunting was to obtain meat/food, and the top reason for hiking was exercise and physical fitness.

Demographics: The North region had the highest percent of respondents born in Alaska (61%) followed by the Southwest. Each region had a small percentage of people who were born in Alaska but spent some time outside of Alaska. For the respondents who were not born in Alaska, Washington, California, and Oregon were the most often cited states as to where people lived before moving to Alaska.

Discussion and Management Implications

This project resulted in data that will serve two purposes: 1) it provides another piece of information regarding subsistence and recreation patterns for resident Alaskans, and 2) it can be used as a much needed source of social science information by various agencies for specific planning purposes. Collaboration on this project ensured that survey results and the initial database will be useful for each participating land management agency. While the information gathered by this project will not replace site specific research, it does support region level planning by identifying how changes in population, growth, and management policies at a particular conservation unit might impact subsistence and recreation activities on public lands.

Significant activity	Rank of significant activity by region				
	North	Interior	Southwest	Southcentral	Southeast
Fishing	2	1	1	1	2
Hiking	5	3	3	2	1
Hunting	1	2	2	4	3
Camping	4	4	5	3	4
Berry Picking and Food Gathering	3	5	4	6	6
Boating	7	7	7	14	5
Snowmachining	8	6	10	5	27

Figure 3. Ranking of significant activity by region. The respondents were asked: "Please list up to two outdoor recreation or subsistence activities that are significant to you. 1 = the most important activity.


NPS photograph by R. Winfree

Figure 4. Wildlife viewing.


NPS photograph by R. Winfree

Figure 5. Hikers on the Chilkoot Trail.

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Towards Predicting the Impact of Climate Change on Tourism: An Hourly Tourism Climate Index

By Sarah F. Trainor, John E. Walsh, and Gongmei Yu

Abstract

This study presents a tourism climate index based on hourly weather data. We use the index to assess changes in weather conditions conducive to outdoor activities at two destinations in Alaska: King Salmon (near Katmai National Park and Preserve) and Anchorage. The results indicate that climate warming has had both positive and negative effects on opportunities for tourism. The overall weather conditions for sightseeing in King Salmon have improved significantly, along with a lengthening of the season. Conversely, weather conditions for skiing in Anchorage have deteriorated since the 1940s, primarily because the end date of weather suitable for skiing during the late winter now occurs earlier. The results indicate that impacts of climate change will vary widely among locations and among different types of tourist activities.

Introduction

Tourism is an important segment of Alaska's economy, with millions of visitors a year. The direct and indirect effects of travel and tourist expenditures (not including multiplier effects) in Alaska have been between $1.5 and $2 billion in recent years. Tourism in Alaska exhibits clear seasonal patterns with 80% of visitors arriving between May and September (*Alaska Economic Performance Report 2005*), the majority of whom engage in outdoor activities. National parks are among the most popular destinations, and there is little doubt that the quality of a visitor's experience is affected by the weather. This work addresses changes in climate and associated changes in weather that have implications for national parks and, more generally, outdoor tourism in Alaska. It draws upon the notion that climate can be viewed as a tourism resource.

Climate can affect tourism in several ways. The direct effect, which is addressed in this work, arises from the effect of weather on the outdoor experience of a tourist. The indirect effect, which can be even more important in the long-term, pertains to effects of climate on wildlife, glaciers and ecology of a region. These characteristics affect the attractiveness of a tourist destination. For example, if climate were to drive a significant exodus of bears from Katmai National Park and Preserve, bear-viewing tourism would obviously be impacted. The present work does not address this type of longer-term climatic impact.

An abundance of evidence suggests that Alaska is warming, most noticeably in winter and spring (*Figure 2*). This has led to an earlier transition from winter to spring and a later transition from fall to winter. The impact of these seasonal changes is already being felt by various sectors of industry and by indigenous communities (*ACIA 2005*). For example, Gregory et al. (*2006*) report that climate changes in Northwest Alaska are impacting the timing of resource availability (fishing, hunting) and access to resources such as ice, rivers, and the ocean.

NPS photograph by Robert Winfree

Figure 1. Bear viewing in Katmai National Park & Preserve.

Despite the overwhelming evidence that significant seasonal changes are occurring in Alaska, and despite the recognition that these climate changes are bound to impact tourism, there has been little empirical research addressing the climate change/tourism domain in Alaska. The present study extends the research on impacts of climate, by using Alaska as a case study for the use of an hourly tourism climate index to assess the existence of favorable weather conditions for specific tourism activities (i.e., summer outdoor activities and winter skiing). More generally, the purpose of this study is to devise and test a quantitative tool for measuring climate as a tourism resource. The methodology presented here utilizes multivariate information at high temporal resolution, thereby bridging the weather that tourists experience in practice and the climate information that is generally represented by averages.

Methods

The methodology utilizes a three-level climate index for tourism (CIT) where a value of 2 denotes favorable conditions for an outdoor activity, 1 denotes marginal conditions, and 0 denotes unsuitable conditions (*Yu and Schwartz 2007*). The CIT combines several critical weather elements, including temperature, wind speed, visibility and falling precipitation. The index builds upon previous attempts to quantify tourism-related climate conditions, allowing for more detailed applications and in-depth statistical analysis.

A unique feature of this index is the use of hourly weather observations. Hourly data contain more valuable information than statistical data (such as averages, maxima and minima) when measuring the suitability of weather conditions for outdoor tourism activity. Weather elements such as rain, thunderstorms and visibility can vary within a day and are often tied to the diurnal cycle, as are many tourist activities. The intermittency of certain types of weather can be lost in daily and especially monthly averages. For example, a day with total precipitation of 1 inch could be the result of a one-hour intense downpour, or 12 hours of lighter rain. It could occur during mid-day or at midnight.

An hourly index can be tailored for a specific tourism activity that requires particular weather conditions during a particular time of day. It can provide micro-level information on the number and seasonal patterns of days or hours suitable for a specific tourism activity, in an area with specific natural resources (e.g., beach and mountain). It can capture, through "frequency" statistics such as those presented here, the probabilities that particular hours (or subsets of hours) will be suitable for a particular outdoor activity—a level of detail that cannot be obtained from monthly or even daily data.

The four variables on which the hourly index is based are (i) perceived temperature (heat index in summer, wind chill in winter), (ii) wind speed, (iii) visibility and (iv) present weather (a synoptic element, indicating type and intensity of any precipitation, thunder, lightning, smoke, blowing dust, etc.). Each variable is assigned a value of 2 for favorable, 1 for marginal and 0 for unsuitable conditions. The four subindex values determine the CIT, which is 2 if all four subindices are 2, 0 if any of the four subindices are 0, and 1 otherwise. This assignment of CIT values illustrates the overriding nature of the four weather elements: if any one of the four is unsuitable, the aggregate CIT index is in the unsuitable category.

Hourly weather observations from two destinations in Alaska, King Salmon (1943-2005) and Anchorage (1942-2005), were used in this study. Summer sightseeing and fishing are the main tourism attractions in King Salmon, which is located a short distance from Katmai National Park and Preserve (Katmai), a renowned area for viewing bears and other wildlife. Here we use King Salmon as a proxy for Katmai. Anchorage is the most popular area for skiing in Alaska. The city's wealth of cross-country ski trails gives it a higher concentration of urban skiers than any other city in the United States, and the close proximity of several major downhill ski areas attracts local as well as out-of-state skiers.

King Salmon's summer season length was quantified using hourly values of the CIT that were based on thresholds specified to capture suitability of weather conditions for sightseeing (favorable conditions require perceived temperature between 40° and 85°F, wind speed less than 13 mph, visibility at least 4 miles, and absence of precipitation/smoke/dust). Anchorage's winter season length was quantified using CIT values based on thresholds specified to capture suitability for skiing (favorable conditions require perceived temperature between -10° and 32°F, and the other variables in the same range as for sightseeing conditions). In addition, for comparative purposes we have performed the same calculations for Orlando, Florida, which is heavily dependent on tourism.

Total Change in Mean Seasonal and Annual Temperature (°F), 1949 - 2007

Region	Location	Winter	Spring	Summer	Autumn	Annual
Arctic	Barrow	6.3	4.3	2.9	3.0	4.2
Interior	Bettles	8.7	4.7	2.1	1.5	4.2
	Big Delta	9.6	3.5	1.5	0.2	3.7
	Fairbanks	8.0	3.8	2.4	0	3.6
	McGrath	7.5	4.8	2.9	1.1	4.1
West Coast	Kotzebue	7.0	1.8	2.7	1.8	3.3
	Nome	5.0	3.9	2.7	1.0	3.2
	Bethel	7.0	5.3	2.5	0.7	3.9
	King Salmon	8.8	5.0	2.0	1.1	4.2
	Cold Bay	1.9	2.1	2.0	1.1	1.8
	St Paul	1.3	2.8	3.1	1.6	2.2
Southcentral	Anchorage	7.1	3.6	1.9	1.6	3.4
	Talkeetna	9.2	5.4	3.4	2.6	5.2
	Gulkana	8.4	2.2	1.1	0.2	3.0
	Homer	6.7	4.1	3.6	2.0	4.2
	Kodiak	1.2	2.5	1.5	-0.1	1.3
Southeast	Yakutat	5.1	3.1	2.0	0.3	2.7
	Juneau	6.8	3.2	2.4	1.4	3.5
	Annette	4.1	2.7	1.9	0.3	2.3
	Average	6.3	3.6	2.3	1.1	3.4

Figure 2. Annual and seasonal temperature changes (°F) in Alaska, 1949-2006. [From Alaska Climate Research Center, http://climate.gi.alaska.edu/ClimTrends/Change/TempChange.html].

Results

At King Salmon, the frequency of favorable CIT (*Figure 3*) exhibits a pronounced seasonal cycle, ranging from zero in the winter to approximately 45% in summer. The corresponding curves for the subindices show that perceived temperature is the main controller of the seasonal cycle. However, the other factors are also important, as they reduce the frequency from about 95% (perceived temperature's summer peak) to about 45% (aggregate CIT's summer peak). Of the other three elements, wind speed has the greatest effect, followed by present weather and visibility.

The average seasonal cycle shown in Figure 3 is subject to substantial interannual variability and also to changes over time. By comparing two years (1956 and 2005), we see the seasonal cycle of King Salmon change (*Figure 4*). If one

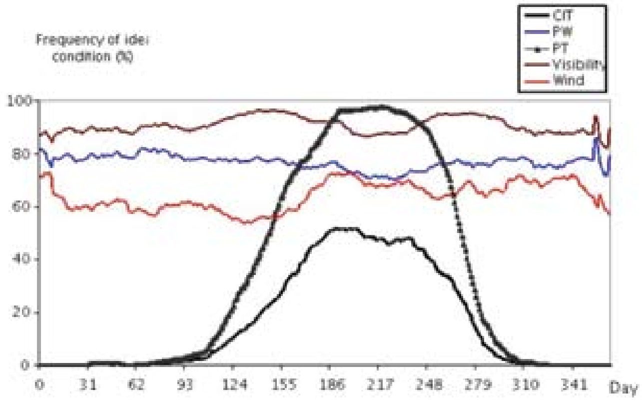

Figure 3. The climate index for tourism (CIT) and the four subindices, present weather (PW), perceived temperature (PT), wind speed and visibility, showing the frequency of favorable conditions for sightseeing at King Salmon. Note the seasonal cycle.

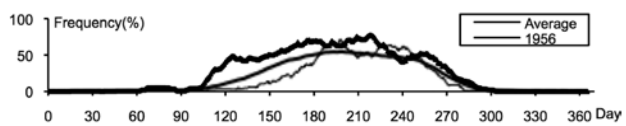

Figure 4. The frequency of favorable conditions for sightseeing (CIT) at King Salmon for two individual years, 1956 and 2005, together with the mean seasonal cycle for 1943-2005.

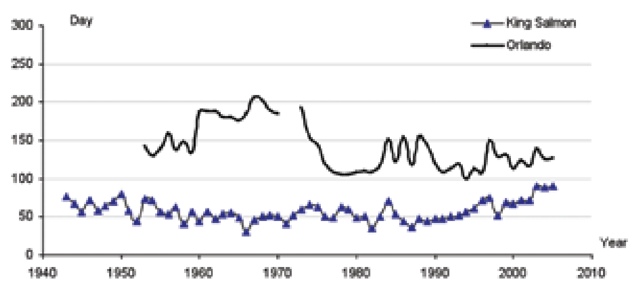

Figure 5. Number of days per year with at least five consecutive hours of favorable sightseeing conditions between 8 am and 7 pm at King Salmon, AK (blue) and Orlando (black).

assumes a threshold frequency of 30-40% for the start and end of the sightseeing season, it is apparent that the start date can vary by nearly two months. While 1956 and 2005 were chosen because they are extreme examples, year-to-year differences in the start and end dates are typically one to several weeks. The data show that the end dates of the 1956 and 2005 seasons were not substantially different. This trend towards an earlier start date but little change in end date is actually representative of the broader time series for King Salmon, as discussed further below.

In addition to the year-to-year variations, there are trends over time in the length and quality of the sightseeing season. As an illustration of the CIT's ability to capture such variations, Figure 4 shows the number of days per year in which sightseeing conditions were favorable for at least five consecutive hours between 8 am and 7 pm. Also shown for comparison is the corresponding curve for Orlando, Florida. The number of days favorable for sightseeing at King Salmon has increased substantially since the 1980s. For the last several years, the season length was about 30 days longer than during the 1960s and 1970s. By contrast, the corresponding series for Orlando shows a post-1970 decrease in the number of favorable days. In both cases, temperature is the main driver of the changes. The springtime warming of Alaska, noted earlier (*Figure 2*), has resulted in more favorable conditions in the early part of the season (May-June), effectively lengthening the season. At Orlando, summer warming has resulted in many days that exceed the heat index threshold during the summer.

We also applied the index to seasonal patterns of weather for skiing at Anchorage. When each year is assigned to a particular pattern by the statistical clustering algorithm, a trend towards less favorable skiing conditions emerged. Specifically, seasons with earlier end dates have increased significantly in frequency in the past several decades, while patterns corresponding to longer seasons have decreased in frequency. The earlier end dates are consistent with the winter-spring warming noted earlier.

Discussion and conclusions

The methodology used here integrates hourly and daily frequency distributions to allow quantification of seasonal patterns for specific tourism activities. It enables more detailed examination of the shift in seasonal patterns as well as closer scrutiny of the impact of climate change on seasonal patterns of weather variables that impact tourists. The results of this study indicate that recent climatic warming has had both positive and negative effects on tourism weather in Alaska. A longer summer season with high-quality weather conditions benefits tourism activities such as sightseeing, whereas a shorter winter season negatively impacts ski tourism. By contrast, subtropical locations such as Orlando are seeing a decline in favorable outdoor conditions during summer, primarily because summer temperatures at such locations are already near the upper limit of the favorable range.

Management implications

The impact of climate change on tourism is expected to be diverse and wide-ranging, and will depend upon location and geography. The method discussed in this paper can be used to assess the impact of climate change on other tourism sectors and other locations. This assessment of the impact of climate change on specific aspects of seasonal patterns could prove useful in tourism planning. For example, tour operators can shift seasonal schedules to take advantage of the shift towards an earlier start of the summer season, and destination marketing could be adjusted to better communicate the changes in favorable conditions to prospective travelers.

Acknowledgments

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NPS photograph by Robert Winfree

Figure 6. Sea kayakers navigate glacial ice.

Tourism: Pros and Cons of Development of Chukotka

By K.K. Uyaganski and O.D. Tregubov. Translated by Gabrielle Jolivette, Nate Nicholls, and Kevin Bibee

Development of tourism in Chukotka is given more attention every year. At the same time as tourist destinations are developing, they are provoking apprehension as to the benefits for Chukotka and its inhabitants. That is why before discussing measures to enliven tourism in the region, the positive and negative sides of tourism development in Chukotka should be analyzed. Positive outcomes of tourism are well known, which is why this paper concentrates more attention on the possible negative effects of uncontrolled tourism development. The world tourism industry is becoming the second largest part of the world economy, but tourism development can cause ecological, cultural, and social problems, along with positive aspects.

Positive sides of tourism: increase in the budget of the region, increase in employment (in the service sector), support of native crafts and traditional culture, cultural education through tourism, and formation of a positive image of the region.

Negative sides of tourism: commercialization of cultures, danger of embezzlement, loss of cultural identity and destruction of cultural values, conflict between the local population and tourists over use of biological resources, increasing roles of unqualified work in the service sector, and ecological problems.

Despite successful realization of many tourism programs on Chukotka, in recent years there have been associated hardships with the effects tourist activity. Currently cruises are the main type of tourism, but they have had an insignificant influence on the economy in the region. Many native villages in the Chukotka Autonomous Region are now in a depression. They have critical social problems: unemployment, low income, alcohol abuse, and lack of career options. These problems cause young people to migrate to cities. These difficult situations in the villages are worse where traditional ways (deer herding, sea trade, hunting) are decreasing. Here tourism must be good for the residents of villages and give support to the traditional ways. Considering the potential of recreational tourist activities, bordering territory residents could be guide consultants, look after the safety of cultural and natural objects, rent out accommodations, and could create small companies for participation in tourism programs.

For the tourism industry, culture is equally important as natural recreational resources. For tourism to be successful, development requires certain considerations for the uniqueness of objects of national and cultural heritage. Chukotka is rich in traditional culture. It has many folk tales of the people, archaeological sites, and native dance groups. Chukotka Peninsula, as part of Beringia, is one of the unique places in the world, where cultural resources are concentrated. Here tourism plays a positive role in saving archaeological sites, and coastal cultures provide support with national trade of bone carving and native dances. This is possible with proper administration of cultural resources and strict control in business as to insure the protection of cultural heritage; however, the real picture may be less optimistic.

According to UNESCO, one of the main concerns regarding mass tourism for the native cultures of the world is the commercialization of culture, especially when the industry's top priority is to achieve maximum profits. This tends to be particularly destructive for the native people of the world. It is necessary to note, that a traditional way of life for the people of Chukotka, is transformed into a substitute of technocratic and traditional culture. It could be said that this is an inevitable process, but it is obvious that this causes people leading a nomadic way of life or engaged in sea hunting to diminish. How will ethnic tourism develop in this situation? Unregulated tourism will only strengthen the growth of behaviour deviations (e.g., the spread of drug addiction, alcoholism, etc.). This collision with aggressive commercial tourism can lead to undesirable consequences for reindeer breeders and sea hunters.

The positive role of tourism in this situation can be expressed in support of a traditional way of life. For example, in tourist programs it is necessary to include popular competitions among local residents, such as reindeer racing in the area of Anadyr (the villages of Lamutskoe, Chuvanskoe, and Vaegi) and in the area of Bilibino (the village of Omolon). In the seaside villages of the Chukchi Peninsula there are the well-known holidays "Whale Holiday" and "Beringia", where whaleboat competitions are conducted between hunters. The support from tourism is achieved by the support of such crafts as making of *yarar* drums, ski skins constructed from reindeer fur, *baidars* or kayaks made from poplar and leather, tailoring of fur clothes, and sleeping bags.

Tourism is considered to promote the protection of the environment. One of the main concerns for tourism is the use of natural resources, therefore the protection of these resources is vital for the continued existence of the tourism industry. Mass tourism, which caused serious environmental problems, led to an alternative, environmentally and ecologically responsible tourism. This type of tourism, under competent management, brings a huge business incentive for the preservation of nature. This brought about specific varieties of tourism such as bird watching and wildlife viewing. In a number of western countries and some regions in Russia (Sakha-Yakutia Republic), the multilevel system of natural parks is being developed, which promotes this ecologically responsible tourism.

Chukotka's potential for the development of this kind of tourism is enormous—great tracts of mostly untouched land; unique Arctic flora and fauna; and the presence of rare species of birds, animals, and plants. But is "ecological tourism", especially in such sensitive territory as the Arctic region, truly ecological in praxis? Poor management of tourism can cause significant damage to the environment of Chukotka. Among the cons in this instance:

1. A problem of debris and food waste. It is necessary to recognize, that Chukotka is polluted by dumps, heaps of garbage in part caused by sightseers. Because of the cold conditions of the region, the dump sites decompose at an extremely slow rate, making them an almost permanent feature in the permafrost. The accumulation of food waste in the territory attracts wild animals and instances of animal death due to cutting themselves or being poisoned at such sites have been recorded time and again.
2. The disturbance factor. Often tourists seek out encounters with wild animals, often resorting to dangerous ends to achieve this communion with nature. Such activity not only compels animals to leave, but also can provoke an attack. On the Chukchi peninsula, such factors stress the animal population.

Photograph courtesy of Vladimir Zhuravkov.

Figure 1. Ergyron traditional music and dance ensemble.

3. Trampling of vegetative cover. The unregulated flow of tourists frequently encroaches upon the environment of Chukotka. In the opinion of many experts on the northern issues (N.K. Zheleznov) the unregulated movements of tourists within the landscapes of the Chukotka Peninsula contribute to the development of erosive processes, such as the destruction of the soil layer or the vegetative cover and the formation of ravines.

Unregulated tourism is causing significant damage to the environment. For many countries of the world, uncontrolled collecting of rare geological minerals and fossils by tourists has become a critical problem. Chukotka is very rich with geological formations, a number of rare minerals, and especially fossilized remains of animals of the Pleistocene era—mammoths, woolly rhinoceroses, etc. In this situation, Chukotka is vulnerable to unscrupulous collecting. Irreplaceable losses occur as a result of the desire of many tourists to have a rare animal or bird “trophy”. Law enforcement organizations of the Chukotka Autonomous Region have already had to detain tourists, including a number of foreign citizens, who tried to remove rare birds of prey like the white gyrfalcon or the peregrine falcon to sell them in other countries. Also under threat are polar bears. Despite all the measures that have been implemented for their protection, their fur is still a prized commodity on the market.

In this way, if the development of the tourist industry in the region of Chukotka continues to mismanage commercial tourism, then the consequences of tourism pointed out above will be realized. Indeed, the degraded territories are of no value to the tourism industry.

In the last year, cardinal changes have occurred in the world tourism industry. The mass tourism is being replaced by the “demanding” client: he or she is educated, has substantial means, and requires the maximum returns from vacations, including those having a cultural and educational nature. Only large corporations with their own infrastructure have the means of satisfying these demands. In particular, the merging of private airlines with tourist corporations has occured. Currently 80% of profits are concentrated in a few leading transnational tourist corporations of the world. In this situation Russia can appear as an eternal outsider. In the opinion of Russia’s scientists (V.A. Kvartalnii), to avoid becoming an outsider, Russia must pay more attention to social tourism, for commercial tourism is not capable of satisfying the requirements of the population of the region.

All mentioned above have a relationship to Chukotka. The overwhelming majority of the residents of Chukotka go as tourists to central Russia or abroad, spending considerable sums of money, which benefit other regions. The program for the development of domestic tourism is necessary for the Chukotka Autonomous Region. This not only promotes social-economic improvement of many depressed areas of Chukotka, but most importantly, will assist in the increased recognition of the nature and culture of the people of Chukotka. State and public support is necessary for the proper development of tourism and its real potential value, including such directions of social tourism as youth and sport tourism, and children’s camps with ecological and cultural programs. But to discuss problems of the development of tourism without paying attention to economic components is impossible. First of all, it is necessary to consider the organizational forms of tourism. In Anadyr and Providenya, there are currently a number of tourist firms, created on the basis of private initiatives. On one hand, of course, this is good, but on the other hand this is a long and often unproductive path. I believe that I am not alone in my opinion, that at the given stage it is necessary to attract to the region the cooperation of large tourist firms of Russia, the United States (State of Alaska), Canada, and Scandinavia that possess sufficient staff, experience in Arctic tourism, and economic potential. I am confident that the traditions of friendship and cooperation between Chukotka and Alaska will successfully develop further, especially in the field of tourism.

Figure 2. (Right) Lavrentiya Bay.

Photograph courtesy of Mikhail Zelenskiy

Outreach and Education

Photograph by Chris Arend

The Connection Between Art and Science in Denali National Park and Preserve

By Annie Duffy

Artists have had a major impact on the creation and development of America national parks since the beginning of the national park movement (*Denali National Park and Preserve 2008*). Similar to Thomas Moran's contribution to the creation of America's first national park, Yellowstone National Park, the painter Belmore Browne was a strong advocate for the establishment of Mt. McKinley National Park, now known as Denali National Park and Preserve (Denali), in 1917. Over the years, many artists have supported the park and worked within its landscape to create powerful works that have merit not only as beautiful objects but also as important tools for interpreting Denali's natural history and its complex ecosystems.

In 2001, the park renewed its commitment to the arts and asked Kesler Woodward to serve as the park's first official artist-in-residence. The program has grown significantly over the past seven years. It is now entering a more mature phase where we are actively examining the merits of the program not only to artists but to the park as well.

The first western artists in the park were part of science expeditions. We are now actively exploring how artists work with scientists and address science in the park today. We are carefully examining the connection between art and science, how artists have played a role in the scientific work being conducted in the park, and how this connection may be further developed in the future.

Figure 1. Detail of "Drifting Clouds, Denali" by Kesler Woodward. Oil on canvas; 24" H x 30" W.

Artist-in-Residence Process

All visual artists are encouraged to apply for an open application call that is held annually. International applications are also accepted.

Application Requirements

Prior to 2009, all applications were in hardcopy format and submitted via mail. This included: 1) a brief statement of intent, stating what the applicant hopes to achieve as a result of a residency at Denali; 2) a personal vita outlining artistic accomplishments, such as participation in juried and invitational exhibitions, solo exhibitions in galleries and public institutions, work included in museum, corporate, and public collections, artist fellowships and residencies, and other honors; 3) no more than six professional quality digital images (all images must be in JPEG format, must be at a resolution of at least 300 dpi when sized at 4" x 6" and no individual image file may exceed 2 MB); and 4) In addition to the image files, artists include a list with thumbnail views of each image, and its title, medium, size, and date of completion.

In 2009 we moved to an online application system and some formatting requirements changed, such as the minimum image resolution and file size. The link to the application system is available at http://arts.alaskageographic.org. The annual application deadline remains the same, it continues to be October 31 for residencies to take place the following summer season.

Photograph by Missy Woodward

Figure 2. Artist-in-residence Kesler Woodward sketches at the creek right next to the East Fork Cabin.

Photograph by Eric Nancarrow

Figure 3. "Glacial Run-off" by Ree Nancarrow. Fiber; 36" H x 21.5" W.

Photograph by Chris Arend

Figure 4. "Baby Raven Trio" by Rachelle Dowdy. Mixed media; 20" H x 20" W x 18" D.

Selection Process

For 2010, the program continues to be open only to visual artists. As there is currently another program for professional photographers, the 2010 program will not accept applications from artists working in the medium of photography. We expect to include a wide range of other types of media in future years.

A panel of artists and NPS personnel appointed by the superintendent of the park reviews applications from professional artists annually. Selection is made on the basis of required entry materials, vision, new and innovative ways of responding to the park, and recognized accomplishment as demonstrated in those materials. Up to four artists are accepted annually. Over 54 applications were received in 2008.

Residency Experience

The Artist-in-Residence program offers professional artists the opportunity to pursue their work amidst the natural splendors of Denali. The park currently provides the use of the historic East Fork Cabin for ten-day periods from June through August. Other accommodations may be available in the future. No stipend is provided.

The East Fork Cabin, also known as the Murie Cabin, was the base from which naturalist Adolph Murie conducted his landmark study of wolves, sheep, and predator/prey relationships in the park from 1939-41. Built in the late 1920s by the Alaska Road Commission, the Murie cabin is located 43 miles into the park, just off the park road, in a dramatic setting on the East Fork of the Toklat River between Sable Pass and Polychrome Pass. A rustic but well-equipped base from which to work and explore, the 14 ft x 16 ft cabin has an outhouse, propane heater, range, oven, refrigerator, bunk beds, and a full complement of cooking equipment. There is no electricity or running water, but water jugs may be replenished at ranger stations and visitors' facilities, and showers are available at the Toklat Ranger Station, 12 miles from the East Fork cabin. Artists chosen must be comfortable in a wilderness setting.

Residency Requirements

Selected artists are expected to give one public lecture about their body of work and artist approach. After the residency is completed, artists-in-residence donate a newly created piece of art to the park collection that reflects their experience in Denali.

Connecting with Science

As part of the connection with science that is currently being explored, there are two specific instances currently in development.

Planning for a special exhibition entitled "Ascension:

Exploring the Art of Denali" at the University of Alaska Museum of the North is now underway. The exhibit will feature ar work from Denali's artist-in-residence collection and writings from selected scientists about how specific pieces enhance scientific understanding. The purpose of the exhibit is to show how the two fields are connecting in Denali, and how they are both valuable avenues to increasing our understanding of subarctic ecosystems and the world as a whole. The exhibition will open in October 2009 and will relate to the *"The National Parks: America's Best Idea"* film by Ken Burns, which is planned to premier on local PBS stations in September 2009.

Three new arts-related field seminars were offered through the Murie Science and Learning Center during Summer 2009. The field seminars were led by artists, and two focused on connections between artand science in Denali. The field seminars were: Knowledge Informs Art: Drawing inspiration from Denali, June 15-17, 2009, with Alaska artist Karin Frazen; Landscape Painting, June 18-21, 2009, with Alaska artist David Mollett; and Denali Field Journaling, August 7-9, 2009, with author Tom Walker.

Other instances are also in development and being researched. This is a new direction for the program, and appropriate documentation is being created.

The Importance of Continued Interaction of Art and Science in Denali

There is a great deal of literature on the art and science connection, but one particular quote is especially useful in our endeavor:

So much great art has come from artists interacting with scientists—perspective, color theory, dynamism, constructivism come quickly to mind—that one wonders what increased interaction might bring. (*Root-Bernstein 2004*)

Although the quote focuses on what science brings to art, it is widely acknowledged that science also benefits greatly.

In recent years, researchers have teamed up with artists to close the gap between art and science. Art and science were once strongly intertwined because observational data and experimental setups could only be rendered by hand, but the connection has generally languished for the last half of the twentieth century. However, the introduction of photography and modern imaging technology to the lab and the field has made capturing images routine. As a result, the aesthetic process of carefully producing images can lead a researcher to examine and think about a topic. Collaborations between scientists and artists serve to help make science more accessible to the public, help researchers to think beyond their own area of science, and benefit science by generating creativity. Examples of these collaborations can be found throughout the world, including important centers of science such as the University of California, Los Angeles, Massachusetts Institute of Technology, and Montana State University (*Felton 2003*).

Increased interaction between the two disciplines in Denali will not only aid artists and scientists directly, but will also help broaden our understanding of the park—its

Photograph by Chris Arend

Figure 5. "East Fork of the Toklat River" by David Mollett. Oil on board; 30" H x 40" W.

history, geography, and all that is contained in its environment. It will aid the park in communicating to the public about the important research being conducted in Denali. As our understanding increases, we can more effectively communicate and educate the public about this unique land.

For additional information:

Visit http://arts.alaskageographic.org for more information about the Denali artist-in-residence program, including program application and history.

An online gallery of artist-in-residence artwork can be found at http://www.alaskageographic.org/static/168/artist-in-residence--gallery.

Visit http://www.alaskageographic.org/static/179/arts-field-courses for a list of upcoming arts courses and enrollment information.

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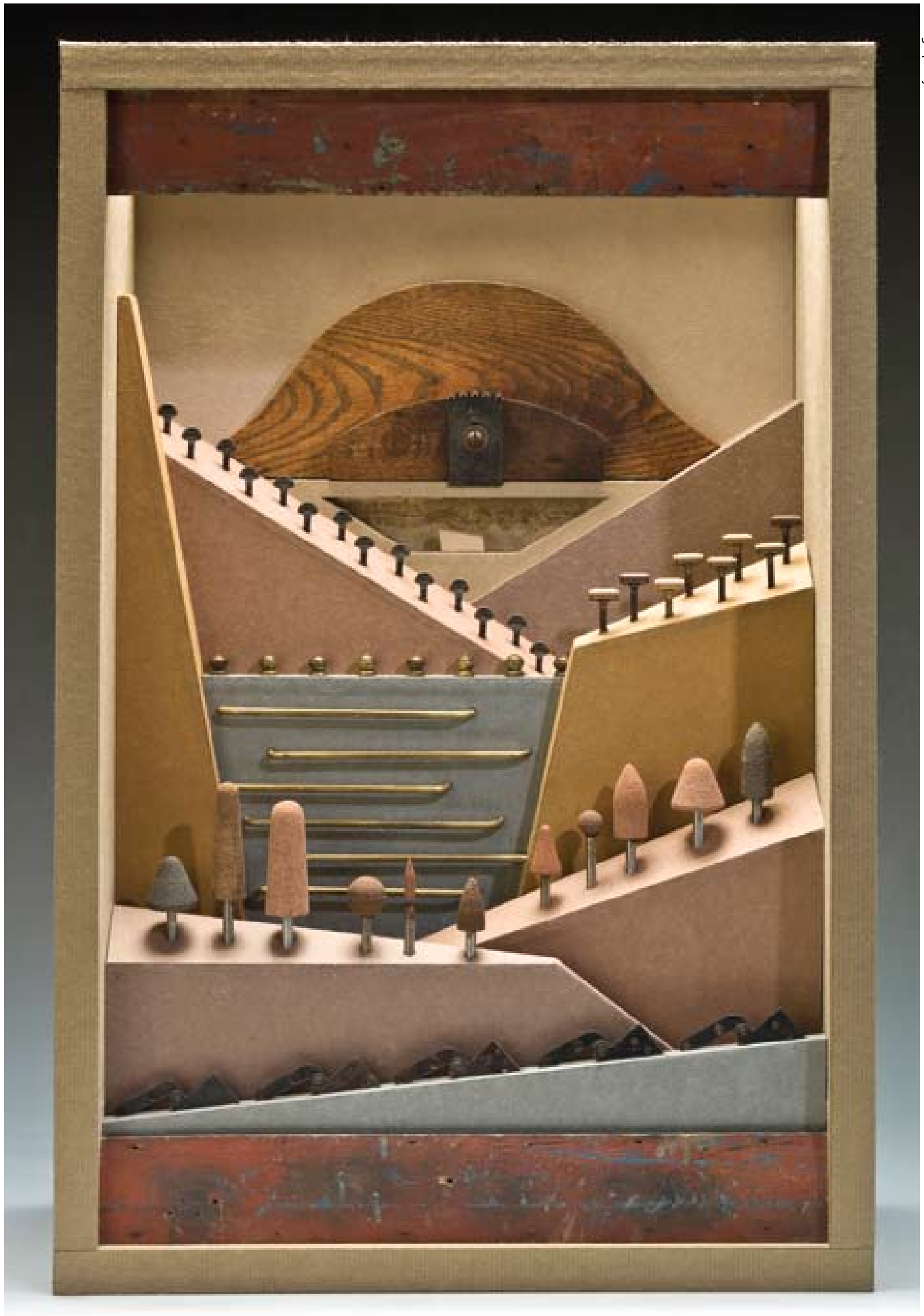

Photograph by Chris Arend

Figure 6. "Denali" by Margo Klass. Mixed media; 30" H x 20" W x 9.5" D.

BeringWatch: Internet Facilitated Community Based Monitoring in the Bering Sea

Karin Holser, Bruce Robson, and Stephen J. Insley

Abstract

BeringWatch is a tool for recording and communicating environmental and ecological events in order to empower remote communities on ecological issues. Our approach combines the use of existing environmental databases with a web-based access portal for efficient and standardized data entry. The existing databases were developed and refined by the Island Sentinel Program on St. Paul and St. George Islands, Alaska, over the past 10 years. It is designed to be expandable to accommodate the diverse needs of multiple communities and the potential for more detailed data formats. We are currently in the implementation phase of the initial system in a selection of remote Aleutian Island and Bering Sea communities, both in Alaska and Russia.

Introduction

Our program is based on a single important premise: for conservation efforts to be truly successful and sustained over long (i.e. biologically significant) time periods, there has to be activity and ownership at the local level. BeringWatch is essentially a method for remote communities to store and share local and traditional environmental data in a standardized format while insuring consistent data quality and accuracy. BeringWatch grew out of the Island Sentinel Program that developed on St. Paul and St. George Islands in the Bering Sea, Alaska, during the past 15 years. The original goal of the Island Sentinel Program was to reawaken the cultural tradition of the Aleut community observer or sentinel. The sentinels were the members of the community who were rooted by traditional observation methods, which, if stories are true, led Aleuts to be so skilled as to make proficient predictions about such things as weather and the impending arrival of seafarers.

There are two key aspects which make BeringWatch unique. First, the database resides on the internet, and second, it is designed as a network. Being web-based solves a number of equipment-based problems (compatibility of data entry and storage programs) and allows for broad networking. A network approach means that permission to access data is granted at the local level, providing local ownership, a necessary part of local stewardship. The network model is also well suited to incorporating rigorous data quality standards through continuous interaction between local observers, regional coordinators, data managers and scientific advisors. Through internet communication (verbal and written) and photographic documentation, this interaction is ongoing while people at different network nodes are separated geographically.

The types of environmental data and how it is collected and stored essentially break down into two broad categories: wide ranging descriptive data and more focused, detailed observations on specific species. The first category is very broad, could be entered by anyone in a community with minimal training and is primarily narrative. This could include anything strange (e.g. an unusual wildlife sighting) or anything the local observer sees as environmentally relevant. This can include local and traditional knowledge passed on to the observer by other community members. It can also include media uploads (e.g. photos) which are permanently linked to the record. The second category is more focused on detailed data from specific target species. This level of data collection involves training and setting up a protocol for the target species and is most likely to be carried out by dedicated and often paid observers, through the Island Sentinel Program or the rangers in the Russian Federation nature park, Beringia.

Our current goal for BeringWatch is to successfully make the transition from a Design/Build phase to an Implementation phase. Our experience at the recent Beringia Days 2008 International Conference held in conjunction with the Alaska Park Science Symposium in Fairbanks, Alaska, clearly demonstrated the need, value and desire for such a product, and several test communities in Alaska and Russia have signed on. We now need to provide sufficient support to get these communities up-and-running and in so doing, realize the potential of the system.

Our four current objectives are: 1) to continue to update the database and web portal in order to successfully accommodate the evolving needs of each test community; 2) to administer and maintain the web-based portal for efficient and standardized data entry; 3) to provide oversight and data collection training where necessary and practical; and 4) to develop metadata standards for the observation program.

Methods

Design

The basic methodology is based on the Island Sentinel model developed and refined on St. Paul Island. At each location there are one or more primary ("target" or "focal") species which are the main focus of attention. In addition to the primary species, observations of other important marine mammal species that are likely to be encountered in the area are recorded opportunistically. The primary species vary from location to location and can be added or updated as the data collection process matures. One of the first tasks of operation at the local level is to refine the methodology to suit the specifics of each community or area and suite of species.

Focal species are chosen considering several criteria, including known consistency in availability, whether it can be consistently observed, and its ecological and local importance. Local importance can be defined as species that are of subsistence value to the community or embody important cultural relationships with the local environment. Ultimately the data collection format should include any species of plant or animal for which there is local importance or interest. Each focal species should be added one at a time so that a consistent protocol can be designed to maximize the reliability of the data over time. As focal species are chosen, it is important to make a conservative estimate about how much time it takes to get a good count or collect other relevant data, particularly in the worst conditions. If adding a new species will negatively impact the existing data collection then it is not advisable to do so. Instead, it is still possible to collect data on the new species but to keep it in the "Opportunistic" rather than the "Focal" category.

Photograph courtesy of authors

Figure 1. The next generation of Island Sentinels collecting water temperature data.

Quality Assurance/Quality Control

A critical component of a community based-monitoring program is the ability to insure the reliability and quality of the data that is collected. There are three basic levels of Quality Assurance/Quality Control (QA/QC) built into the current program that are designed to ensure the data being collected is reliable and of high quality. These are training, standardized methodology, and oversight. Each of these aspects are briefly touched upon here.

Training: Training will be conducted at centralized locations whenever possible. A recent training session for several Aleut communities that occurred on St. Paul Island in October 2008 is a good example of such an opportunity. Here we were able to review and design counting techniques for the communities present, use of the Sentinel database, and design an observation schedule for each location. The goal is to standardize the specific types of data and how it is collected. In doing so, the data will be made comparable across sites. Secondary training is equally important. The Beringia participants will be responsible for training anyone else in their area that will be collecting data. This includes formal assistants as well as anyone conducting secondary observations like schools or other community members.

Standardized Methodology: Training emphasizes the importance of entering data in a timely manner in order to ensure quality is maintained. The Pribilof Island Sentinel programs use a PDA or handheld field computer system to insure that data entry is standardized automatically in the field, and the chance of error during this stage of activities is greatly reduced. Other communities will rely on paper forms or notebook formats that provide a standardized template for recording necessary data fields. Proofing data after it has been entered is part of the scheduled data collection activities and occurs on a regular basis.

Finally, reliability tests will be taught during training and conducted subsequently by Sentinels. Two data sets are routinely focused upon: animal counts and species identifications. Tests are conducted in order to ensure the results are correct, or in the case of counts, are within a preset tolerance range. These tests can be conducted at the same time, through observations. However, these tests are often best conducted with video examples. Ultimately we envisage a standardized video, a general version which could be made centrally and to which locally made parts could be added.

Oversight: The final aspect of QA/QC involves oversight. A more detailed QA/QC protocol will provide a framework for recording observation activities and will help with data proofing. Data and techniques will be reviewed externally on an ongoing basis. External reviewers include NMFS personnel as part of the broader NMFS co-management program, other Sentinel programs such as the St. Paul ECO office, and external scientific advisors. Such external reviews will continue to ensure that high quality data is collected and maintained and will help foster a network of experts to reinforce data quality standards.

Education and Outreach

The BeringWatch program provides an excellent opportunity for local-scale education and outreach to multiple sectors of the community. The flexibility and accessibility of the descriptive interface of the BeringWatch online database provides an easy to use vehicle for local users to enter observations pertaining to the local environment. This information can then be summarized and displayed on the BeringWatch webpage for the general public (*http://www.BeringWatch.net/joomla/*). The BeringWatch webpage is a content management web page which can be accessed and used by designated observers and lead members of each community. The technical infrastructure for the page has been set up so that articles of interest for each community and data summaries can easily be posted to the BeringWatch page on a regular basis with no formal XML programming experience. Text and images are added to the page using a simple text editing interface. Images that are uploaded to the BeringWatch database can be automatically imported to the webpage gallery if the user wishes to do so. Overall, the webpage is designed as a means to communicate the results of the BeringWatch community-based monitoring between local communities.

In addition to broadly targeted outreach via the BeringWatch webpage, a targeted series of simple projects are planned through which local students will be able to use the BeringWatch database to enter observations of local wildlife and display the results on the webpage. A collaboration with the Pribilof School District is designing projects where students follow a predefined protocol to collect data on local wildlife. An example project is the use of the remote video camera installed at Dalnoi Point on St. George Island to monitor Steller sea lions. Students will work with local observers to conduct census counts and look for branded sea lions from images and recorded by the Dalnoi Point camera. Student data will be recorded in the online database and posted on the BeringWatch webpage. If the Pribilof School District pilot project is successful, these efforts will be extended to other communities.

Summary and Conclusions

The BeringWatch methodology is currently operating or ramping up operations in a number of Bering Sea communities on the Pribilof and Aleutian Islands in conjunction with the Island Sentinel Programs. In addition to these communities, the BeringWatch methodology is also being integrated into a number of communities in Russia, in the western Bering Sea. Over the next five years we envision the program including a number of additional communities throughout the Bering Sea and the potential to export the model to other geographic regions. More importantly we are witnessing the direct empowerment of local communities in the long-term stewardship of the environment and a meaningful dialogue between locals and outside environmental authorities. We see these developments as a significant turning point that is critical to any ultimate conservation success. Moreover, it has given locals a sense of purpose and power, and is helping to build bridges between community elders and the new internet savvy generations of today – the local leaders of tomorrow.

Photograph courtesy of authors

Figure 2. Scanning for killer whales from shore with "Big Eye" binoculars on St. George Island, 2008.

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DIG* National Parks: Scientists in Alaska's Scenery

By Elizabeth O'Connell

Abstract

The DIG National Parks: Scientists in Alaska's Scenery project (DIG) aims to connect the general public with meaningful scientific research, and to pilot informal inquiry-based learning through use of digital media on video enabled devices. DIG will encourage youth, diverse audiences and the general public to co template cutting edge research, where the truth may not be certain, along with the process of research. By working closely with scientists, the national parks in Alaska, the University of Alaska Museum of the North, and the Univeristy of Alaska Fairbanks Arctic Region Super-computing Center, research science will be viewed on mobile devices, the web, broadcast on television or incorporated into museum exhibits. Planned national promotion with "Science Friday" and partners will highlight playing of the video podcasts, called vodcasts, before, during and after a park visit.

Introduction

The DIG project, to produce more than 32 vodcasts, has been proposed to the Informal Science Division of the National Science Foundation (NSF). The intended audience of visitors to the national parks in Alaska ranges from high school age to 90. Only 6% of visitors are under 18 years old, while the average age of the rest of the visitors is 51.6 years old and trending older (*Meldrum 2006*). The challenge is to introduce park visitors to the scientific research conducted in the parks and to spark interest in young people who have been increasingly disconnected from nature (*Louv 2005*).

An important question to undertake before launching this effort is to understand how visitors to national parks understand, think about, and connect with the research conducted in these areas. A review of the literature reveals some sources. For instance, in one front end study by Selinda Research Associates in Yellowstone National Park, they found that visitors to the park "either knew about scientists working in the park or assumed they had to be somewhere, behind-the-scenery, doing their work" (*Gyllenhaal 2002*). Yet, "the respondents seemed less knowledgeable of the role that science plays in wildlife conservation and park management."

Some Findings

Most studies conducted in national parks only addressed visitors' likes/dislikes of interpretive messages, effective signage and ratings of exhibits at the visitor centers, not whether they understood science research going on in the parks. This belies the fact that scientists have been conducting research in the parks since the first national park designation in 1916. For example in 2007, there were over 4,700 permits approved for research conducted in national parks, up from the 2,700 permits issued in 2001 (*Bill Commins, personal communication 2008*). There is some research in this area that has been conducted in museums. The 1995 Field Museum of Chicago study, The Exploration Zone at the Field Museum by Selinda Research Associates examined visitors' understandings of science research (*Perry and Forland 1995*). Of interest are the findings concluding that visitors: seemed to think about what goes on behind-the-scenes primarily in terms of exhibits rather than scientific research; were rated 0 to 2, of a possible 7, in understanding scientific research; were particularly confused by scientific and museum terminology; and had varying amounts of interest in science in their personal lives but indicated a number of possible connections with stories about the scientists.

So even though scientific literacy among citizens has only slightly risen to 20% in the U.S. population over the past decade (*Miller 2004*), the general public is interested in knowing more about science. An NSF study from 2001-2006 indicated that 83-87% of Americans said they had "a lot" or "some" interest in new scientific discoveries. Three out of five Americans said they visited an informal science institution such as a zoo or museum in 2006. To learn about specific scientific issues more than half of Americans choose the internet as an information source (*National Science Board 2004*). The internet ranks second to television as a source for information about science and technology.

In order to appeal to the publics' interest, we intend to present vodcasts about scientific research in parks that will reach an expanded age range, touch diverse audiences and encourage use of vodcasts before, after and during a visit to a park. The vodcast platform will naturally expand the age range of visitors to national parks in Alaska. A natural expansion will occur because mobile devices are a youthful technology that interests a wide age-range of the population.

The goal for this broad public audience, from high school age youth to senior adults, is to move the visitor farther around the learning cycle. In the book *Finding Significance* Sue Allen described the process a visitor goes through when attending the Exploratorium, in San Francisco (*Allen 2004*). We have modified the simple learning cycle (*Figure 2*) to explain how a national park visitor may interact with science oriented vodcasts.

Focus on Climate Change

Alaska, October 2008: a person from the U.S. Coast Guard had just traveled on a Canadian ice breaker from Northern Canada to Dutch Harbor, Alaska. She said there was no ice on her journey. She was amazed to see this graphic (*Figure 3*) showing sea ice thickness by Dr. Wieslaw Maslowski (*Maslowski 2008*).

A visitor to national parks in Alaska is surrounded by the effects of climate change. Will he/she notice? *We can't experience climate directly. The climate we perceive is a metaphor for the sum of weather conditions. Ecosystems describe climate zones by where they grow. Weather statistics define climate using mathematical averages at particular spots. Subsistence hunters know climate through their experience of their home country.* (*Wohlforth 2004*).

During the planning for the project, the project and evaluation teams will work together to develop a carefully articulated "Big Idea" centered around climate change that will be incorporated into each of the vodcast scripts (*Serrell 1996*). Primarily the vodcasts will deepen the public understanding of climate change research in Alaska national parks, get the public to think about the importance of each different area of research, and how it may affect them. Below are four primary outcome objectives.

Knowledge/Attitude: Viewers will become aware of, and gain a deeper understanding of and appreciation for the range of scientists' work that is being conducted in national parks across the country, and in the Alaska national parks in particular.

Knowledge/Attitude: Viewers will develop a greater understanding of and appreciation for the effects of climate change, as it is evidenced in the Polar Regions and in their local communities around the country.

Knowledge/Interest: Viewers will become aware of, interested in, and curious about an area of climate-change scientific research that is highlighted in a vodcast.

Attitude/Skill: Viewers will develop a greater appreciation for and become more skilled at using cell phone technology and other mobile viewing devices in outdoor settings.

A Podcast is a Story Poem

DIG intends to encapsulate a scientist's research into a "story" of 2-10 minutes. NOVA producer Nancy Linde described three important elements in creating the perfect Nova as "Story, Story and Story" (*Linde 2004*). Imagine that a poem is a podcast as prose is a documentary. We are guided by Robert Frost's take on storytelling. He explains from these excerpts in his essay "The Figure a Poem Makes" (*Frost 1965*).

It begins in delight and ends in wisdom. … It has denouement. It has an outcome that though unforeseen was predestined from the first image… No surprise for the writer, no surprise for the reader. For me the initial delight is in the surprise of remembering something I didn't know I knew.

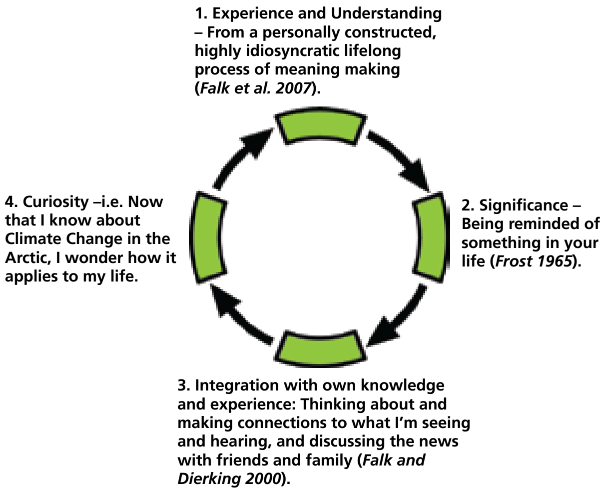
The science vodcasts will be a documentary poem crafted to entertain, stimulate and enlighten the tourist with a "story" about the scientist's research. If a tourist is sparked by a scientist's "story" they will make personal connections and be motivated to further participation and social interplay via on-line science networks.

The scientist's work will be deconstructed (*Figure 4*). It would be difficult to cover a scientist's work in one vodcast. There will be several vodcasts about one scientist's work. Each vodcast will focus on a specific aspect of their work. Or, a series of vodcasts will follow a scientist's work over the duration of the project to emphasize the ongoing aspect of research. During the vodcast we'll get to know the personality of the scientist. We will pair the scientist with an intern, a park visitor, or native who will ask the questions that any park visitor might ask. The vodcasts will be scripted in advance with the scientist. We want to structure for STEM (science, technology, engineering and math) content and anticipate visuals. However, spontaneous and natural interchanges will be incorporated when appropriate. Each vodcast will contain a Google map locating the area of the research (*Figure 4*).

NPS photograph by Joshua Foreman

Figure 1. Exit Glacier

Figure 2. Learning Cycle.



DIG's Team and Collaborations

A project of this scope and complexity in the national parks of Alaska can only be accomplished through the collaboration of the NPS and with professional expertise in science, technology, engineering, math and the arts. The Co- Principal Investigators are: Dr. Robert A. Winfree, science professional for the NPS, Alaska Regional Office; Christie Anastasia, education coordinator for the Murie Science and Learning Center, Denali National Park and Preserve; Elizabeth O'Connell, director, WonderVisions; Laura Conner, education director, Museum of the North; and Dr. Gregory B. Newby, chief scientist for the Arctic Region Supercomputing Center, University of Alaska Fairbanks. Many others, scientists, Alaska Natives, authors, education specialists, and tourism experts have pledged support and participation to DIG.

To succeed in achieving its goals DIG has fostered several significant partnerships with organizations that can contribute to the development, creation, implementation and promotion of the project. Science Friday is a 19 year old nationally recognized radio science series hosted by Ira Flatow. Ira's audio podcasts have reached a new peak of 250,000 downloads per program. Flora Lichtman, who creates video content for sciencefriday.com and curates third party videos, will join a scientist in Alaska and produce a vodcast to be featured as a "Pick of the Week".

The University of Alaska Museum of the North (UAMN) is the premier repository for artifacts and specimens collected in Alaska and a leader in northern natural and cultural history research. The UAMN faculty research taking place in Alaska national parks will be highlighted in a number of vodcasts available on our website, the UAMN website and on-site in UAMN exhibition galleries. UAMN will also hire a student production assistant to produce vodcasts with Laura Conner, director of education at the museum.

Our Web 2.0 effort will be strengthened by collaborations with museums in Alaska and across the country such as: the Alutiiq Museum and Archaeological Repository, Kodiak; Pratt Museum, Homer; Science Museum of Minnesota, St. Paul; Museum of Nature & Science, Dallas; and the Museum of Life and Science in Durham, North Carolina.

Critically important to DIG is our Alaska Native participants who will voice oral traditions and life experience that will add longevity and cultural meaning to the vodcasts. They are: Sven D. Haakanson, Jr., Old Harbor Alutiiq, anthropologist, carver, executive director of the Alutiiq Museum; Ronald Brower, Sr., Barrow Inupiaq, artist, Alaska Native Language Center teacher and translator; Kenneth J. Grant, Hoonah Tlingit, management assistant at Glacier Bay National Park and Preserve; Samuel S. Demientieff, Holy Cross Athabascan, River Journeys of Alaska, past executive of Native associations; and Nick Tanape and James Kvasnikoff, Nanwalek Alutiiq, tribal leaders.

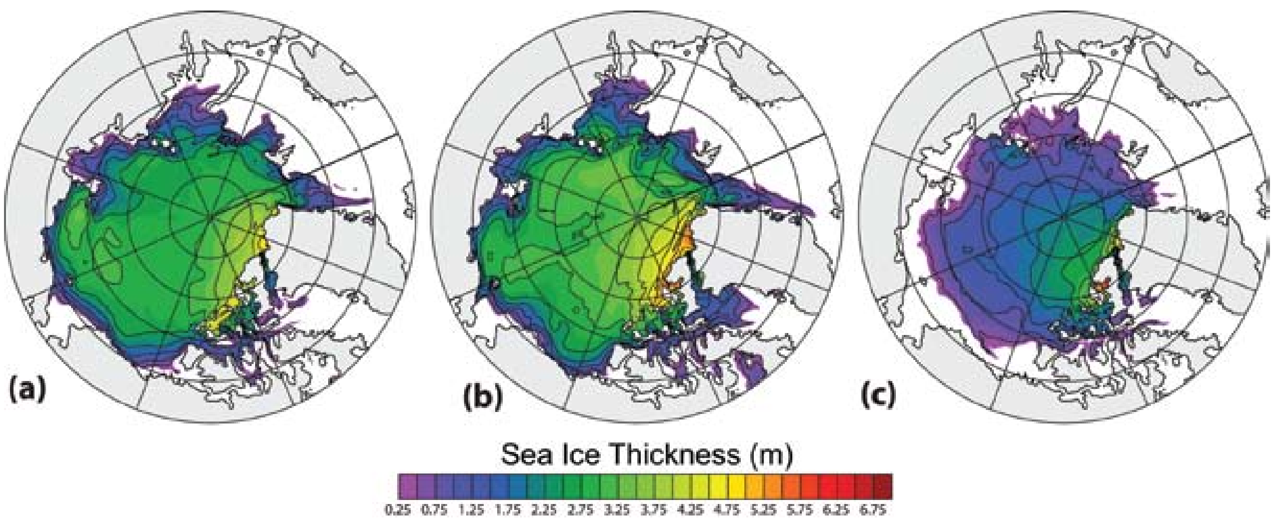
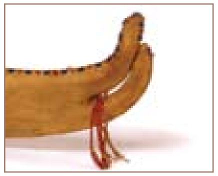


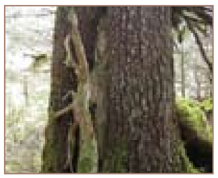
Figure 3. Arctic sea ice thickness (in meters) distribution simulated by Naval Postgraduate School Model.

Kenai Fjords National Park… Menu for Archeologist, Aron Crowell



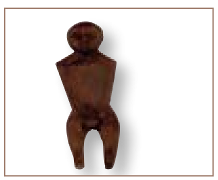
I can qayaq or baidarka can you qayaq or baidarka?
6 minutes

Dig a Dig
4 minutes



A CMT is What?
2 minutes

If I had an adze
7 minutes



I feel the earth move, YIKES!
2 minutes

When the tide is out the table is set
3.5 minutes

Bead by Bead
5 minutes

Figure 4. Menu example for podcasts in Kenai Fjords National Park.

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http://www.nps.gov/akso/AKParkScience/index.htm

NPS photograph by Robert Winfree

During the last few years, several issues of the *Alaska Park Science* journal have received awards in judged competitions for writing, design and illustration. Two more issues received awards in 2009. The December 2008 issue Scientific Studies in Marine Environments received an APEX Award of Excellence from Communications Concepts, Inc., publishers of Writing That Works, a subscription bimonthly for professional communicators (http://www.apexawards.com/announcingthewin-ners_2009.htm). The December 2007 issue Crossing Boundaries in a Changing Environment: Proceedings of the Central Alaska Park Science Symposium received an ECO Award of Excellence from Global Environmental Communications, LLC, publisher of The Environmental Communicator (http://www.environmentalcommunicator.com/ECOAwards.aspx).