Alaska Park Science

National Park Service
U.S. Department of Interior

Alaska Regional Office
Anchorage, Alaska

Resource Management in a Changing World

In this issue:

...and more.

Volume 14, Issue 1

Table of Contents

Cover photo: Passing Ipnelivik Valley in Gates of the Arctic National Park in August 2014.

Photo by M. Gaige

National Park System Areas in Alaska Mentioned in This Issue

This project is made possible through funding from the National Park Foundation. Additional funding is provided by the National Park Service and other contributors.

Alaska Park Science is published twice a year. Back issues of *Alaska Park Science* are available for sale by Alaska Geographic (www.alaskageographic.org). Charitable donations to help support this journal may be sent to: Alaska Geographic Association,
241 North C Street, Anchorage, AK 99501
ATTN: Alaska Park Science.

Alaska Geographic
NATIONAL PARK FOUNDATION

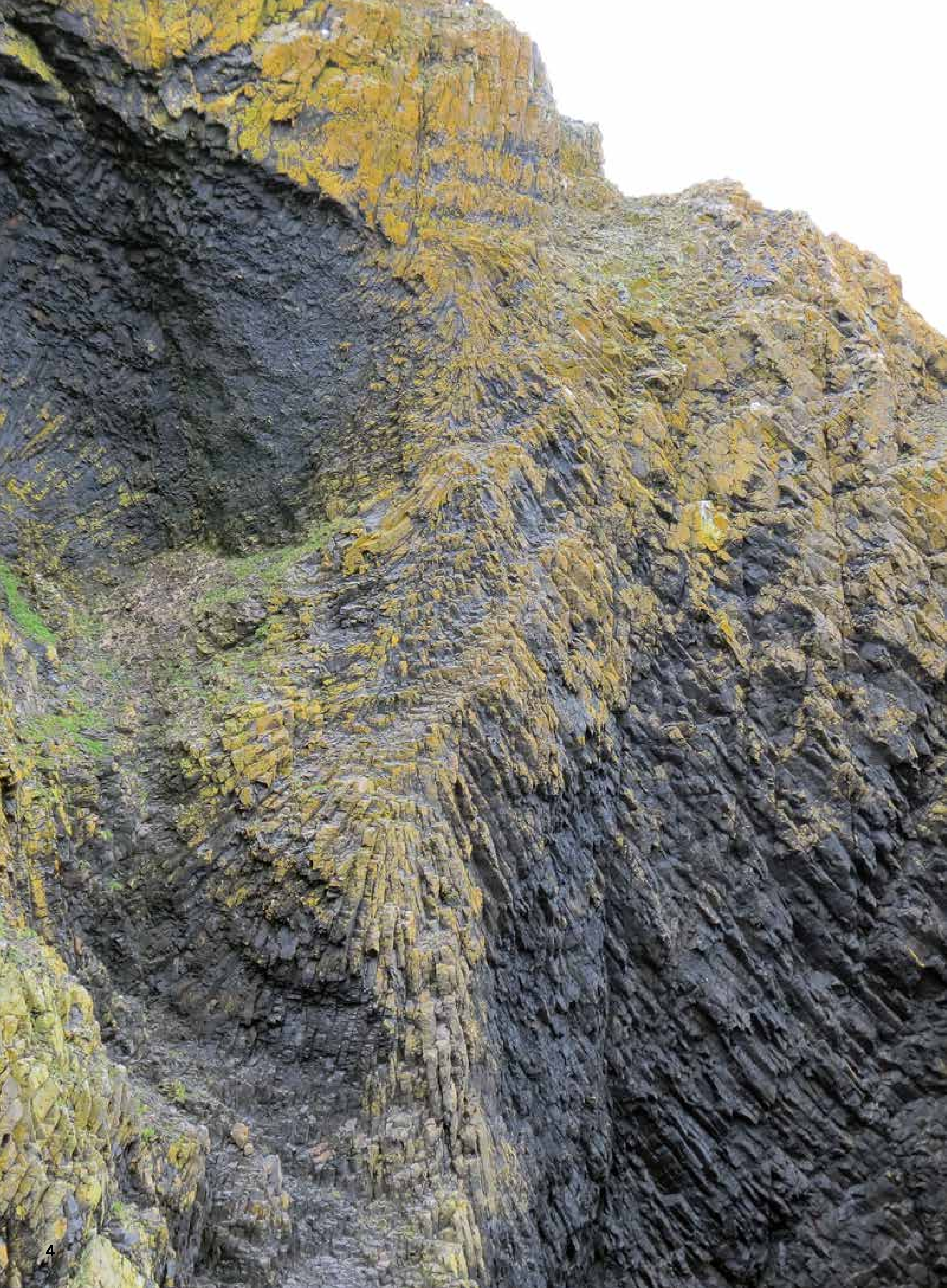
Alaska Park Science

ISSN 1545-4967
June 2015

Project Lead: Robert Winfree, Regional Science Advisor, email: AKR_Alaska_Park_Science@nps.gov

Editor: Susan Sommer, www.akwriter.com

Published twice a year in June and December by Alaska Geographic, a nonprofit partner of the Alaska Region of the National Park Service, supporting educational programs through publishing and operation of visitor center bookstores.



About the Authors

John Branson, Historian, National Park Service

Matthew T. J. Brownlee, Assistant Professor of Natural Resources Recreation Planning and Management, Department of Parks, Recreation, and Tourism, University of Utah

Don Callaway, Cultural Anthropologist Consultant

Miki and Julie Collins graduated from the University of Alaska in 1981 with biology degrees and promptly returned to their roots in bush Alaska. They are authors of two Alaska adventure books and a book on dog mushing and live in Lake Minchumina, Alaska.

Michael Gaige, Instructor of Environmental Studies and Adventure Education, Prescott College

Lee James, Professor of Adventure Education, Prescott College

David R. Klein, Professor Emeritus, Institute of Arctic Biology, University of Alaska Fairbanks

Richard Kleinleder, Biologist, URS Consultants

James P. Lawler, Program Manager, Arctic Network Inventory and Monitoring Program, National Park Service

Margaret MacCluskie, Program Manager, Central Alaska Network Inventory and Monitoring Program, National Park Service

James T. Peterson, Assistant Unit Leader, U.S. Geological Survey, Oregon Cooperative Fish and Wildlife Research Unit

Angela Romito, Fish and Wildlife Biologist, Ecological Services, Southeast Regional Office, U.S. Fish and Wildlife Service

Jeffrey C. Skibins, Assistant Professor of Park Management and Conservation, Department of Horticulture, Forestry and Recreation Resources, Kansas State University

Art Sowls, Retired Wildlife Biologist, Alaska Maritime National Wildlife Refuge

Rose I. Verbos, Doctoral Candidate in Natural Resources Recreation Planning and Management, Department of Parks, Recreation, and Tourism, University of Utah

Robert Winfree, Alaska Regional Science Advisor, National Park Service

Opposite: Colorful basalt on east coast of St. Matthew Island.

Photo by Richard Kleinleder

Knowledge, Understanding, and Information Overload

By Robert Winfree

It wasn't that long ago that studying a topic meant a trip to the library and a search through stacks of dusty books and periodicals. If the library was large and up to date, and the student familiar with how the library is organized and diligent with their search, then they could expect to be rewarded with something about their subject. Rapid internet growth and automated search engines have changed that picture. Today, almost anyone can place an online search and instantly receive thousands of pages of information competing for their attention. The challenge has become not just to find information, but to wade through what seems like an endless ocean of facts and opinion, with some of dubious veracity.

Park people need current and useful information too. Without knowledge about what the parks encompass, how and when they came to be there, and where they seem to be headed, how will park managers know which questions to focus their limited financial resources on? How can park communicators share knowledge, inform, educate, and inspire park visitors without a good grasp of the particulars themselves? And how can America's National Park System prosper during its second century if not through the support of a well-informed public and passionate park advocates?

The authors in this and every issue of *Alaska Park Science* have exceptional knowledge, insight and understanding about very special places that many, perhaps most, of us will never visit in person. In the following pages, Maggie MacCluskie and coauthors describe new approaches to analyzing and presenting resource data to support better informed and more transparent decision making by park managers. Miki and Julie Collins, David Klein et al., and Don Callaway share first-hand observations of environmental and climate change across widely separated parts of Alaska. They invite our readers to consider the effects of environmental changes, both recent and future, on natural, cultural, and subsistence resources; and their implications to the livelihood, heritage, and legacies of people who cherish these resources. John Branson shares histories and cultural significance of parks on the Alaska Peninsula and demonstrate why vigilance is still necessary even for established parks. Michael Gaige explores innovative experimental learning opportunities that are designed to introduce our next generation of scientists, scholars, and citizens to Alaska's amazing wilderness areas, while Rose Verbos investigates how real-life wildlife encounters can affect visitors' conservation commitment.

Parks are all about celebrating and preserving the wonder and diversity of the world around us, and knowledge is a big part of that. It is our sincere wish that these articles, photographs, and illustrations increase your knowledge and understanding, enhance your enjoyment, and elevate your appreciation of America's National Park System and Alaska.

Are we succeeding? Please let us know at: AKR_Alaska_Park_Science@nps.gov.

Figure 1. Students, educators, and the author (with red pole) engaged in field studies at Denali National Park during the 2014 Climate Change Academy, a partnership between the National Park Service Climate Change Response Program and the non-profit No Barriers Youth.

A Formalized Approach to Making Effective Natural Resource Management Decisions for Alaska National Parks

**By Margaret MacCluskie, Angela Romito,
James T. Peterson, and James P. Lawler**

Introduction

A fundamental goal of the National Park Service (NPS) is the long-term protection and management of resources in the National Park System. Reaching this goal requires multiple approaches, including the conservation of essential habitats and the identification and elimination of potential threats to biota and habitats. To accomplish these goals, the NPS has implemented the Alaska Region Vital Signs Inventory and Monitoring (I&M) Program to monitor key biological, chemical, and physical components of ecosystems at more than 270 national parks. The Alaska Region has four networks—Arctic, Central, Southeast, and Southwest. By monitoring vital signs over large spatial and temporal scales, park managers are provided with information on the status and trajectory of park resources as well as a greater understanding and insight into the ecosystem dynamics. While detecting and quantifying change is important to conservation efforts, to be useful for formulating remedial actions, monitoring data must explicitly relate to management objectives and be collected in such a manner as to resolve key uncertainties about the dynamics of the system (*Nichols and Williams 2006*). Formal decision making frameworks (versus more traditional processes described below) allow for the explicit integration of monitoring data into decision making processes to improve the understanding of system dynamics, thereby improving future decisions (*Williams 2011*).

There are a variety of processes by which park managers make natural resource decisions but perhaps the most common is a heuristic approach. In this case the decision maker uses professional experience, input from trusted advisors, and possibly consults reports or other literature to arrive at a decision. The decision is essentially made in a black box (the decision maker's head) making transparency and repeatability challenging. This can be especially problematic for complex decision problems, such as those involving multiple use resources, those that may lead to litigation, and those that are iterative.

For managers of national parks, this situation becomes more complex in light of the essential mandate of the agency, which compels managers to consider future generations in daily operations and management of resources. This necessitates that managers consider how today's decisions influence tomorrow's resources and, in turn, the decisions that will be available to managers in the future. In addition, the management policies of the NPS state that management decisions will incorporate best available science into decisions (*National Park Service Management Policies 2006*). Formalized decision frameworks accomplish both.

Elements of a formalized decision process include (1) defining the decision problem, (2) identifying and structuring objectives, (3) developing a set of management alternatives, (4) evaluating the consequences of alternatives relative to objectives (usually via modeling), and (5) selecting the best decision action (*Clemen and Reilly 2001; Conroy and Peterson 2013; Figure 2*). This five-step decision making process is a useful framework for evaluating a very broad range of decision problems, ranging from the very simple to the very complex (*Keeney 2004*).

Adaptive management includes all of the components listed above, but is applied to sequential (in time or space) decision problems (*Williams 2011*). In adaptive management frameworks, uncertainties about how the system works are explicitly represented as competing models representing alternative hypotheses. Monitoring programs are designed to discern the alternative hypotheses that produce better predictions and to evaluate the success of management schemes (*Nichols and Williams 2006*). Future decisions can then be adapted based on the improved understanding of how the system works.

With the creation of the I&M program, long-term data sets have become increasingly available for managers to incorporate into decisions. Over the last five years, the Alaska Region I&M program has worked with parks to

Figure 6. Brown bear in northwest Alaska.

Photo by Carl Johnson, Artist in Residence, Gates of the Arctic National Park and Preserve.

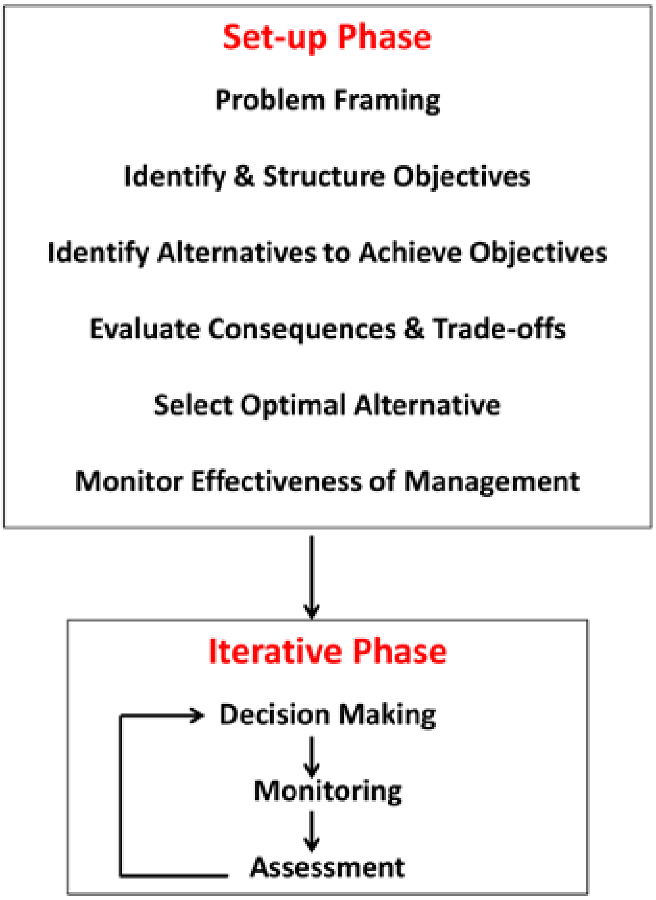


Figure 2. The elements of a decision process. Illustration from Williams 2011.

address complex management issues by using formalized decision processes that are transparent and repeatable and that formally link monitoring programs to management decision making. To highlight the benefits of using a formalized (versus traditional) decision process, we present examples of how components of formalized decision processes aided NPS decision making involving sea otter, brown bear, golden eagle, and wolf management below.

Problem Framing

While at first glance defining a problem may sound simple, the act of articulating a problem statement can lead to insights about an issue that may help to reframe them in a more productive light. For example, as the Alaska Department of Fish and Game (ADFG) prepared to conduct lethal wolf control in 2009, concern was expressed by Yukon-Charley Rivers National Preserve over the potential effect of control on wolves that use the preserve. The initial goal stated by ADFG was to reduce the fall population size of wolves in the control area by 80 percent. However, during a problem-framing exercise, preserve managers realized that framing their management problem in terms of wolf density was problematic. The exercise helped them to discern that a more appropriate way of framing their problem was to consider maintaining a functioning predator/prey system. For example, the preserve could have a high or a low density of wolves and not have an ecologically functioning predator/prey system (which is required per the Alaska National Interest Lands Conservation Act, or ANILCA). In this case, the first step of a formalized decision process, problem framing, allowed preserve management to realize that initially, they had incorrectly framed the management problem.

Identifying objectives

Once a problem has been clearly defined, a decision maker's next task is to identify and structure the objectives of their management problem. Structuring objectives involves the identification and separation of fundamental and means objectives (*Clemen and Reilly 2001; Conroy and Peterson 2013*). Fundamental objectives are those that relate to the decision-maker's core values and thus are not usually negotiable. In contrast, means objectives are actions that need to be accomplished in order to achieve the fundamental objectives. It is also important to identify measurable attributes, which are or can be monitored, to assess the effectiveness of management actions post-implementation.

Thus, identification of management objectives will not only identify an appropriate metric for management effectiveness, but also provide insights into the relative values that decision makers have tied to their objectives (in multiple objective problems) and, in turn, the trade-offs that must be considered to find an optimal solution to the problem. For example, as part of a formalized decision process for management of brown bear (*Ursus arctos horribilis*), NPS managers developed the following series of fundamental objectives for Katmai National Park and Preserve, and Noatak National Preserve: (1) optimize the structure and function of brown bear populations using NPS lands, (2) optimize sport and federally-qualified subsistence harvest, (3) minimize human-bear incidents, and (4) optimize non-consumptive use opportunities. These objectives recognized that (1) brown bear populations naturally fluctuate, (2) park resources (including brown bear) are to be managed for public enjoyment and this may include consumptive (subsistence and sport harvest) and non-consumptive uses, but not to the point of impairment (*National Park Service Management Policy 2006*), (3) deference to non-conflicting state harvest regulations (*ANILCA 1980*), and (4) realization that brown bear populations extend beyond park boundaries. In multiple objective problems, balancing competing objectives such as minimizing human-bear incidents and optimizing consumptive and non-consumptive use opportunities, can be problematic if attempted via a traditional (heuristic) decision process. Alternately, the formalized decision

Photo by Dr. David L. Mech

Figure 3. Wolves howling in Denali National Park.

NPS photo by Dr. Carol McIntyre-Hander

Figure 4. Golden eagle nestlings in Denali National Park.

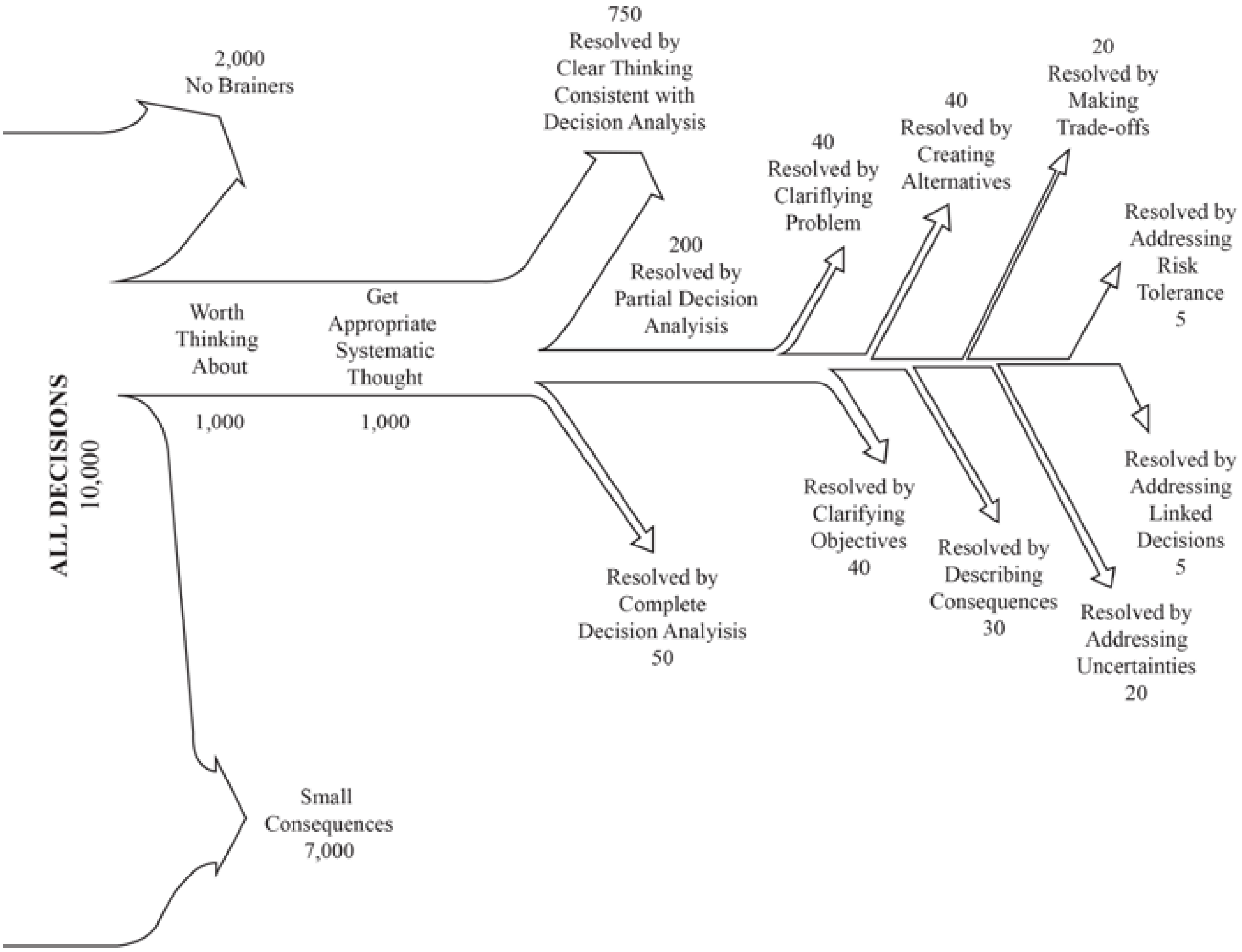


Figure 5. Not every decision warrants an expansive decision analysis. Keeney (*2004*) provides a prescription for how 10,000 decisions should be resolved.

process used by this team provided a means by which managers could evaluate and balance trade-offs of (seemingly) competing objectives. Moreover, the formalized decision framework provided a means by which managers could be explicit and transparent about how objectives were valued relative to one another, and, in turn, how objective ranking ultimately influenced decision optimization.

Evaluating Consequences with Models

Once the scope of a decision problem has been defined (i.e., decision statement, objectives, and management alternatives), alternate actions can be evaluated by predicting resource outcomes with respect to the objectives for each option. In the case of sea otters, which have experienced drastic declines in southwest Alaska, abundant empirical data (published reports) and NPS monitoring data was available to construct a relatively strong quantitative model that represented the most current understanding of sea otter system dynamics. Combining existing data into a single framework that can easily be updated as new data is collected helped NPS identify important uncertainties that can be used to focus inventory and monitoring efforts so that data can be collected in such a way as to resolve those uncertainties that are important to decision-making.

Adaptive Management for Recursive Decisions

For the past 20 years golden eagles have been monitored in Denali National Park and Preserve. In 2004, golden eagles were incorporated into the Central Alaska Network I&M Program because they are a top avian predator and as such, provide insight into functioning of park ecosystems (*MacCluskie et al 2004*). Monitoring data showed that from 1988 to 2010 there was a 25 percent decline in the probability of a female laying eggs and the average number of fledglings produced from a territory. Thus, there was interest in reducing disturbance to nesting pairs. To this end, the park needed to be able to determine if trail access near eyries (bird of prey nests) should be restricted at critical times. Given that trail closure decisions would impact park visitors, it was important that park managers had an explicit and defensible process for making decisions regarding trail closures. A formalized decision framework was constructed to help park managers determine when trail closures were needed to minimize disturbance to golden eagles nesting in the park. This decision tool not only provides a transparent and defensible mechanism by which park managers can make decisions using the best available science, it also allows for adaptation of decisions to fluctuating system dynamics (i.e. adaptive management). Moreover, the implementation of selected, optimal actions combined with ongoing monitoring of measurable objectives will allow for active learning and improved decision making over time (*Williams 2011*).

Summary and Conclusions

Over the past seven years, data from long-term monitoring has been used to assist with park management in Alaska by explicitly incorporating objectives, science, and decision making into integrated decision frameworks. Often at the beginning of these processes there has been trepidation on the part of managers that the process will be too onerous or complicated. We have several points to make in response to this assertion. First, formalized decision processes do not need to be arduous or complex. By quickly working through each step, a process called rapid prototyping, a manager can often gain great insight into a decision problem with very little investment. Second, we encourage managers to avoid the common misconception that decision processes are purely quantitative exercises. A majority of problems can be resolved, and many can benefit, from walking through the early design and development phases of formalized decision processes including problem framing, identifying objectives, and considering means of achieving those objectives (*Keeney 2004; Figure 5*). We contend that we have presented a number of examples of formalized decision processes that are improving park management decision making, and we encourage continued applications of this approach. Moreover, considering that the NPS is legally mandated to incorporate perpetuity into its decisions, we believe that adopting adaptive management as a means for making decisions (when they are iterative in nature) is especially appropriate.

Acknowledgments

Special thanks to the biologists and managers that contributed to the decision-making process for wolves, brown bears, sea otters, and golden eagles in Alaska parks over the last seven years. Thanks also to Michael Conroy, Jim Nichols, and Julien Martin for contributing their expertise to natural resource decision making in Alaska parks.

Photo by Ben Weitzman, USGS.

Figure 6. Sea otter in southwest Alaska.

REFERENCES

Clemen, R., and T. Reilly. 2001.
Making Hard Decisions. Mason, OH: South-Western.

Conroy, M., and J. Peterson. 2013.
Decision-making in Natural Resource Management: A Structured Adaptive Approach. Hoboken, NJ: Wiley-Blackwell.

Keeney, R. 2004.
Making better decisions. *Decision Analysis.* 1(4):193-204.

MacCluskie, M., K. Oakley, and D. Wilder. 2004.
Central Alaska Network Vital Signs Monitoring Plan. Fort Collins, CO: National Park Service.

Nichols, J., and B. Williams. 2006.
Monitoring for conservation. *Trends in Ecology and Evolution* 21:668-673.

Williams, B. 2011.
Adaptive management of natural resources—framework and issues. *Journal of Environmental Management* 92:1346-1353.

Williams B., R. Szaro, and C. Shapiro. 2009.
Adaptive management: The U.S. Department of the Interior technical guide. Washington, D.C.: U.S. Department of the Interior, Adaptive Management Working Group.

U.S. Congress. 1916.
National Park Service Organic Act 16 USC 1-4.

U.S. Congress. 1980.
Alaska National Interest Lands Conservation Act (ANILCA). Public Law 96-487. Section 201.

U.S. Department of the Interior. 2006.
National Park Service Management Policies 2006.

CRASH! The Alaskan Bush Hits Climate Change... or Does it?

By Julie and Miki Collins

Living a subsistence lifestyle in the remote Lake Minchumina area northwest of Denali National Park and Preserve (Denali Park) since our birth in 1959 has given my twin sister Miki and me decades to observe environmental changes. As we ramble about gathering berries, fish, furs, game, firewood, and other wild supplies (as allowed under rural Alaska subsistence rights affirmed by Congress in the Alaska National Interest Lands Conservation Act), we can't help but notice many changes. But how much is truly climate change?

In November of 2010, an unprecedented rain storm flooded the frozen, snowy lake. Was that climate change? Maybe, maybe not—but when bizarre November rains hit us again for two of the following three years, it was easy to think so.

For most of the 1990s, extreme winter snowfalls made dog team travel so tough that we shortened our trapline and caught less fur. We were sure it was climate change and we'd be wading through snow forever.

Then in the first decade of the 2000s, we had so little snow through January that the dog team took a terrible pounding on bumpy trapline trails. Often late-winter blizzards broke the dry spells. After one of these storms, it took 10 days to travel 60 miles to the last tent camp on our trapline.

These extremes are more frequent and last longer. We have seen warmer weather, especially in the fall and winter, extremely late freeze-ups, record or near-record rainfall, longer droughts, more significant windstorms, and these creepy winter rains. Not many people remember that 2004, the worst wildfire year in Alaska history, had exceptionally rainy weather during May before the drought began. In 2013, we had the latest breakup anyone could remember; in 2014, the earliest.

While I have no proof that these unusual conditions are from climate change, I can say that they affect our lives, from how we plan our subsistence activities and the way we travel to our simple enjoyment of (or frustration with) the wilderness. The land and water, so familiar and cherished, sometimes act foreign and unpredictable.

Figure 1. Instead of being padded with snow, rough trails often last until January. Working in these pounding conditions for months and years can cause injuries and early-onset arthritis in the sled dogs.

© Miki & Julie Collins

At 11 miles long and three to five miles wide, Lake Minchumina is considered to be the largest lake in interior Alaska, yet it is actually just a remnant of a much larger body of water that formed prior to 34,000 B.P. (*Alaska Anthropological Association 2012*). Backed to the north and west by gentle birch hills and the rugged Kuskokwim Mountains, much of the original lake has filled in with Foraker River silt carried from Alaska Range glaciers. During our lifetime the average lake level has dropped almost six feet. However, ancient shorelines well above the current ones tell us that this process is not necessarily a recent development. Can we blame climate change? Who knows?

Instead of insisting that climate change caused this or that, we are simply going to list some of the changes that we have witnessed and tell how they affect our lives. Maybe someone with more expertise can sort out causalities.

Trapping

Rivers now usually freeze two or three weeks later than in the 1980s, delaying our departure at the most important time of the trapping season. We cannot access our primary trapping areas in Denali Park until we can safely cross frozen rivers and streams. When we began subsistence trapping full time in 1981, we usually crossed those rivers during the first few days of November. In the 1990s, late freeze-ups delayed our travels more than half the time, and in subsequent years this hindrance has gotten worse. In 2013, a very late freeze-up coupled with late-November rainstorms and virtually no snow meant trapping was delayed into December (*Collins 1979-2014*). November 2014 saw less rain, but only a couple inches of snow until early December.

In the last few years, these unprecedented November rains have brought a nightmarish combination of slush, flooding streams, dangerous ice, and melting snow. In addition to creating logistical problems, warmer winters result in fewer top-dollar pelts with their prized dense, cold-resistant fur.

We catch two-thirds of our marten in November and December, before the onset of deep cold and before natural mortality reduces the population. When we lose the first month, it greatly reduces our income. Also, if heavy snows accumulate as we wait for rivers to freeze, this makes heavy going for the dog team, reducing mileage and fur take. This problem was worst during the deep-snow years of

© Miki & Julie Collins

Figure 2. Deluges and the subsequent flooding cause rapid erosion. When this trapping cabin was constructed in the early 1970s, it lay just over 80 feet (about 25 meters) from the river with several large trees in the front yard. Most of this erosion occurred in just two or three years.

© Miki & Julie Collins

Figure 3. More frequent storms increase the difficulty of running a fish net. During a big storm like this one, we may have to pull the net or deal with the consequences of the equipment blowing ashore and jumbling in the surf.

© Miki & Julie Collins

Figure 4. Late freeze-ups are frustrating because we pull the nets when freeze-up appears imminent, and may run out of fish (to feed our sled dogs) before we can re-set nets under the ice. A slow freeze-up means we might set a net under marginally safe ice, even if open water beyond warns of the hazards.

the 1990s. Since then, snowfalls have been too light to pad and lubricate the trails, so early travel is dangerously rough. Most years have seen ankle-deep snowfall in early winter, then very little accumulation until February.

This shallow snow cover helps explain the current low wolf population because moose, their long-legged prey, easily elude capture. Warmer weather might explain or contribute to the wolves' lice infestation that only recently penetrated north of the Alaska Range, and which stresses wolves and can destroy the pelts' value.

A changing climate can affect hare populations for better or for worse, which causes rippling effects in fur populations. Although steadily-accumulating snow depths allow hares to eat higher up on willows, in this area the last population peak lasted abnormally long despite the low snow. This gave us years of good lynx harvests.

Conversely, marten populations plummeted during this period, possibly because of the high lynx numbers. Marten numbers in our area have been depressed for over 15 years. In one Alaska Department of Fish & Game study, the number of juveniles relative to adults failed to reflect the fertility rates in females (*Gardner 2014*).

Marten are affected by the microtine populations on which they prey. Dry summers mean fewer of these small rodents, while drenching rains can flood their nests. Forest fires reduce marten populations initially but, unless the fires burn so hot that they destroy the topsoil, the burns eventually re-grow into superior microtine habitat and bring in more marten. The voles and other subnivean creatures are also impacted by November rain, which destroys the insulating quality of the snow.

While the marten population has remained low, we are seeing more weasels (ermine). Perhaps these smaller vole-eating mustelids are filling a void left by marten.

Drying lakes reduces wetland habitat, impacting beaver and muskrat populations. (This loss of habitat is not offset by increasing areas of poor-habitat bogs created by thawing permafrost.) The muskrat population crashed statewide decades ago and has only recently shown signs of recovering.

Some permanent sets (trap locations) placed beside drainages must be moved to higher ground every few years and with increasing frequency as thawing permafrost slumps into the water.

Moose Hunting

Climate change can impact moose positively and negatively. Warmer weather allows brush to grow at higher latitudes and elevations so they can expand their range. More forest fires add habitat as burns regrow with choice saplings.

Low-snow years increase moose survival, which will reverse if we return to extremely deep snow. Dry summers and drying lakes reduce forage. Moose also depend on deeper ponds to escape horse flies, which proliferate during hot summers (while mosquitoes have not been as bad). Lower water levels make it harder to access marshy hunting areas and bring out meat. Conversely, storms and flooding can drown calves and cover pondweed to a depth that moose may be unable to feed on it. Invasive plant species that proliferate due to climate change could displace moose browse. Our chokecherry trees with their poisonous leaves have started spreading by seed in the last 15 years, which they never did before.

In the late 1990s many of the mature alders along local rivers died, reducing important autumn moose forage. Since alders fix nitrogen, this die-off could also negatively impact soil fertility.

If climate change does increase the moose population, this makes it easier to find our winter's meat supply. Good calf survival means more young bulls which we prefer to tough old moose.

The massive size of mature bulls makes them overheat easily. While the rut is triggered by the decreasing day length, unusually warm September weather reduces rut activity because the bulls overheat. This puts the rut out of synch with the legal hunting season. (State and federal authorities have been shifting the season later in some game units.)

Warmer fall weather and delayed freeze-ups also make it difficult to let meat hang outside until winter weather freezes it. The long tradition of sawing frozen roasts from a hanging leg of moose may die out if we continue to see above-freezing weather for most of October.

Fishing with Gill Nets

Over the decades we have caught fewer and fewer whitefish to feed our sled dogs despite greatly increasing our efforts. However, the last three years have given us fish numbers that we haven't seen since the late 1970s, possibly due to cooler summers and higher water. Warmer water reduces fish movement while wind and high water both increase fish catch.

During the whitefish spawning runs in the fall and early winter, we hope to freeze 800 to 1,200 fish for winter dog food. Despite warmer autumns, whitefish spawning seems to start earlier and run longer, so the run dribbles through. Fish caught in an early run can't be frozen outside (especially with the delayed cold temperatures) and a long thin run means more fishing effort. The recent slow late freeze-ups also push back the date that we can safely set nets under the ice for more productive catches. On the other hand, warmer weather and thinner ice result in less effort to open frozen fishing holes and keep nets running through December.

When wind storms blow the snow away, fishing holes freeze faster and working on the slippery ice is difficult. The early heavy snows in the 1990s created serious overflows and dangerous ice conditions. (While checking one net with a pack horse, I did not realize the ice had deteriorated dangerously until my horse alerted me to the peril.)

The lower water level has reduced shallow-water habitat that is important to young fish. Whitefish used to move freely between Minchumina and outlying lakes and ponds, but many of the smaller bodies of water are now land-locked or drying out.

Gardening

Between 1970 and 2010, our growing season lengthened by 20-40 days. The accepted frost-free season used to be June 1 to September 1, but in some recent years the last frost occurred in April and the first fall frost hit in October. In the last three years, we have seen somewhat more normal freezes in September, but winter has still been significantly delayed.

Despite several cooler, rainy summers, we also see longer droughts which increase irrigation efforts and reduce yield and quality. Warm, dry weather helps our heat-loving plants (corn, squash, beans, pumpkins and tomatoes) but stresses the cole crop varieties and root vegetables, thus expanding the range of vegetables we can cultivate, but reducing the quality of the cold-weather plants that are our staple crops.

Pounding deluges wash out seeds, batter delicate crops and cause erosion; frequent rain increases weeds and mildews.

Pests and plant diseases are likely to appear or increase with a longer, hotter growing season or when plants are stressed. Invasive plants may be spreading faster, including seeds imported in hay, straw, and commercial garden sets, and ornamental or experimental plants that run wild. We've seen the spread of chokecherry, hempnettle, dandelion, hawksweed, pepper grass, and fox tail (in addition to the many weeds that accumulated after the land was first settled in the 1920s).

Starting in the late 1990s, our highly productive domestic strawberries became increasingly diseased until we had to destroy the patch. The cooperative extension service identified scorch, a fungal disease normally killed by cold winters. However, we are not confident of this diagnosis.

© Miki & Julie Collins

Figure 5. In 2010 an unprecedented November rain covered the frozen lake with water. On November 24 we waded almost a mile (about a kilometer) in shin-deep water to reach the fish net.

Other Harvest

Warmer temperatures certainly demand less firewood for heating the home and trapping cabins. With the recent early spring thaws and their dwindling snow trails, we've sometimes been forced to choose between hauling summer supplies or filling the wood shed (with wood stacked in the forest the previous summer). Early springs do allow us to start wood-cutting sooner in April when the snow softens, but birch trees must be cut down earlier to beat the spring run of sap. We are seeing more lichens and fungus growing on birch trees, not just gnarly old trees but also young and prime ones.

Blow-downs of large trees are common in dry windy years when the soil lacks water to anchor the trees.

Hot dry weather or very cold wet weather reduces the quality and abundance of berries. Our main wild berries are raspberries, blueberries, and cranberries. In 2014, following a very early spring and a cool, wet summer, we saw a poor raspberry harvest and a dismal crop of blueberries and cranberries. When blueberries and cranberries fail, we increase bear alertness, knowing that the bears are hungry.

Blueberries and morel mushrooms thrive in many burned areas and may benefit from more wildfires if the fires don't destroy the organic materials in the underlying soil, and if the new growth gets adequate rainfall.

Travel

Warm weather and early heavy snows create overflow on lakes and swamps that greatly impedes winter travel. Conversely, low snow accumulations and cold weather will freeze spring-fed streams to the bottom, leading to flooding and glaciering (layers of frozen overflow) on top of the ice. Any water under the snow creates treacherous conditions, especially in bitterly cold weather. With the warmer winters, we have encountered less overflow in the last 15 years despite low-snow conditions.

As the average temperature rises, permafrost warms enough to become unstable. When the thawing soil slumps in trapline trails, it requires strenuous travel or re-routing of sections of trail. Some slumps that developed in our trail are over 10 feet deep. Most are associated with water erosion, such as where the trail crosses gullies that sink deeper and deeper into the permafrost, or where a creek undercuts whole sections of trail that collapse into the water. Although our trapping area was established almost a century ago, after inheriting it we re-opened 100 miles of old trails and never found jags where the original trail had been re-routed around eroded ditches or riverbanks. In the 1980s, we moved the trail in a couple of places where permafrost thaw made it impassable. We made

© Miki & Julie Collins

Figure 6. This wall of exposed permafrost on the Foraker River near the boundary of Denali Park is part of a hill that has been slumping into the river for years; the photo was taken in 1993.

© Miki & Julie Collins

Figure 7. This area burned in 1986 and again around 2009, making travel easier if sooty. Burns that sweep through forested land completely change habitats, scenery, and travel conditions.

several more detours in the 1990s, and over the last 15 years we find ourselves cutting detours almost every year.

The worst permafrost slumps seem correlated more to summers with torrential rains rather than to hot summers. A level spot becomes a jarring hole, which erodes into a sled-eating ravine. As creeks and rivers deeply undermine frozen ground, large sections cave in, sometimes carrying bits of trail along. These upheavals cause delays, extra trail work, and broken sleds, and can potentially injure sled dogs or travelers.

Following a late-1990s statewide die-off of tamarack trees from insect infestation, the dead blow-downs have been cluttering up our trails for almost 15 years. Burned-over trails require extensive work to reclaim and make travel difficult for decades due to toppling trees, more snow drifting, and possibly increased melting of the exposed permafrost.

Along our trapline, normally shifting glacier streams are stabilizing, incising their channels deeper while sand bars are becoming overgrown. The steeper banks and new brush interfere with winter travel and make summer travel problematic as brush impedes walking and swift rivers tend to be deeper instead of spread out. Overland summer travel is also hampered by heavier summer rains that flood streams and rivers, and by increased brush above treeline.

Animal Husbandry

In warm weather sled dogs overheat while working, but it is easier to keep weight on the animals, which saves on the food bill. Winter rain—increasingly common—stresses sled dogs and especially horses. Snow levels impact whether the horses can forage effectively, which affects our work load and feed bill. Drier summers or flooded grasslands reduce horse forage. Early winter rain makes bluejoint grass unusable for bedding straw in dog houses.

Other Observations

In the last few years we have seen fewer geese, terns, shore birds, song birds, hawks and owls, but more bald eagles and robins.

The Foraker River, which feeds Lake Minchumina, recently shifted so that over half of its water diverts around the lake, contributing to lower lake levels. The change occurred partly because permafrost subsided so it no longer barred the way, but also from natural filling and shifting. A small stream upriver also diverted its outlet to take advantage of thawing permafrost.

While permafrost thaw has always caused submersion of black spruce bordering lakes and marshes, this process is increasingly rapid in some areas. Although sad to see, it does provide us with more dead spruce for firewood.

During dry summers, moss insulating trapping cabin roofs is more likely to die or turn grassy (a fire hazard). As forest fires destroy larger areas more frequently, trapping cabins are at increased risk of burning.

Conclusion

Weather extremes…warm falls and delayed freeze-ups…permafrost slumps…drying lakes—we have seen it all. Has climate change actually created these problems for the subsistence way of life? As I said at the beginning, things have certainly changed, but we don't know if it's from natural fluctuations or man-made global changes.

Life has certainly gotten harder, but what do you expect? We age a lot in 55 years. In conclusion, all I can say is "Change? Yes! Climate change? Yes...maybe…probably."


© Miki & Julie Collins

Figure 8. A major forest fire creates heavy smoke conditions that impact health and also reduce visibility enough that boating across Lake Minchumina requires a compass or GPS.

Interactive iBooks and ePubs

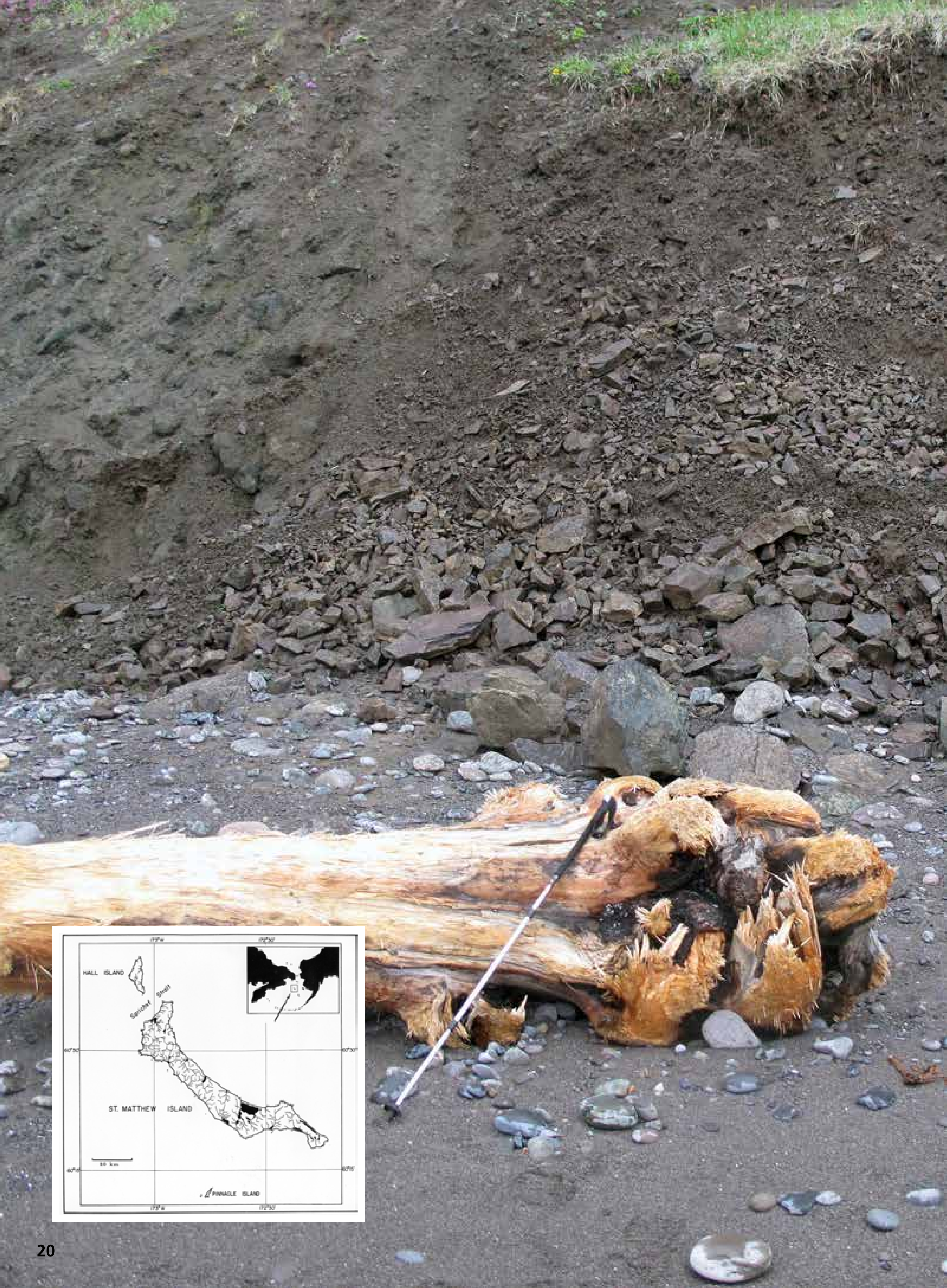
Explore two popular topics more fully through digital publications loaded with interactive text, photo galleries, audio, and video clips. The *Denali Climate Anthology* invites five accomplished local authors to chronicle the effects of a changing climate on the lives and landscape they treasure here. The *Artist-in-Residence* Catalog is a comprehensive exhibit of all the art, writing, and music that participants have donated to the program collection since 2002. Learn how you can download free copies at http://go.nps.gov/DenaliMedia.

REFERENCES

Alaska Anthropological Association. 2012.
39th annual meeting. Seattle, WA.

Collins, M., and J Collins. 1979-2014.
Dog Log. Private collection.

Gardner, C. 2014.
Personal communication.


173°W
172°30'
HALL ISLAND
Sarichef Strait
60°30'
ST. MATTHEW ISLAND
10 km
60°15'
PINNACLE ISLAND

Differential Effects of Coastal Erosion on Colonial-Nesting Sea Birds on the St. Matthew Islands, Alaska

By David R. Klein and Richard Kleinleder

Introduction and Background

The St. Matthew Islands, which include St. Matthew, Hall, and Pinnacle islands and are a part of the Alaska Maritime National Wildlife Refuge, are the most remote lands in the entire 50 states (*Figure 1*). They support perhaps a million or more colonial-nesting and ground-nesting bird species. Coastal erosion through wave action as sea levels rose during the early Holocene, flooding much of the Beringian coastal plain, played a major role in creating the coastal landscapes that have been so propitious for colonial sea birds by providing secure nesting sites on the coasts of the Pribilof and the St. Matthew archipelagoes. Refuge expeditions to the St. Matthew Islands have returned about every five to seven years to monitor the rich bird populations and other life forms and their habitats. The occurrence of increased coastal erosion in recent decades on Alaska's north and northwest coasts associated with climate change influences (*ACIA 2005*) raised our interest in the possible consequences of coastal erosion on colonial-nesting sea birds on the St. Matthew Islands (*Figure 2*). Pronounced erosion on specific portions of the coastal cliffs of these islands where sea bird colonies were located has been observed in the last century. The biologist G. Dallas Hanna described one of the regions of significant erosion on a visit to the St. Matthew Islands in 1916: "The earth and cliffs are torn and tumbled in the greatest confusion. New slides are seen and the beach line boulders are not much rounded. In some places rocks are constantly falling, making it dangerous to go beneath the cliffs" (*Hanna 1920*).

The St. Matthew Islands are largely of volcanic origin, their exposed coastal rocks dating from ~60 to ~77 million years ago (*Dawson 1893; Patton et al. 1975*). The rocky coastal cliffs of the St. Matthew Islands have provided the locations where over a million sea birds have been able to establish their colonial-nesting sites (*A. Sowls pers. comm*) (*Figures 3a and 3b*). Following an assignment by the Biological Survey of the U.S. Department of Agriculture to do a reconnaissance survey of the mammals of St. Matthew Islands in the summer of 1916, G. Dallas Hanna (*1920*) provided a most perceptive description of the coastal landscape of St. Matthew:

> The mountains are cut into by the sea on every side of the island, making long stretches of towering cliffs, between which the sea has built up beaches of such an extent as to give the impression that the island is much older than the Pribilofs. The cliffs display wonderful geological formations. There are blues, yellows, greens and bright reds in layers or dikes. The large number of cliffs with their grand scenic display are notable as the nesting places of countless sea birds. Of all the places I have visited St. Matthew Island is rivaled in this respect only by that incomparable bird cliff on St. George Island; the ledges on St. Matthew are more nearly perpendicular and thus afford less favorable nesting sites.

Hanna's asigned focus while on St. Matthew and Hall islands was primarily the mammals; thus, his comments on birds were limited to the obvious dense aggregations of birds nesting on the steep ciffs, primarily murres, kittiwakes, and fulmars. He made no mention of the large colonies of crevice-nesting least (*Aethia pusilla*) and crested auklets (*A. cristatell*a) that are largely obscure to the casual visitor to these islands when birds are hidden from view and on their nests. Hanna disagreed with John Muir's suggestion, made when visiting St. Matthew in 1899 with the Harriman expedition, that glacial scouring accounted for the rounded nature of the mountain landscape (*Merriam 1901-10*). In this regard Hanna noted that (The action of ice (meaning glacial ice) on these islands seems inconsequential.) While there is no evidence of the St. Matthew Islands being overridden by a glacial advance during the last glacial maximum of the Pleistocene as suggested by Muir, Potter et al. (*1975*) did identify and map several small cirque basins in the mountains of St. Matthew extending from the northeastern coast inland, providing evidence that a few small glaciers were present in these mountains during full glaciation when sea levels were lowered 328 feet (100 meters) and the St. Matthew Islands were part of Beringia and the Alaska mainland.

Accelerated erosion of portions of the rocky coasts of the St. Matthew Islands was documented during the 2005 expedition to these islands (*Renner and Jones 2005*). In view of the accelerated coastal erosion rates on Alaska's northern coasts in recent years (*ACIA 2005*) and the potential for even higher coastal erosion rates in the future in a dynamic climate (*Anisimov et al. 2007; Hinzman et al. 2005*), we investigated effects of coastal erosion on the colonial-nesting sites of sea birds during our 2012 expedition to these islands.

Figure 1. (Map) Location of the St. Matthew Islands.

Figure 2. Accelerated erosion of fractured basalt on the northeastern coast of St. Matthew Island, August 1, 2012.

Photo by D. Klein

Methodology

During July 29 to August 7, 2012, we collected representative samples of rock types at sea bird colonies where we were able to gain access on St. Matthew and Pinnacle islands. The rock samples that we collected on Pinnacle were from a small rock fan composed of rocks that had eroded and fallen from the steep rocky slope above; thus, they included rocks representative of the basic rock types of the island. All rock samples were examined for specific rock type and density at the Geochronology Laboratory at the University of Alaska Fairbanks. We took reference photos at the rock collection sites, which enabled correlation of rock type, density, and possible vulnerability to coastal erosion with the geomorphically detailed Reconnaissance Geologic Map of St. Matthew Island produced by Patton et al. (*1975*) in conjunction with their 1971 geological work on the island. Turbidity plumes in the adjacent sea, visible on 1948 U.S. Navy aerial photos, and satellite imagery from southwestern Hall and northwestern St. Matthew were used in defining locations of active erosion of silicic pyroclastic deposits. Locations and relative size of sea bird colonies were available from Renner and Jones (*2005*) and Alaska Seabird Information Series (*USFWS 2006*).

Results and Discussion

Assessing Effects of Coastal Erosion on Colonial-Nesting Sea Birds

In recent decades, as a consequence of global climate warming, sea levels have risen more than 11.8 inches (30 centimeters). Duration of the annual presence of sea ice at the St. Matthew Islands has declined markedly, at least through 2011 (*NASA 2013*). The southern extent of winter sea ice however, has shown little change from the long-term mean. As a consequence of the delay in formation of sea ice and associated shore-fast ice in early winter, wave action enhanced by the extreme storms of early winter have created conditions that can accelerate coastal erosion on the St. Matthew Islands where rock types are sensitive to erosion. Luchin et al. (*2002*) reported on a pronounced decrease beginning in the late 1970s in mean seasonal duration of sea ice in the northern Bering Sea, presumably a consequence of accelerated climate warming throughout the Arctic (*IASC 2005*). This decline in duration of Bering Sea ice and associated warming of ambient temperatures was most pronounced in the eastern Bering Sea where warmer North Pacific waters moving with northeastward flowing currents also accounted for warming of ambient temperatures there


Photo by D. Klein

Photos by M. Romano

Figure 3a and b. Coastal land forms of the St. Matthew Islands; the southeast coast of St. Matthew Island (left) and the northeast coast of St. Hall Island (right).

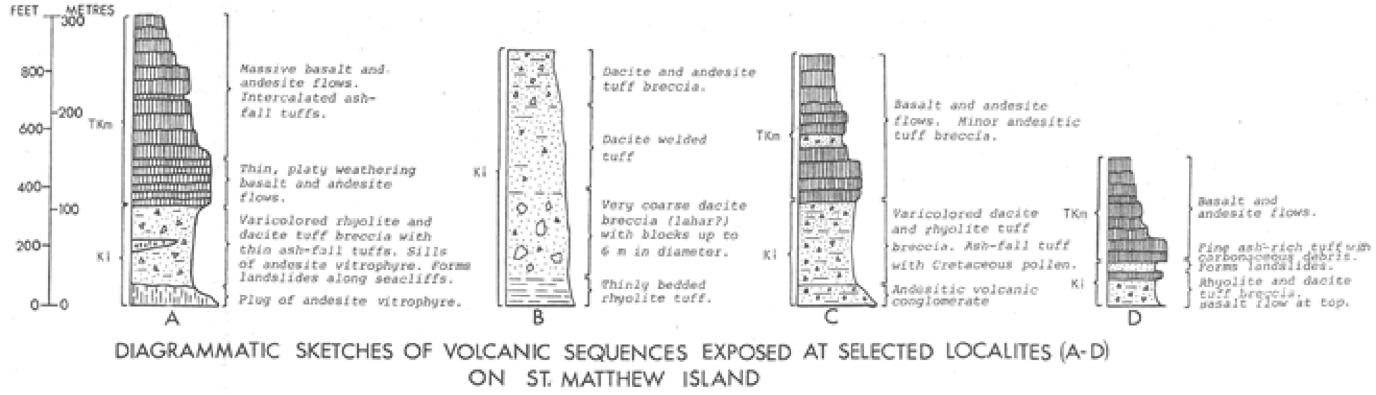


Figure 4. Diagrammatic sketches of volcanic sequences exposed at selected coastal locations on St. Matthew Island (From Patton et al. 1975).

(*Grebmeier et al. 2006; Klein and Shulski 2009*). In the western Bering Sea however, cooling was associated with southward flowing ice and waters (*Stabeno et al. 2005*). The mean annual extent of sea ice and annual duration of sea ice in the region of the St. Matthew Islands, and the associated climate inclusive of both cooler and warmer years, appears to have been more greatly influenced by the North Pacific Ocean via the Pacific Decadal Oscillation and El Niño events than by Arctic Ocean influences (*Kitaysky and Golubova 2000; Luchin et al. 2002*).

The surficial geology of the St. Matthew Islands testifies to its volcanic origin (*Potter et al. 1975; Wittbrodt et al. 1989*). The nature of the coastal rock however, varies in its morphology, hardness, stratification, and metamorphic history, accounting for wide local variation in its vulnerability to coastal erosion. Following periods of active volcanism in the late Cretaceous and early Tertiary ages, ~ 77 to ~ 60 million years ago (*Patton et al. 1975*), both St. Matthew and Hall islands have remained horizontal and relatively free of tilting and folding by tectonic movements (*Wittbrodt et al. 1989*). This is more evident on Hall and northern St. Matthew than in the central and southern portions of St. Matthew. The volcanic rock forms, transformed through erosion processes, provide the sites now occupied by myriads of colonial-nesting sea birds. These coastal rocks are a product of the volcanic past when basalt and andesite flows were interlayered with pyroclastic fine- and course-grain, ash-rich tuffs, sometimes including dacite blocks of up to 3.2 feet (1 meter) or more in diameter (*Potter et al. 1975; Coombs and Bacon 2012*). Diagrammatic profiles of the rock strata that reflect these volcanic sequences at specific coastal localities on St. Matthew Island are shown in Figure 4. These coastal profiles illustrate how the less dense, and more erodible rock derived from pyroclastic flows, overridden by the harder rock from lava flows of basalt and andesite, have over time and with differential responses to erosion by the sea, created nesting habitats for both the crevice nesting auklets and the typical cliff ledge-nesting murres (*Uria aalg* and *U. lomvia*), kittiwakes (*Rissa tridactyla*), and fulmars, *Fulmarus glacialis*.

The rocky nesting habitat of the crevice-nesting small auklets, primarily the least auklet and crested auklet on St. Matthew and Hall islands is generally the product of past coastal erosion. These nesting colonies are often associated with massive slumps into the adjacent sea where highly erodible thick layers of intermediate and silicic pyroclastic deposits had been overridden by thin basalt and andesite flows (*Coletti 2012; Figure 4*). The relation between sea bird nesting colony location and volcanic rock types on the St. Matthew Islands is illustrated in the map in Figure 5. This has presumably been an active process as rising sea levels throughout the Holocene engulfed the mountainous landforms that ultimately became the St. Matthew Islands. Within the pyroclastic deposits a fine bentonite-like material, white and multicolored and with an affinity for water, often forms layers in the coastal strata, which act as a lubricant that facilitates movement and the slumping of denser basalt and andesite in the above strata. These massive slumps and their active nature have been described by early visitors to the St. Matthew Islands (*Elliott 1882; Dawson 1883*). Pronounced turbidity resulting from the continuing leaching and erosion of the fine light-colored tuffs into the adjacent sea is apparent in 2009 satellite imagery (*Aleutian and Bering Sea Islands Land Conservation Cooperative 2009; Figure 6a*). Auklets choose nesting sites among and under large boulders that remain on the surface of slopes or benches where the slumps have occurred (*Figure 6b*). Earlier visitors to the St. Matthew Islands have noted the continuing slow movement of these slumping and fractured rock strata toward and into the sea (*Elliott 1882; Hanna 1920*). Rock falls from the head or edge of the slumps often pose risks to the nesting auklets, their eggs, and young as well as the biologists attempting to monitor the extent of auklet nesting within the slump areas (*Renner and Jones 2005*). This is where thin layers of the basalt and andesitic mafic flows are intermixed with or abut softer and more erodible pyroclastic strata (*Table 1*). These are the locations where coastal erosion is active in the softer, more water-permeable

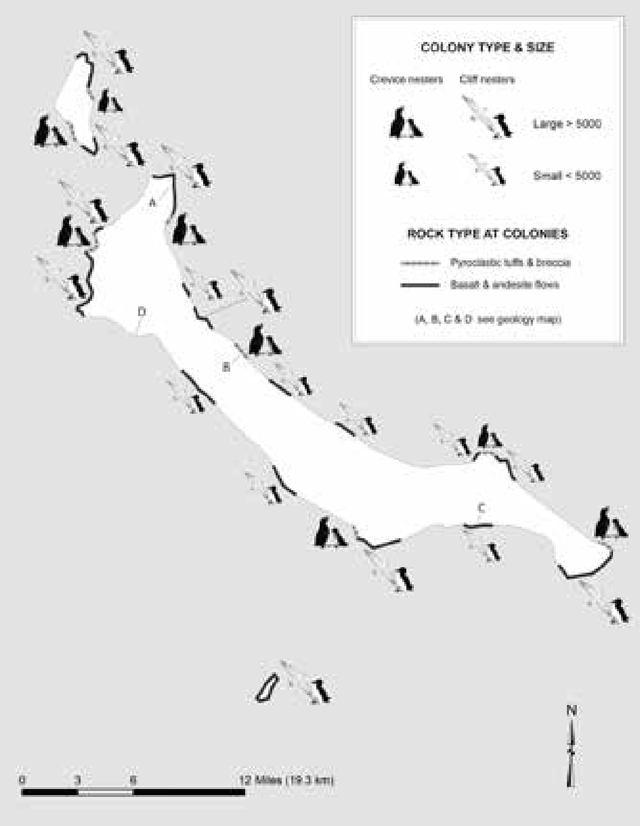


Figure 5. Location of sea bird colonies in relation to coastal geology, rock type, and its relative vulnerability to erosion on the St. Matthew Islands. Small auklet species are crevice-nesters in colonies of thousands of birds located where coastal deposits of pyroclastic materials of variable textured tuff breccia from Late Cretaceous volcanism, most similar to profile B in Figure 4, have slumped to the sea. (*Potter et al. 1975*). Colonies of murres, fulmars, and kittiwakes, cliff-ledge nesters, are primarily restricted to sheer cliffs of erosion-resistant basalt and andesitic flows of late Cretaceous and early Tertiary volcanic origin, most similar to profiles A, C, and D of Figure 4.

Figure 6a. The August 9, 2009, satellite image (*ABSILCC 2009*) shows dense turbidity plumes in the sea adjacent to northwestern St. Matthew (lower right) and southwestern Hall (upper right) indicating ongoing erosion of the fine pyroclastic tuff brecias present in the coastal rocks and soils.

Photo by Ian Jones

Figure 6b. Erosion has generated habitat for crevice-nesting auklets on northwestern St. Matthew and on western Hall.

Photo by R. Kleinleder

Figure 6c. Crested and least auklets are the primary nesters in the large auklet colonies on the St. Matthew Islands.

Rock Sample Type-Morphology	Density
SM 1: Altered rhyolite, alteration mineralogy is epidote and secondary biotite	2.87
SM 2: Altered porphyritic rhyolite, alteration mineralization is epidote, chlorite, and secondary biotite. Rock was altered after intrusion of hot fluid circulating through overlying rock. Original rock was rhyolite with visible feldspar crystals.	3.00
SM 3: Basalt from old crater rim	2.50
SM 4: Vesicular basalt, greenstone from flow in wet environment	2.83
SM 5: Rhyolite and dacite, hypabyssal	2.35
SM 6: Altered porphyritic from tuff	2.67
Mean density of collected St. Matthew Island rocks	2.72
P 1: Altered epidote, pyrite, with some chalcopyrite	2.79
P 2: Fine tuff, altered porphyritic and marine hardened	3.01
P 3: Flow-banded rhyolite, alteration and mineralogy is pyrite and epidote	2.64
P 4: Flow-banded rhyolite, alteration and mineralogy is pyrite and epidote, marine hardened	3.20
P 5: Marine hardened intrusion in basalt	3.91
Mean density of collected Pinnacle Island rocks	3.11

Table 1. Comparison of coastal rock density of rock samples from St. Matthew (SM) and Pinnacle (P) islands.

pyroclastic materials and therefore have generated massive earth slumps, which are often topped by fields of fractured basalt, andesitic, and dacite boulders. The resulting boulder fields sloping to the sea provide relatively secure crevice-nesting habitat for the small auklets. These auklet nesting colonies are therefore the product of past as well as continuing coastal erosion. Although accelerated coastal erosion was observed to be ongoing at the existing auklet colonies on Hall and northern St. Matthew islands, contributing to dynamic changes in the surface landscape at these coastal locations, we observed no detrimental consequences for the nesting auklets except at the Glory of Russia colony. There, where the adjacent mountain slopes are composed of highly disrupted pyroclastic material, a massive mud slide of fine ash-fall tuff has in recent decades bisected the colony, covering extensive areas that had been used by breeding auklets in the 1970s (*Art Sowls, pers. comm. in Renner and Jones 2005*). Auklet nesting habitat is, however, being generated on Hall and was being used by some nesting auklets in 2005 (*Figure 7*). Rock types where murres, kittiwakes, and fulmars—the cliff-ledge nesters—concentrate are consistently among the much harder rock types derived from the massive andesitic and basalt flows (*Figure 8; Table 1*). These high-density, hard rocks are resistant to erosion by the sea, in contrast to the dacite, rhyolite, and andesitic tuff breccias whose erosion creates habitat for nesting auklets. Thus, it is the erosion resistance of the thick and massive basalt and andesitic flows where they interface with the sea that generates the sheer cliffs where the most extensive nesting habitat for murres, kittiwakes, and fulmars are found. These rock faces also contain crevices

Photo by D. Klein

Figure 7. This relatively small slump into the sea on the east coast of Hall Island was shown through satellite imagery to be actively expanding into the sea in recent decades providing new habitat for nesting auklets as well as a secure haul-out area in summer for adult male walrus (August 1985 photo).

Photo by D. Klein

Figure 8. On the St. Matthew Islands, sea cliffs that provide habitat for murres, fulmars, kittiwakes, and other ledge-nesting birds result from ancient lava flows of dense basalt and andesite.

Photo by R. Kleinleder

Figure 9. MacKay's buntings, endemic to the St. Matthew Islands, nest in crevices on cliff faces as well as in coastal driftwood accumulations, and other locations where cover limits visibility of the nest by avian predators or foxes.

that are used for nesting by puffins (*Fratercula corniculata and F. cirrhata*), the larger auklets, MacKay's buntings (*Plectrophenax hyperboreus*) (*Figure* 9), and rosy finches (*Leucosticte tephrocotis*). The relationship of coastal rock type to the crevice nesting auklets versus cliff-ledge nesting murres, kittiwakes, and fulmars is illustrated on the map in Figure 5.

Fracturing of some of these mafic basalt and andesitic flows, which initially occurs during the cooling process of volcanism, renders these rocks subject to weathering as moisture readily enters the fracture cracks and seasonal freezing and thawing makes these rocks, where exposed at the coast, highly vulnerable to erosion by wave action during

Photo by R. Kleinleder

Figure 10. Near Glory of Russia Cape on northeast St. Matthew, light-colored and soft pyroclastic rock at left interfaces with dark, heavily fractured rock from a basalt-andesite flow at right. Both rock types show considerable ongoing active erosion, accelerated by wave action during storm surges; July 2012.

Photo by D. Klein

Figure 11a. Fractured basalt and andesite, eroded by freeze-thaw effects of the climate as well as storm surge wave action near Bull Seal Point is largely avoided by colonial nesting birds.

Photo by R. Kleinleder

Figure 11b. Pigeon guillemots find isolated sites in this type of eroding coast where single pairs nest successfully; early August 2012.

storm surges (*Figure 10*). The resulting eroded slopes of relatively thin plate-like rocks do not provide secure nesting habitat for either cliff-ledge or crevice-nesting sea birds though single pairs of pigeon guillemots (*Cepphus columba*) find isolated nesting sites (*Figures 11a and 11b*). Large nesting colonies are absent at such locations. Coastal erosion on the St. Matthew Islands is highly variable in relation to the rock types present, their volcanic origin, morphological history, and nature of the adjacent coastal landscape (*Figures 12a and 12b*).

Pinnacle Island is composed of strata of rock types similar to those of St. Matthew and Hall islands; however, the strata of basalt, andesitic, and pyroclastic tuffs of Pinnacle are tilted to a nearly vertical position in contrast to the predominant horizontal rock strata of St. Matthew and Hall (*Figure 13*). The volcanic rocks of Pinnacle are denser and harder than similar rock types on St. Matthew, a presumed consequence of their composition and tectonic deformation history following their volcanic origin. Potter et al. (*1975*) were limited in their assessment of Pinnacle Island's geology to observations made from shipboard. The island's geology nevertheless, as seen from the ship, appeared to them to be composed of mafic dikes of low silica andesite, basalt, dacite, and rhyolite, which had been morphologically altered prior to the tectonic action that resulted in the emergence of Pinnacle Island from the sea.

We were able to get ashore on Pinnacle briefly in 2012 to collect rock samples, including rocks fallen from the near vertical rock slope above; thus, they included rocks representative of at least three of the primary rock types of the island. Table 1 shows the comparative density analysis of similar coastal rock types collected from Pinnacle and St. Matthew. The higher mean densities of the rock samples collected from Pinnacle of 3.11 versus 2.72 for those from St. Matthew as also determined by Barnes and Eastlund (*1968*) are consistent with the geology Potter et al. (*1975*) had suggested for Pinnacle, though they had not been able to land on the island. The rocks we collected at Pinnacle, derived originally from the dark, massive basalt and andesitic flows as well as the generally lighter colored rocks of pyroclastic origin, had become hardened through metamorphic alteration prior to their uplift. The lighter colored rocks derived from the volcanic tuffs were considerably much denser and harder than those from comparable rock types on St. Matthew (*Table 1*). The harder rocks of Pinnacle Island and its vertical rock strata rising abruptly from the sea have been much more resistant to coastal erosion in the past and currently than has been the case with the coastal rocks in horizontal strata on St. Matthew and Hall islands. Thus, while the cliff-ledge nesting murres, kittiwakes, and fulmars are abundant nesters on Pinnacle, there is an absence of least and crested auklet nesting colonies. Without vegetated lowlands and coastal beaches on Pinnacle Island, a consequence of the highly erosion-resistant geomorphology of Pinnacle both in the past and at present, the island lacks suitable habitat for the endemic singing vole (*Microtus abbreviatus*), as well as the arctic fox, (*Alopex lagopus*), and the more recently arrived red fox (*Vulpes vulpes*). In the absence of the threat of predation by foxes on Pinnacle Island, birds, especially murres, fulmars, and kittiwakes, are able to nest on the steep slopes of the island from just above the wave splash zone to the ridge tops of the island. Hence the rock type and subsequent geomorphology of Pinnacle Island allows both prime nesting habitat for murres, fulmars, and kittiwakes and for these birds species to take full advantage of all nesting sites due to the lack of nest predators.

Conclusions

It was the Holocene rise of sea levels that brought about the present insularity of the St. Matthew Islands by the mid-Holocene. The accelerated rise in sea levels in recent decades, a consequence of climate warming, has resulted in shortening of the duration of seasonal sea ice, a corresponding sea level rise, and increased frequency and severity of extreme storm events, especially in early winter before sea ice has reformed, all of which collectively have accounted for greater erosive force of wave action on the St. Matthew Islands. The nature of the coastal rocks and variable tectonic history on these volcanic islands places a first order control on the geomorphology of the individual islands, their pronounced differences in vulnerability to erosion, and thus their relative security as sites for colonial-nesting birds. This variability in coastal rock types is primarily associated with specific eruptive events during the volcanically active period of the late Tertiary and early Cretaceous ages, namely mafic basalt and andesitic lava flows versus volcaniclastic deposits of ash of varying texture and subsequent rock type and density. Both the initially harder flow rocks and softer ash-derived rocks also underwent differential further hardening or fracturing whether above or below sea level during the cooling process and through metamorphosis in relation to their position to regional structures. Whereas coastal erosion has been an ongoing process on the St. Matthew Islands in the past, the shape of the present shoreline is largely a product of variation in rock lithology and their topography at the interface of


Photo by R. Kleinleder

Figure 12a. This rocky slope of eroding welded tuff, encompassing dacite boulders, provides the nesting habitat for the Glory of Russia auklet colony on the northeastern coast of St. Matthew Island.


Photo by D. Klein

Figure 12b. Fulmars prefer to nest on the ground surface if inaccessible by foxes, as on the top of a giant basalt pillar, eastern coast Hall Island 1985. Note that the flat topped pillars on the left without fulmars can be reached by foxes.

land and sea. The marine birds nesting colonially on the St. Matthew Islands, although dependent on proximity to the sea for the food source it provides during nesting and rearing of young, also require secure nesting locations on the rocky coasts of these islands. The harder rocks, more resistant to erosion by the sea, now form the points and headlands of these eroded island coastlines. The increased erosive force of the open sea and its longer mean annual ice-free period in recent decades appears, nevertheless, to have had minor consequences for the colonial sea birds that nest on these islands. The hard rocks of the cliffs where colonies of the cliff-ledge nesting murres, kittiwakes, and fulmars are located are highly resistant to erosion by the sea and have shown little change in their extent despite the increased potential of the erosive force of the sea in recent decades. The large coastal slumps where thin basalt and andesite flows were underlain by fine pyroclastic materials have, through their long-term erosion of the soft underlying pyroclastic strata, created nesting habitat for the crevice-nesting small least and crested auklets; the slumps are most common on the coasts of western Hall and northern St. Matthew. Erosion of the fine-grained pyroclastics at these auklet colony nesting sites is continuing, as is evidenced by turbidity in the adjacent sea visible in recent satellite imagery; existing auklet nesting habitat seems to be minimally affected. In fact, small numbers of auklets appear to be pioneering establishment of a new nesting colony in a recently expanding slump area on northwestern Hall Island. Thus, although these slump areas remain active and their erosion appears to be accelerated by rising sea levels and increased seasonal duration of wave action, new auklet nesting habitat is correspondingly being generated.

Acknowledgements

We appreciate the competent and safe logistic support provided by the entire crew of the M/V *Tiglax* during the 2012 expedition to the St. Mathew Islands. Field camp and logistic support was provided by the Alaska Maritime National Wildlife Refuge. Carla Tomsich, a PhD student in the geology department at University of Alaska Fairbanks (UAF) provided assistance in identification of rock types. Jeff Benowitz, a research geologist with UAF, assisted in measurement of rock density at the Geochronology Laboratory at UAF and provided a review of a draft manuscript from a geological perspective. We appreciate the use of Dan Mann's notes on landform geology following his review of the 1948 U.S. Navy aerial photo coverage of the St. Matthew Islands. Satellite imagery was made available by Douglas Burn through the Aleutian and Bering Sea Islands Land Conservation Cooperative 2008-2014. Marc Romano provided excellent photo coverage of bird colony locations on the coast of Hall Island. Laura Weaver prepared the map with bird icons (*Figure 5*) showing relation of colonial-nesting colonies to coastal geomorphology. We appreciate reviews of the manuscript by Heather Renner, Art Sowls, Tony DeGange, and Marc Romano.

Photo by D. Klein

Figure 13. The marine hardened volcanic strata of Pinnacle Island are particularly resistant to erosion by the sea. It is suggested that this strata became tilted about 90 degrees before emergence from the sea presumably by tectonic action (*Potter 1975; Wittbrodt et al. 1989*). The island rises abruptly to more than 1,900 feet (2,860 meters) from the sea, providing nesting habitat for several hundred thousand seabirds.

Glossary of Geological Terminology

Andesite: **volcanic rock containing feldspar microliths and crystals of plagioclase**

Basalt: **dark volcanic rock of mafic composition, fine grained with varying portions of calcium and sodium, primary component of lava and magma**

Dacite: **felsic to intermediate volcanic rock containing hornblende with plagioclase**

Diorite: **course-grained intermediate plutonic rock composed of plagioclase, pyroxene, and/or amphilode**

Epidote: **gray-green semitransparent crystalline rock of monoclinic volcanism**

Granite: **coarse-grained plutonic rock composed of orthoclase, plagioclase, and quartz**

Hornblendite: **mafic or ultra-mafic cumulate rock with greater than 90 percent hornblende**

Hypabyssal: **consolidated or partly crystalline from fusion at moderate depths underground**

Mafic: **volcanic rocks high in silicate and heavier minerals such as magnesium and ferric elements**

Obsidian: **volcanic glass**

Porphyritic: **rock type, usually granitic, with crystals embedded in a fine-grained mass**

Pyrite: **rock composed of iron sulfide, often called "fool's gold"**

Pyroclastic: **rock types composed of ash and breccia resulting from explosive volcanic eruptions**

Rhyolite: **felsic volcanic rock**

Tuff: **porous rock composed of scoria and ash formed in proximity to volcanic craters**

REFERENCES

Arctic Climate Impact Assessment (ACIA). 2005.
Arctic Climate Impact Assessment: Scientific Report. Cambridge: Cambridge University Press. 1042.

Aleutian Island and Bering Sea Islands Land Conservation Cooperative (ABSILCC). 2009.
GeoEye-1 Satelllite Imagery. August 9, 2009. Worldview-2 Satellite Imagery. Anchorage: U.S. Fish and Wildlife Service.

Anisimov, O., D. Vaughan, T. Callaghan, C. Furgal, H. Marchant, T. Prowse, H. Vilhjálmsson, and J. Walsh. 2007.
Polar regions (Arctic and Antarctic). *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Barnes, D., and M. Eastlund. 1968.
Gravity Map of St. Matthew and Hall Islands. Miscellaneous Field Studies Map MF 642, U.S. Geological Survey open-file Report, page 8, 31 tables.

Coletti, H. 2012.
Possible effects of a volcanic eruption on the nearshore marine environment. *Alaska Park Science* 11(1):79-81. Anchorage: National Park Service.

Coombs, M., and C. Bacon. 2012.
Using rocks to reveal inner workings of magma chambers below volcanoes in Alaska's National Parks. *Alaska Park Science* 11(1):27-33. Anchorage: National Park Service.

Dawson, G. 1883.
Geological notes on some of the coasts and islands of Bering Sea and vicinity. *Bulletin of the Goelogical Society of America* 5:138.

Elliott, H. 1875.
Polar bears. *Harpers Weekly* 19(957):1-2.

Elliott, H. 1882.
A monograph of the seal islands of Alaska. Washington, DC: U.S. Commission on Fish and Fisheries. 162.

Grebmeier, L., et al. 2006.
A major ecosystem shift in the northern Bering Sea. *Science* 311:1461-1464.

Hanna, G.D. 1920.
Mammals of the St. Matthew Islands, Bering Sea. *Journal of Mammology* 1(3):118-122.

Hinzman, L., et al. 2005.
Evidence and implications of recent climate change in northern Alaska and other arctic regions. *Climatic Change* 72(3):251-298.

Klein, D., and M. Shulski. 2009.
Lichen recovery following heavy grazing by reindeer delayed by climate change. *Ambio* 38:11-16.

Klein, D., and A. Sowls. 2011.
History of polar bears as summer residents on the St. Matthew Islands, Bering Sea. *Arctic* 64:429-436.

Luchin, V., I. Semiletov, and G. Weller. 2002.
Changes in the Bering Sea region: atmosphere—ice—water system in the second half of the twentiethcentury. *Progress in Oceanography* 55:23-44.

Merriam, C., ed. 1901-1910.
The Harriman Alaska Expedition (the Harriman Alaska Series). Vol. 1-5. New York: Doubleday. Page and Company.

Patton, W. Jr., et al. 1975.
Reconnaissance geologic map of St. Matthew Island, Bering Sea. Miscellaneous Field Studies Map MF-641. Washington, DC: U.S. Geological Survey. U.S. Government Printing Office.

Renner, H., and I. Jones. 2005.
Mapping distribution and relative density of auklets at selected colonies on Hall and St. Matthew Islands. U.S. Fish and Wildlife Service Report. Alaska Maritime National Wildlife Refuge 05/20.

Smith, J., G. Gray, and N. Kinsman. 2012.
Annotated bibliography series in support of coastal community hazard planning—Northwest Alaska Division of Geological and Geophysical Surveys Miscellaneous Publication 147:5.

Stabeno, P., G. Hunt Jr., J. Napp, and J. Schumacher. 2005.
Physical forcing of ecosystem dynamics on the Bering Sea Shelf. *The Sea.* Vol. 14. Chapter 30. Eds. A.R. Robinson, and K. Brink.

U.S. Fish and Wildlife Service (USFWS). 2006.
Alaska Seabird Information Series. Anchorage: U.S. Fish and Wildlife Service. 43 information sheets.

Wittbrodt, P., D. Stone, and D. Turner. 1989.
Paleomagnetism and geochronology of St. Matthew Island, Bering Sea. *Canadian Journal of Earth Science* 26:2116-2129.


Figure 2.


Figure 3.


Figure 4.


Figure 5.


Figure 6.

Red Foxes Replace Arctic Foxes on a Bering Sea Island: Consequences for Nesting Birds

By David R. Klein and Art Sowls

Red foxes, *Vulpes vulpes*, have reached and established a breeding population on the remote and uninhabited St. Matthew Islands in the northern Bering Sea in association with climate warming in recent decades (*Figure 1*) (*Matsuoka 2003; Post 2009*) and are suppressing native arctic foxes (*Alopex lagopus*). The St. Matthew Islands, part of the Alaska Maritime National Wildlife Refuge, are the most remote lands in the United States (*Klein et al. 2015*). They support over a million colonial-nesting sea birds (*Figure 2*), as well as ground-nesting bird species, including the endemic McKay's bunting (*Plectrophenax hyperboreus*) (*Figure 3*) and a major portion of the total breeding population of Pribilof rock sandpipers (*Erolia ptilocnemispiolosemis*) (*Ruthrauff et al.2012*) (*Figure 4*). During a Refuge expedition to the islands in summer 2005 we observed that red foxes (*Figure 5*), presumably having arrived over the sea ice, which is seasonally present there (*Luchin et al. 2002*), were suppressing the native arctic foxes (*Figure 6*) on St. Matthew Island. On another visit to these islands in 2012 (July 29 to August 8) we found red foxes abundant and with large litters of young on St. Matthew Island (*Figure 7*), the largest island in the three-island group. No arctic foxes appeared to be remaining there, whereas on adjacent Hall Island only arctic foxes were observed to be present. In addition to the two fox species, the only other land mammal native to the St. Matthew Islands is an endemic singing vole (*Microtus abbreviatus*) (*Figure 8*), and it was presumably a primary prey species, along with colonial-nesting sea birds, of both fox species in the summers of 2005 and 2012 when vole population levels on both St. Matthew and Hall islands were moderately high. Neither voles nor foxes are resident on Pinnacle Island (*Figure 9*) which is composed of marine hardened volcanic rocks and lacks lowland tundra habitat of importance for voles and denning foxes (*Klein et al. 2015*).

Figure 1. (map) The St. Matthew Islands and their location in the northern Bering Sea.

Figure 2. Murres, kittiwakes, and fulmars are the major colonial nesting sea birds on the basalt cliffs of the St. Matthew Islands.

Photo by D. Klein.

Figure 3. The McKay's bunting is endemic to the St. Matthew Islands. It is nearly all white in the male breeding plumage, nests in crevices on cliffs, among driftwood on the beaches, and on the tundra if cover is available.

Photo by D. Klein.

Figure 4. The Pribilof rock sandpiper nests more abundantly on the St. Matthew and Hall islands than in the rest of its distribution in the Eastern Bering Sea.

Photo by D. Klein.

Figure 5. Red foxes have replaced arctic foxes on St. Matthew Island.

Photo by D. Klein.

Figure 6. The arctic fox originally resident on St. Matthew and Hall islands prevailed on Hall in 2012 where red foxes had not yet become established. This arctic fox was photographed on St. Matthew in 2005 where a few remained but could not breed successfully in the presence of the red foxes.

Photo by I. Jones.

Figure 7. The red foxes had large litters of young in both 2005 and 2012. These eight pups were photographed at a den adjacent to North Lake.

Photo by R. Kleinleder.

Complex questions for conservation of life forms within island ecosystems are posed by arrival of a new mammal species to the St. Matthew Islands. How do red and arctic foxes differ in their predatory behavior and what are the consequences for colonial-nesting sea birds, ground-nesting land birds, and the endemic vole?

Adaptability of the Foxes to a High-Latitude Maritime Environment

Natural distribution of the arctic fox throughout the coastal regions of the circumpolar Arctic is consistent with the species' evolutionary adaptations for life under the extreme seasonal variability that characterizes its wide distribution (*Bancroft 1886; Audubon et al. 1967; Wilson and Ruff 1999*). On St. Matthew and Hall islands, surrounded by sea ice for about five months during winter and where there is wide intra-annual variation in food abundance and availability, arctic foxes appear well adapted to the northern


Photo by L. Jones

Figure 8. The singing vole is endemic to the St. Matthew Islands and present on St. Matthew and Hall islands where it was relatively abundant in 2005 and 2012. They live in colonies and the "singing" is the alarm signal of adults on lookout for potential avian and ground predators.

maritime coastal environment (*Audubon et al. 1967; Wilson and Ruff 1999*). This is borne out by the arctic fox's continued historical presence on the St. Matthew Islands, as noted by early explorers and others visiting these islands (*Elliott 1875; Merriam 1901-1910; Hanna 1920; Klein 1959, 1968, 1987, 2009*). In 1997 red foxes were first observed to be breeding there (*Matsuoka 2003*), although a single red fox was observed there in 1966 (*Klein*). The red fox in North America has roots of evolutionary adaption to the boreal forest environment (*Wells 2011*). Differences in the feeding strategies, predatory behavior, and prey selection of arctic versus red foxes presumably are a product of the environmental influences within the biomes in which these two fox species evolved and currently exist.

Changing Predator Prey Relations

Weighing consequences of predation by arctic versus red foxes on nesting birds and the singing vole of the St. Matthew Islands is aided by Olaus J. Murie's investigations in the late 1930s in the Aleutian Islands that border the Bering Sea on the south (*Murie 1959*). In 57 red fox scats from Dolgoi Island examined by Murie, small mammals (mostly *Microtus spp.*) predominated over birds (52 percent versus 22 percent) among items identified. Other food remains present in the droppings included sand fleas (*Orchestia traskiana* and other amphipods), sea urchins (*Strongylocentrotus spp.*), mussels (*Mytilus spp.*), small fish, and hair seals (*Phoca spp.*). In a similar comparison of 25 red fox droppings from Unalaska Island, where a greater diversity of small mammal species were available (*Citellus spp., Microtus spp., Dicrostonyx spp.*), as well as greater numbers and species diversity of colonial nesting sea birds, small mammals again predominated over birds (82 percent versus 18 percent) among the identified items. Murie observed that when present on larger islands red foxes spent more time foraging inland than at the coast whereas the reverse was true of arctic foxes. He also observed that arctic foxes readily swam while foraging for food when preying on birds in contrast to the general reluctance of red foxes to swim. To add emphasis, he noted (page 303) that Aleuts had described to him how "On occasion…a fox will stand on a point of rock where ducks are diving and, when a duck is rising in the water nearby, the fox will jump in and seize it while it is still below the surface." He further observed that arctic foxes readily swam from one island to another when the distance is not great. The aversion to swimming by the red fox may partially account for the failure as yet of the red fox to cross three-mile-wide Sarichef


Photo by D. Klein

Figure 9. The geological history and rock structure of Pinnacle Island differs markedly from the other St. Matthew Islands; its marine-hardened volcanic rock presumably emerged from the sea after the period of volcanism that produced the lava flows and pyroclastic tuffs common to the St. Matthew Islands (*Potter et al. 1975; Klein et al. 2015*). It provides abundant habitat for cliff-nesting birds but lacks lowland tundra habitat required for voles. Without suitable habitat for voles as potential prey for foxes neither voles nor foxes are resident there.


Photo by D. Klein

Figure 10. Fulmars prefer to nest on the vegetated ground surface in areas not accessed by foxes. Only one of the flat tops of these three massive basalt pillars on eastern Hall Island could not be reached by foxes allowing fulmars to nest densely on its surface.

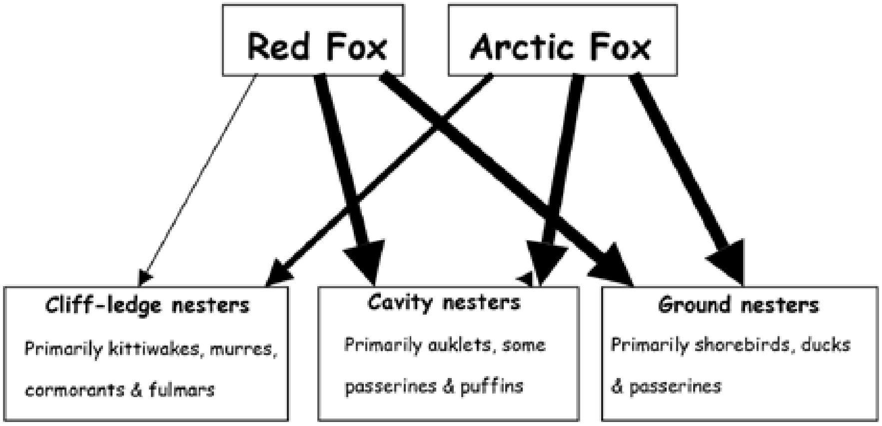


Figure 11. Thickness of arrow lines indicate expected predation pressure by arctic versus red foxes on nesting birds of the St. Matthew Islands assuming only red foxes on St. Matthew and only arctic foxes on Hall. Our assumptions are based on our field observations; extrapolation from Murie's 1936-1938 faunal survey in the Aleutian Islands (*Murie 1959*); other relevant references on species-specific prey selection preference; and consideration of the role of body morphology in accessing nesting birds, alternative prey types, and other food seasonally present on the St. Matthew Islands, as well as expected future density differences of the two fox species (*Pruitt 1978; Fay and Stevenson 1989; Henry 1996; Wilson and Ruff 1999; USFWS 2005; Smith 2008; Aubry et al. 2009*).


Photo by D. Klein

Figure 12a. Fresh digging by voles in an *Empetrum nigrum* community on an old beach ridge near Big Lake observed by Marc Romano.


Photo by D. Klein

Figure 12b. Dense vole activity at site of remains of fox trapper hut on southeast coast of St. Matthew Island.

Strait that separates St. Matthew and Hall islands (*Figure 1*) in sufficient numbers to establish a breeding population on the latter island. Strong currents in the strait, which generate more turbulent seas than in the surrounding waters, would be a further deterrent to swimming. And the strong currents through the strait and increased wind velocities in winter would presumably account for highly fractured, rougher, and moving sea ice, which would discourage winter crossings.

Comparing Predation by Arctic versus Red Foxes on Fauna of the St. Matthew Islands

Nest site preferences of colonial-nesting sea birds vary by species among cliff ledges, rock crevices, the soil surface, or earthen burrows and this necessarily is a factor governing the degree of influence of fox predation on bird population dynamics. Fulmars prefer nesting on the ground surface but can only do so where foxes cannot reach their nests (*Figure 10*). Assumed predation effects of the red fox in comparison to the arctic fox on bird species nesting on the St. Matthew Islands based on our observations there and relevant publications on the two fox species is graphically modeled in Figure 11. Waterfowl and shore birds are typically ground-surface nesters in similar arctic and subarctic habitats. St. Matthew passerine species include typical ground-surface nesters such as Lapland longspurs (*Calcarius lapponicus*), as well as those that are variable in nest site selection between the ground and crevices, including McKay's bunting (*Figure 3*), and rosy finches (*Leucosticte tephrocotis*). Unlike birds, other vertebrate species present on the St. Matthew Islands—the singing vole and fish—are resident throughout the year. The voles, at least, can be expected to play a greater role as prey of foxes when birds are absent from the islands. The singing vole most likely has been of primary importance as a food source for both red and arctic foxes during winter in past years on the St. Matthew Islands when vole numbers were at high levels in their population cycles (*Figures 12a and 12b*). This was apparently the case in the severe winter of 2011-2012 in the eastern Bering Sea region (*Alaska Climate Research Center 2012*), when sea ice was present longer in the eastern Bering Sea region and extended further south, as observed by residents of both St. Paul and St. George islands, than has been the case in past decades (*Shulski and Wendler 2007*). During our presence on the islands in summer 2012, it was apparent that high vole numbers had coincided with the previous severe winter on the St. Matthew Islands as evidenced by the remains of winter vole runways and their nests remaining on the tundra surface after the snow had melted. Additionally we found voles to be relatively abundant during summer in 2012.

Differences in body morphology of arctic and red foxes, most notably the longer legs and larger body mass of red foxes, results in a higher center of gravity that renders red foxes substantially less efficient climbers on the coastal cliffs than arctic foxes (*MacDonald and Cook 2009*). On St. Matthew Island, predation on birds, the eggs, and young of those nesting on the coastal cliffs (*Figure 13*) can therefore be expected to be considerably less with only red foxes present in contrast to the past when only arctic foxes were there (*Klein 1959*). By contrast, the crevice-nesting small auklets (*Figure 14*) usually occur in large numbers and high density in large boulder-field colonies. Foxes primarily prey on adult and fledging young auklets when synchronously emerging from nest cavities to socialize on the surface above before leaving for and returning from their daily flights to forage at sea. Predation by both fox species at auklet colonies is substantial even though most nesting cavities are relatively secure from being dug into by the foxes. Predation impact of either fox species on auklet colonies is expected to be closely tied to the relative density of the foxes.

Density of foxes is also important in assessing effects

Photo by R. Kleinleder

Figure 13. Cliff-nesting murres and kittiwakes on this unique volcanic era extrusion of columnar basalt are relatively secure. Being mostly surrounded by water makes it difficult for foxes to approach and the columnar basalt very difficult for them to climb. Comparing photos from 1985 with those from 2012 shows no evidence of erosion of the hard basalt from coastal wave action.

Photo by R. Kleinleder

Figure 14. Crevice-nesting small auklets are equally preyed on by red and arctic foxes, but their large colony size and synchronous activity tend to swamp predators, thus minimizing predation risk at the individual level.

on nesting success of ground nesting birds by red foxes on St. Matthew versus arctic foxes on Hall Island. On northern St. Matthew Island, where two auklet colonies offered perhaps the most abundant bird prey available to the foxes, we found only two active red fox dens with young in 2005 and these same dens were similarly used by the red foxes in 2012 (*Figure 15*). The dens were about 2.4 miles (4 kilometers) apart, adjacent to the Bering Sea coast, but on opposite sides of the island. Each den was sited about .9 miles (1.5 kilometers) from one of the two auklet colonies on the northern portion of St. Matthew Island. The adult foxes from each den presumably exercised some control over access to the proximate colony by other foxes. Arctic fox maternal dens on St. Matthew Island in the past, before the arrival of the red foxes, were frequently found at the edges of auklet colonies and with dens often within .6 miles (1 kilometer) of one another, which has been the pattern observed on Hall Island. On the much larger St. Lawrence Island about 186 miles (about 300 kilometers) to the north, Stevenson (*1970*), in a study of summer food habits of the arctic fox, found that active and presumably maternal arctic fox dens in areas of high prey availability were generally separated by .6 to .9 miles (1 to 1.5 kilometers). Both fox species, however, must contend with high variation seasonally in prey availability, abundance, and importance of other food types, inclusive of marine invertebrates, and carcasses of fish and marine mammals that are washed onto the beaches by wave action. The latter food resource however, may not be refreshed when shore-fast ice is present during the four to five months of winter during which the St. Matthew Islands are surrounded by the Bering Sea ice pack. On the St. Matthew Islands birds and their eggs are only directly available as a potential food source for the foxes through predation during the short summer period of nesting and rearing of young. Foxes of both species however, do cache food for possible future use (*Stevenson 1970; Fay and Stevenson 1989; Wilson and Ruff 1999*).

Population numbers of the singing vole have varied widely in the past on a cycle of three to five years as has been common among other small rodents at high latitudes (*Smith 2008*). On the St. Matthew Islands voles are active under the snow cover in winter, as is evident when melting snow exposes winter nests and runways, as are other voles

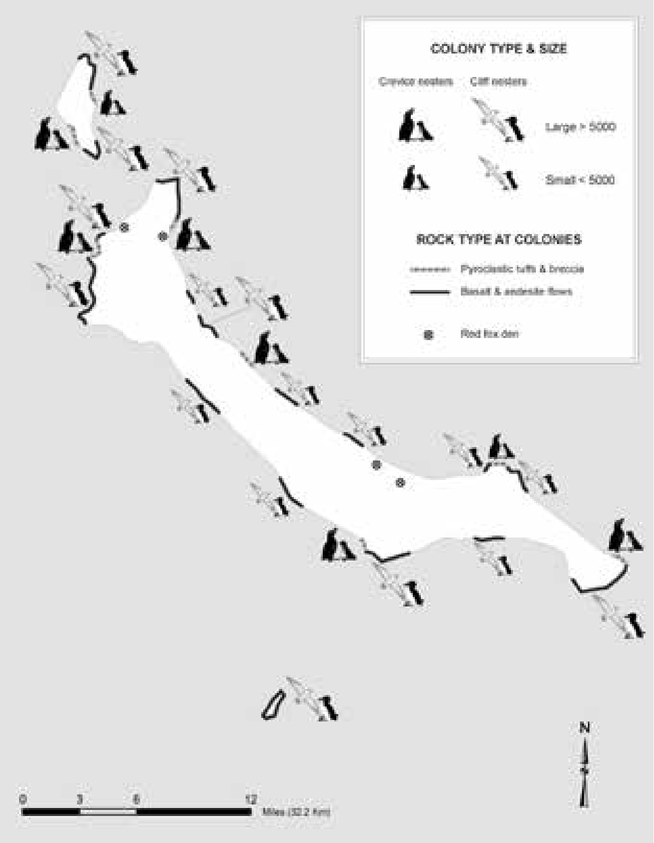


Figure 15. Location of the four fox dens found in 2012 are indicated in relation to the location of colonial cliff-nesting and crevice-nesting sea birds and their selection for erosion-resistant massive basalt and andesite ancient lava flows and eroding pyroclastic strata. The map is adapted from Klein et al. (*2015*) and was drafted by Laura Weaver.

at northern latitudes (*Pruitt 1978*). Red foxes, because of larger body size, longer legs, and behavioral adaptations for hunting small mammals under snow and vegetative cover, are presumably somewhat better adapted than arctic foxes for preying on voles in winter on the St. Matthew Islands (*Henry 1996*). Small rodents however, made up a large portion of the winter diet of arctic foxes on St. Lawrence Island, 186 miles (300 kilometers) to the north in the absence of red foxes (*Stevenson 1970; Fay and Stevenson 1989*). Small mammal prey diversity for foxes is considerably greater on St. Lawrence Island than on the St. Matthew Islands. In alpine habitats in the Scandinavian Arctic, another study found that the lemming (*Dicrostonyx groenlandicus*), a typical arctic alpine species, made up 80 percent and voles 20 percent of the prey items in scats of arctic foxes (*Frafjord 1995*). Red foxes at the time favored lowland habitats where they preyed exclusively on voles. On the St. Matthew Islands, both fox species have been observed in the past preying significantly on voles when their numbers were high on both St. Matthew and Hall islands. In 2005 when our base camp on St. Matthew was located 328 feet (100 meters) from a red fox den with eight young, we observed adult foxes returning to the den with food for the young foxes. These foxes were generally consistent in carrying either voles or least auklets hanging from their mouths. This pattern of prey selection coincided with the direction in which each adult fox had set out from the den to begin its foraging bout: the direction being inland when a fox later returned with voles, and north along the shore when returning with only auklets, presumably secured from the auklet colony that was about a mile north of our camp. Although our observations were made opportunistically as we carried out camp activities, we estimated that about equal amounts of biomass of voles and auklets were returned to the den during our observations.

Overwintering a Bottleneck for Fox Survival on the St. Matthew Islands

DNA analyses suggest that the arctic fox evolved in the maritime coastal environment of the North American arctic and subarctic where sea ice was present at least seasonally (*Henry 1996*). Red foxes, Eurasian in origin, first entered North America in the Illinoian glaciation with subsequent mixing of North American and Eurasian clades in Beringia during the Wisconsin glaciation (*Heptner and Naumov 1998*). During the Holocene, mixing with the North American boreal clade continued (*Aubry et al. 2009*). Though specialized for the northern boreal rather than the arctic environment, the red fox is highly adaptable to environmental change and is considered among the animals of least concern for extinction by the International Union for the Conservation of Nature (*2008*). This is a valid assessment in view of the global distribution of the red fox and its history of success in adapting to human-altered environments. When viewed at the population level on a remote maritime island with an arctic climate in winter however, there are qualifying constraints that may limit sustainability of the St. Matthew red fox population. The history of the demise of the St. Matthew reindeer brought about by extreme winter weather in 1964 points out the vulnerability of the more recently established red fox population in view of the increased likelihood of extreme weather events anticipated with continuing global climate change (*Klein et al. 2009*). These include low likelihood of red fox dispersal via the sea in contrast to the arctic fox to relieve population pressure during periods of seasonal food limitation. Conversely there is limited potential for increasing the gene pool of the present population most likely founded by a single pair of foxes that were able to reach the island via seasonal sea ice in the northern Bering Sea. Low genetic diversity may contribute to lowered resistance to certain diseases in semi-isolated populations (*Geffen et al. 2007*). This is a likely risk factor for the red foxes on St. Matthew Island where diseases, such as rabies, may be brought to the island by other foxes reaching the island in the future (*Rausch 1958*).

In a comprehensive study of interspecific competition and geographical distribution of red and arctic foxes by Hersteinsson and Macdonald (*1992*) that included consideration of interference competition, cold tolerance, body size, and related energetics, and climate change influences on habitat, they concluded that "the northern limit of the red fox's geographic range is determined directly by resource (food) availability (and thus ultimately by climate), whereas the southern limit of the distribution of the arctic fox's range is determined, through interspecific competition, by the distribution and abundance of the red fox."

Recent reports of displacement of arctic foxes by red foxes appearing in both the public and scientific media often emphasize correlation with climate change without explaining the climate-driven and often complex cause and effect relationships within intertrophic level processes (*Ims and Fuglei 2005; Post et al. 2009*). In the Bering Sea coastal areas of Alaska's Yukon Delta, increasing numbers of red foxes as well as arctic foxes in recent decades, although correlated with declining nesting success of black brant and climate warming, appears to have been more directly tied to increased numbers of microtine rodents, an important food source for both fox species during winter. The increase in rodents was a direct product of climate-induced improvement of habitat conditions for the rodents through lengthening of the summer period for plant growth and rodent reproduction (*Anthony et al. 1991*). The decrease in black brant nesting success in this case was found to be tied to increased nest predation by arctic foxes that prefer wetter sedge-dominated coastal marshes where brant nesting is concentrated. Red foxes at the time however, were at high density in the adjacent slightly higher and drier, low-shrub tundra during summer where small rodents continued to be their major prey component (*Feldhamer et al. 2003*). A study in northern Norway concluded that competition between red and arctic foxes had been more important than changes in prey dynamics associated with climate change in accounting for the failure of arctic foxes to recolonize (*Hamel et al. 2013*). We suggest that it has been the mediating climate in recent decades on St. Matthew Island, allowing for increased and extended seasonal vascular plant growth that has enabled vole populations to remain at moderately high levels interannually (*Klein and Shulski 2009*), rather than cycling between low and high population numbers as appeared to have been the case among microtine vole populations throughout the Arctic (*Ims and Fuglei 2005*), thus enabling red foxes to establish and maintain a population there.

Conclusions

Multiple factors are involved in assessing the nature and magnitude of ecosystem change on St. Matthew Island since displacement of arctic foxes by red foxes. On St. Matthew Island in the presence of only red foxes:

1. Cliff-nesting birds should experience considerably less predation than when the arctic fox, more adept at climbing, was the only fox species present.
2. Predation selection for crevice-nesting birds, primarily the small auklets, although about equal by the two fox species, should be less in the presence of red foxes because of their larger home ranges, more strongly defended maternal den territories leading to presumed ultimate lower population density than was the case in the past when only arctic foxes were there.
3. Ground-nesting birds may suffer less predation under an expected lower red fox density on St. Matthew Island, with the following constraints: a somewhat higher predation rate by individual red foxes as a function of their larger body size; when singing vole numbers are low, red foxes may focus more on ground-nesting birds than arctic foxes have in the past, especially when their home ranges do not include auklet colonies.
4. On the basis of pronounced differences in intraspecies tolerance of the two fox species and poorer adaptability of the red fox for over-winter survival on St. Matthew Island, which is surrounded by sea ice in winter, red fox density will likely remain considerably lower there than would have been the case if only arctic foxes were present.
5. The endemic bird MacKay's bunting, because of its presence and abundance over the entire island and use of diverse and predominately secure crevice-nesting habitats should be little affected by the shift from arctic to red foxes on St. Matthew Island.
6. The singing vole, also endemic to the St. Matthew Islands, can be an important food item for both fox species when in the high phase of their population cycles, especially in winter when other food is limited. Whereas voles appear adapted to sustain high fox predation at the peak of their population cycles, they are protected from significant predation at the low of their cycles by their relative scarcity. In winter, areas where snow is drifted and wind-packed also provide some protection for the subnivian voles from fox predation.

The above assessment of consequences of the presence of red versus arctic foxes on the vertebrate fauna of St. Matthew Island focuses on relative numbers of prey species removed through predation. Possible benefits of species-specific predation that may accrue to the genome of prey species on the St. Matthew Islands through selective removal of less fit individuals (*Gilg and Yoccoz 2010*) will remain for future assessment of this naturally occurring exchange of predator species.

We propose that the stronger territoriality and larger home range size of the red fox will limit fox population density on St. Matthew Island in contrast to its predecessor the arctic fox that is known to be more tolerant of high population density (*Murie 1959; Wilson and Ruff 1999*). Our analysis in the absence of a sufficient time line to measure the actual consequences for nesting bird species resulting from a change in the major predator species suggests little likely overall change from the past in the impact of fox predation on populations of nesting birds on the St Matthew Islands. Assessing such consequences for bird populations on the St. Matthew Islands in the future will be constrained by the difficulty in distinguishing between concurrent influences of climate change in both the terrestrial and adjacent marine ecosystems where colonial sea birds seek food during nesting and spend their non-nesting portion of the year. Additionally, present understanding is inadequate for assessing the impact of the Bering Sea commercial fisheries on sea bird populations.

Acknowledgements

Assistance in the field recording observations of foxes and their natal dens during 2005 was provided by Karin Holser, Ian Jones, Max Malavanski Jr., Anne Morkill, Evie Whitten, Randy Hagenstein, Mike Boylan, and Sasha Kitaysky; and in 2012 by Marc Romano, Aaron Poe, Marianne Alpin, Tony Degange, Steve Delehanty, Rich Kleinleder, Ned Rozell, Dennis Griffin, Casey Bickford, Derek Sikes, and Monte Garroute. We appreciate the logistic and field support provided by the Alaska Maritime National Wildlife Refuge in 2005 and 2012 and the safe transport to the St. Matthew Islands and skilled support in the field provided by the crew of the M/V *Tiglax*. Douglas Burn provided access to available satellite imagery through the Aleutian and Bering Sea Island Landscape Conservation Cooperative (ABSILCC), which has aided in several aspects of the 2012 St. Matthew expedition. We appreciate manuscript review and constructive comments provided by Ned Rozell, Rich Kleinleder, and Marc Romano. Assistance provided by Dan Mann in interpreting land form morphology from 1948 Navy aerial photography aided in planning for the 2012 field activity.

Photo by R. Kleinleder

Figure 16. Most of the 2012 St. Matthew Expedition team awaiting pick up by the *Tiglax* for departure from the St. Matthew Islands. Left to right are: Mirianne Alpin, Aaron Poe, Marc Romano, Heather Renner, Tony Degange, Monte Garroute, Rich Kleinleder, Steve Delehanty, Dave Klein, and Dennis Griffin.

REFERENCES

Alaska Climate Research Center. 2012.
Winter Weather Summary. Alaska Climate Dispatch. Alaska Center for Climate Assessment and Policy (National Oceanic and Atmospheric Administration). Spring 2012:2-7.

Anthony, P., P. Flint, and J. Sedinger. 1991.
Arctic fox removal improves nest success of black brant. *Wildlife Society Bulletin* 19:176-84.

Aubry, K., B. Statham, J. Mark, B. Sacks, J. Perrines, and S. Wisely. 2009.
Phylogeography of the North American red fox: vicariance in Pleistocene forest refugia. *Molecular Ecology* 18(12):2668–2686.

Audubon, J., J. Backman, and V. Cahalane. 1967.
The imperial collection of Audubon animals. Ed. V.H. Cahalane. *The Quadrupeds of North America.* Maplewood, NJ: Hammond Incorporated.

Bancroft, H. 1886.
History of Alaska 1730-1885. New York: Bancroft.

Elliott, H. 1875.
Polar bears. *Harpers Weekly* 19(954):1-2.

Fay, F. 1963.
Field trip to St. Matthew Island, July 17-August 7, 1963. Correspondence to Chief, Zoonotic Disease Section, Arctic Health Research Center, Anchorage. September 6, 1963.

Fay, F., and R. Stevenson. 1989.
Annual, seasonal, and habitat-related variation in feeding habits of the arctic fox (Alopex lagopus) on St. Lawrence Island, Bering Sea. *Canadian Journal of Zoology* 67:1986-1994.

Feldhamer, G., B. Thompson, and J. Chapman, eds. 2003.
Wild mammals of North America: Biology, management and conservation. Baltimore: Johns Hopkins University Press.

Frafjord, K. 1995.
Summer food habits of arctic foxes in the alpine region of southern Scandinavia, with a note on sympatric red foxes. *Annals Zoologica Fennici* 32:111-116.

Geffen, E., S. Waidyaratue, L. Dalén, A. Angerbjörn, C. Vila, P. Hersteinsson, E. Fuglei, P. White, M. Goltsman, C. Kapel, and P. Waune. 2007.
Sea ice occurrence predicts genetic isolation in the arctic fox. *Molecular Ecology* 16(20):4241-4255.

Gilg, O., and N. Yoccoz. 2010.
Explaining bird migration. *Science* 327: 276-277.

Hamel, S., S. Killengreen, J. Henden, N. Yoccoz, and R. Ims. 2013.
Disentangling the importance of interspecific competition, food availability, and habitat species occupancy: Recolonization of the endangered Fennoscandian arctic fox. *Biological Conservation 160:114-120.*

Hanna, G. 1920.
Mammals of the St. Matthew Islands, Bering Sea. *Journal of Mammalogy* 1:118-122.

Henry, J. 1996.
Foxes: living on the edge. Minocqua, WI: Northword Press, Inc.

Heptner, V., and N. Naumov. 1998.
Sirenia and Carnivora (Sea cows; Wolves and Bears). *Mammals of the Soviet Union.* Vol.II. Part 1a. Science Publishers, Inc. USA.

Hersteinsson, P., and D. Macdonald. 1992.
Interspecific competition and geographical distribution of the red and arctic foxes Vulpes vulpes and Alopex lagopus. *Oikos* 64:505-515.

Ims, R., and E. Fuglei. 2005.
Trophic interaction cycles in tundra ecosystems and the impact of climate change. *Bioscience* 55:311-322.

Intergovernmental Panel on Climate Change (IPCC). 2007.
Climate Change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report. Eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis. K.B. Averyt, M. Tignor, and H.L. Miller. New York: Cambridge University Press.

International Union for the Conservation of Nature (IUCN). 2008.
Red List of Threatened Species. Gland, Switzerland: IUCN.

Klein, D. 1959.
St. Matthew Island Reindeer range study. Special Scientific Report-Wildlife No. 43. Washington D.C.: U.S. Fish and Wildlife Service.

Klein, D. 1968.
The introduction, increase, and crash of reindeer on Saint Matthew Island*. Journal of Wildlife Management* 32:350-367.

Klein, D. 1987.
Vegetation recovery patterns following overgrazing on St. Matthew Island. *Journal of Range Management* 90:336-338.

Klein, D., and M. Shulski. 2009.
Lichen recovery following heavy grazing by reindeer delayed by climate warming. *Ambio* 38:11-16.

Klein, D., J. Walsh, and M. Shulski. 2009.
What killed the reindeer of St. Matthew Island? *Weatherwise* 62(6): 32-38.

Klein, D., R. Kleinleder, and H. Renner. 2015.
Differential effects of coastal erosion on colonial nesting sea birds on the St. Matthew Islands. *Alaska Park Science*, 14(1). Anchorage: National Park Service.

Luchin, V., I. Semiletov, and G. Weller. 2002.
Changes in the Bering Sea region: atmosphere—ice—water system in the second half of the twentieth century. *Progress in Oceanography* 55:23-44.

MacDonald, S., and J. Cook. 2009.
Recent mammals of Alaska. Fairbanks: University of Alaska Press.

Matsuoka, S. 2003.
Observations of Arctic and Red Fox on St. Matthew and Hall Islands. May 26-July 8, 2003. Tony Degange USFWS files, Anchorage AK.

Merriam, C., ed. 1901-1910.
The Harriman Alaska Expedition (the Harriman Alaska Series). Vol. 1-5. New York: Doubleday. Page and Company.

Murie, O. 1959.
Fauna of the Aleutian Islands and Alaska Peninsula. *North American Fauna* 61:1-364, Washington, D.C.: U.S. Fish and Wildlife Service.

Pruitt, W. 1978.
Boreal ecology. Southhampton, England: Camelot Press Ltd.

Post, E., M. Forchhammer, M. Bret-Harte, T. Callaghan, T. Christtensen, B. Eberling, A. Fox, et al. 2009.
Ecological dynamics across the Arctic associated with recent climate change*. Science* 325:1355-1358.

Rausch, R. 1958.
Some observations on rabies in Alaska, with special reference to wild Canidae. *Journal of Wildlife Management* 22:246-260.

Ruthrauff, D., T. Tibbitts, R. Gill Jr., M. Dementyev, and C. Handel. 2012.
Small population size of the Pribilof Rock Sandpiper confirmed through distance-sampling surveys in Alaska. *The Condor* 114(3):1-8

Shulski, M., and G. Wendler. 2007.
The climate of Alaska. Fairbanks: University of Alaska Press.

Smith, R. 2008.
Interior & Northern Alaska: A natural history. Bothell, WA: Book Publishers Network.

Stevenson, R. 1970.
A study of the summer food habits of the arctic fox on St. Lawrence Island, Alaska. MS thesis. College, Alaska: University of Alaska.

U.S. Fish and Wildlife Service (USFWS). 2005.
http://alaska.fws.gov/mbsp/seabirds/pdf/citations.pdf

Wells, G. 2011.
Tracing the fox family tree: The North American red fox has a diverse ancestry forged during successive ice ages. *Science Findings.* Issue 132 (April/May). Portland OR: Pacific Northwest Station.

Wilson, R., and S. Ruff. 1999.
The Smithsonian book of North American Mammals. Washington, DC: Smithsonian Institution Press.


or Change
The future of the National Parks depends on citizens recognizing the implications of changing climate.
Climate literacy is an understanding of climate's influence on society, as well as society's influence on climate.
IMPLICATIONS AND ACTIONS
UAF
"EDO"


Arrange for Change
NASA

Disciplines and Institutions in Denial: The Case for Interdisciplinary/Interagency Research/Mitigation on Climate Change Impacts

By Don Callaway

Introduction

Today, advocating for use of interdisciplinary research to address issues associated with climate change seems almost rhetorical. For example, an advisory committee to the National Science Foundation (NSF), the U.S.'s major source of funding for scientific research, states:

> With respect to climate change NSF places a high priority on research that integrates behavior and life sciences, earth and atmospheric sciences, social sciences and mathematical, physical, engineering and informational sciences.
>
> Interdisciplinary priorities for NSF and other agencies will not achieve all they could achieve if the institutional practices within the research and education communities are not adapted to facilitate interdisciplinary action (*Advisory Committee for Environmental Research and Education 2009*).

Echoing this position, the National Park Service Climate Change Response Strategy incorporated six principles from a 2009 National Research Council report "to provide a framework for building the collaborative and flexible response capacity that the NPS needs to effectively address climate changes." Of particular interest to the thesis of this article is Principle 4: building connections across disciplines and organizations.

> To ensure that the best information is available for decision makers as knowledge about climate change and effective responses increases, significant effort must go into building networks that encourage interdisciplinary collaboration among people with a wide range of technical expertise within the bureau and the department **as well as across other agencies, partners and stakeholders** (emphasis added) (*National Park Service 2010*).

Despite the self-evident nature of this proposition NSF added the following caveat:

> Current practices in academic and government institutions, with their traditional disciplinary funding and evaluation mechanisms, often inhibit the truly innovative and integrative science and education the nation needs. NSF should adopt organizational and review strategies that promote interdisciplinary innovation and ensure that programs funded for interdisciplinary activities have the longevity necessary to attract scientists to work collaboratively across the disciplines (*Advisory Committee for Environmental Research and Education 2009*).

This article reflects NSF's concern by providing a brief description of long-term difficulties in building this vision of **multidisciplinary** research into subsistence issues in the Alaska region. In contrast to this disappointing precedent we will next describe a very solid **interdisciplinary** effort to produce sub-regional climate change scenario planning documents for Alaska. Finally, we end with a more sobering tale of the difficulties of inter-organizational coordination and cooperation in responding to climate change impacts to rural coastal communities in Alaska.

The preceding paragraph highlights the terms "multidisciplinary" and "interdisciplinary." We suggest that "multidisciplinary" efforts are research projects where separate disciplines each write their own proposals, set their own budgets and research designs, and collect and analyze their data independently. What ties a "multidisciplinary" effort together is that the outcomes of their research share a topical link, e.g., caribou—their biological status and their human harvest and cultural uses. In addition, the findings of these independent research efforts are produced within a short enough temporal window that both types of data can be used to inform management decisions. In contrast, "interdisciplinary" research often shares a common funding "pot" (a useful but not essential condition) and a coordinated and collaborative overall research design. Such a research design has milestones whereby the products of one discipline; for example, geophysics/climate modeling, is a necessary input for other disciplines, e.g., biology/ecology, to conduct their own analysis. All disciplines perceive that their research and/or analyses are critically integrated in the production of a final report containing a shared vision.

Coordinating Disciplinary Research in Subsistence Management: The Regional Studies Plan Proposal

In Alaska, the Federal Subsistence Board (FSB) manages eligibility, access, and harvest of wildlife resources on federal lands through a regulatory system that emphasizes "seasons and bag limits." The regulations that they promulgate state when (season) and how much (bag limit) of a species can legally be harvested. Most of the FSB decisions revolve around linking two facts: (1) the population status (health and number) of a wildlife species, e.g., caribou, which is linked to additional information and analysis on which rural residents

Figure 1. and Figure 2.

are eligible to harvest caribou (based on their residence and cultural uses), and (2) how much of a species is traditionally harvested, consumed, and shared as needed. A number of disparate professional disciplines, from biology, ecology, and anthropology, are employed to provide this information.

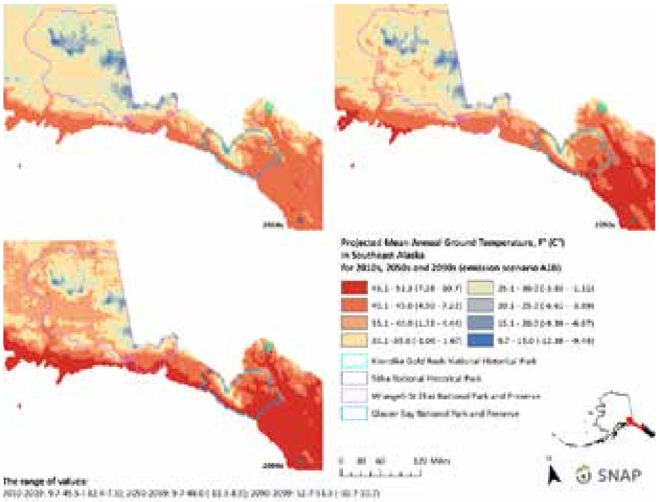


Figure 3. Mean annual ground temperature at one meter depth. Based on Scenarios Network for Alaska Planning climate data and Geophysical Institute Permafrost Lab permafrost modeling, these maps depict projected ground temperature conditions. Extensive permafrost thaw is likely by the end of this century.

However, it has often been the case that the requisite data for an FSB management decision was missing. Often there were no data relating to a specific issue, or there could be recent social data available without recent biological data on the status of the resource, or vice versa. Thus, often there was no data, or the simultaneous provision of both sets of data was serendipitous.

Between 1995 and 2009 numerous proposals were suggested to rectify this situation, most often in the form of an integrated regional studies plan. Within NPS, research proposals were (and still are) submitted by park and regional personnel to two overarching deliberate panels: the Natural Resource Advisory Council (NRAC) and the Cultural Resource Advisory Committee (CRAC). These two panels were later supplemented by a third panel, the Subsistence Advisory Committee (SAC).

Selected NRAC and CRAC proposals for research were supported by national funding "pots" allocated to regions, e.g., the Alaska Region. Advisory panels would review proposals for technical merit, keeping in mind an equitable distribution of funds between parks over time and perceived need. The concept of a regional studies plan

Southeastern Park Units

Climate Variable	Projected Change by 2050	Projected Change by 2100	Confidence	Source
Temperature	+2°C ±1.5°C	+4°C ±2°C	>95% chance of increase	IPCC (2007); SNAP/UAF
Precipitation (rain and snow)	Increased precip (10%-20%), possible decrease in winter snow	Increased precip (20%-40%), possible decrease in winter snow	High uncertainty in timing of snowmelt	AMAP/SWIPA; SNAP/UAF
Freeze-up Date	5-10 days inland; freezeup may not regularly occur in coastal areas	10-20 days inland; freezup may not regularly occur in coastal areas	>90%	SNAP/UAF
Length of Ice-free Season (rivers, lakes)	7-10 days inland; freezeup may not regularly occur in coastal areas	14-21 days; freezeup may not regularly occur in coastal areas	>90%	IPCC (2007); SNAP/UAF
River and Stream Temps	1–3°C	2–4°C	>90%	Kyle & Brabets (2001)
Length of Growing Season	increase of 10–20 days	increase of 20–40 days	>90%	IPCC (2007); SNAP/UAF
Sea Level	3–24 inches	7–72 inches	>90% chance of increase	IPCC (2007)
Water Availability (soil moisture = precip minus PET)	decrease of 0–20+%	decrease of 10–40+%	>66%; varies by region	SNAP/UAF; Wilderness Society
Relative Humidity	0% ±10% increase or decrease	0% ±15% increase or decrease	50% = *as likely as not*	SNAP/UAF
Wind Speed	2–4% increase	4–8% increase	>90% chance of increase	Abatzoglou & Brown
Pacific Decadal Oscillation (PDO)	Uncertain effect of atm circulation anomalies on Alaska's climate	Uncertain effect of atm circulation anomalies on Alaska's climate	High degree of natural variation	Hartmann & Wendler (2005)
Extreme Events: Temperature	3-6 times more warm events; 3-5 times fewer cold events	5-8.5 times more warm events; 8-12 times fewer cold events	>95%	Abatzoglou & Brown; Timlin & Walsh (2007)
Extreme Events: Precipitation	Change of −20% to +50%	Change of −20% to +50%	*Uncertain*	Abatzoglou & Brown
Extreme Events: Storms	Increase in frequency/intensity	Increase in frequency/intensity	>66%	Field et al. (2007)

Table 1. Southeast Alaska Network Climate Drivers (*Fresco et al. 2014:55*)

was that a regional panel of resource managers, including superintendents or their designees, creates a top-10 list of existing or expected resource management issues (e.g., the perceived decline of a caribou herd). These 10 issues could then provide general overall guidance on upcoming research needs to the advisory committees—for example, biological research on the caribou herd in question along with social/cultural information on the communities that harvested from that herd. There was no expectation that all the research monies from these funding sources would be applied to issues identified in the regional studies plan, but that at least some priorities submitted for consideration by more than one advisory committee would be coordinated among multiple disciplines, i.e., multidisciplinary research.

Why, over a span of nearly 15 years, did multiple proposals and multiple presentations to both groups, with support from the associate regional director, fail to be adopted? There seem to be two key dimensions that contributed to this failure. The first dimension is the structure, organization, process, and allocation of research funds, which have been, for the most part, "stove-piped" along disciplinary lines. The second dimension, recognized by NSF, relates to how incentives and rewards are distributed. Broad divisions between the physical, biological, and social sciences are organized in NPS to mirror their organization in higher education. Research universities organize their incentives and rewards along strictly disciplinary lines. Higher rewards, such as tenure, are offered to researchers who publish along disciplinary lines. Senior authorship or co-authorship of a peer-reviewed journal article or book counts much more towards tenure than does the contribution of the sixth of 12 authors on a larger multidisciplinary research effort.

Also, a multidisciplinary research effort can create the specter of turf battles. Researchers tend to protect disciplinary pots of money within their own control, and resist dividing funds to support research expenses in other disciplines.

Finally, it warrants mention that the above-mentioned regional studies plan proposal was advanced only within NPS. A truly integrated regional studies plan should of necessity involve all the federal agencies within the FSB and similar agencies within the state, e.g., the Alaska Department of Fish and Game. As the NPS climate change response strategy noted, "as well as across other agencies, partners and stakeholders" (*National Park Service 2010*).

The fact that such an integration of research resources was not even suggested speaks volumes.

Climate Change Research: the National Park Service's Scenario Planning Initiative

As already mentioned, the proposals for multidisciplinary efforts to coordinate biological and social sciences on subsistence issues have been slow to take hold. A contrasting example is provided by the NPS Climate Change Response Program's funding for a large ($600,000) interdisciplinary effort for climate change scenario planning across multiple large areas of Alaska.

Five climate change scenario planning workshops were conducted for geographically associated park clusters within Alaska. We will refer to three of those workshops in this article. One workshop included Southeast Alaska Network (SEAN) parks and coastal Wrangell-St. Elias. Another included all of the Southwest Alaska Network (SWAN) parks, the Kenai Peninsula, and Bristol Bay region. The third focused on coastal northwest Alaska, while two others focused on interior arctic Alaska and on central Alaska. Brevity precludes a detailed discussion of the scenario planning process, which is described in each of the reports generated by these five workshops (*Winfree et al. 2014a, 2014b, 2014c, 2014d, and 2014e*). However, it is key to the thesis of this article to note the close coordination demonstrated among a variety of disciplines in researching and producing these workshops.

The scenario planning process began with elicitation of several focal questions about uncertainties that have important long-range strategic consequences for NPS. A focal question at each workshop was: How can NPS managers best preserve the natural and cultural resources and values within their jurisdiction in the face of climate change?

Workshop participants were then asked to evaluate driving forces that affect these focal questions. Driving forces are key processes that influence or shape the focal questions in fundamental ways. The University of Alaska Fairbank's (UAF) Scenarios Network for Alaska Planning (SNAP) provided a set of "driver tables" for each workshop.

As you can see from the SEAN example driver table (*Table 1*), each row contains one climate variable (e.g., temperature), the modeled specific changes expected in this variable (e.g., an increase of 2 degrees Centigrade by the year 2050), the pattern of change (more pronounced in northern latitudes), and the confidence associated with this prediction.

SNAP also provided maps depicting baseline (recent historical) climate and modeled output for future change to key variables, including monthly mean temperature, monthly mean precipitation, date of freeze, date of thaw, summer season length, and mean annual ground temperature at just over a yard (1 meter) depth (*Figure 3*).

What is crucial to recognize is the large number of disciplines involved in the production of these climate drivers. Principals in SNAP included PhDs in forest ecology, botany and plant ecology, science communication (and rural development), programmers, software engineers, statisticians, geophysicists, and so forth. In essence, multiple disciplines coalesced to provide high-resolution climate modelling output for sub-regions within the state of Alaska.

Another critical step in the process was that these climate drivers were evaluated by a whole host of other workshop participants, having expertise in a wide range of disciplines—ecologists, biologists who specialize in land or marine mammals, mycologists, hydrologists, anthropologists, economists, and—just as important—a host of local residents, hunters, and others, each bringing a lifetime of experience on the land observing both the landscape/habitat, and the activities, behaviors, and life cycles of numerous species.

Keeping in mind the effects tables that had been developed in webinars and discussions prior to the workshop, all workshop participants voted on what climate drivers they thought and felt were both important (in terms of impacts) and highly uncertain as to their outcomes. Table 2 from the SEAN workshop shows the ranking outcomes of workshop participants.

Participants in the coastal subgroup of the Southwest Alaska workshop considered a very similar set of drivers, ultimately choosing two as the most critical, uncertain, and likely to affect their region in the next 50-100 years: ocean acidification and water availability (a combination of storms and precipitation). Potential impacts to park resources and infrastructure were identified and analyzed by considering a matrix of four plausible combinations of these two drivers. Based on this local climate drivers matrix, each workshop also developed several scenarios to explore potential impacts of climate change to park resources. The biophysical climate scenarios were also nested within a social/institutional framework. A dimension of social concern strongly influenced the potential outcomes for several climate scenarios. For example, people who were broadly informed and shared a heightened sense of urgency about climate impacts could be expected to respond differently than if there was widespread indifference to climate change and its impacts.

As mentioned above, prior to each workshop, participants helped to flesh out a climate effects table (*Table 3*). These tables organized potential effects to resources, operations, and people that might accrue from changes in the climate drivers mentioned above. Brief descriptions of the potential effects were collected and assessed by project team members with diverse disciplinary backgrounds. For example, anthropologists helped to identify potential impacts to subsistence, wilderness, tourism, economic development, and social and cultural impacts. As an illustration, we provide one brief write-up from the northwest Alaska workshop report (*Winfree et al. 2014b*), which describes the potential effects of community relocation resulting from storm surges, coastal erosion, flooding, thawing permafrost and other climate drivers:

> Relocating indigenous communities represents a large social burden, not just financial cost for governments, but also impacts to the communities themselves, potentially resulting in loss of integral cultural elements such as access to traditional use areas for subsistence activities, loss of history and sense of intact community, and potential loss of social networks and extended kin support. Significant increases in social pathologies such as alcoholism and domestic violence may also be anticipated. Tremendous stresses may also be placed on traditional means of conflict resolution. In addition multiple strains will be placed on local governance and delivery of services. Finally, state and federal governments will have huge additional burdens placed on them as they try to provide relief from the impacts of climate change.

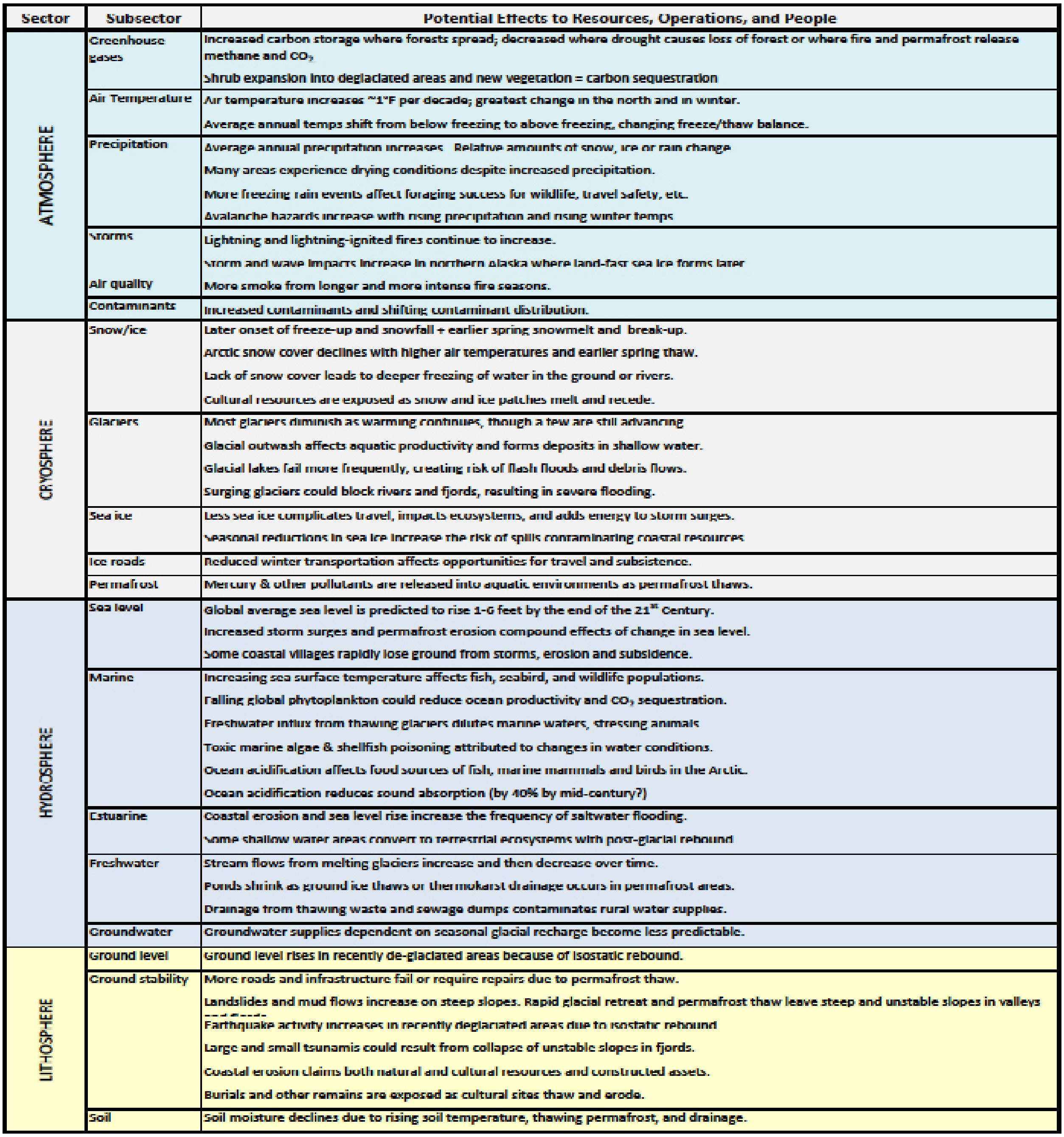
Research and Mitigation of Climate Change Impacts at Various Scales

The NSF advisory committee recognized the necessity of moving beyond researching issues to help develop mitigation strategies to aid communities suffering the consequences of climate change:

> Environmental science must move beyond identifying issues and toward providing sound bases for the development

	High Uncertainty	High Confidence	High Impact
Temperature			X
Form: rain & snow (changed)	X	X	X
Timing & magnitude of stream flow (added)	X		X
Freeze-up date			
Length of growing season		X	X
River/stream temperatures		X	X
Sea level rise		X	(isostatic rebound?)
Water availability (soil moisture)	X	X	
Relative humidity	X		
Wind speed			X
PDO	X	X	X
Extreme events:			X
higher temperatures	X	X	X
Extreme events: precipitation	X		X
Extreme events: storms			X
Ocean temperature increasing (added)		X	X
Ocean acidification (added)		(but not degree)	
		X	

Table 2. Rankings of climate drivers for the Marine work group of the Southeast Alaska workshop. Group members discussed the impact and uncertainty of each potential driver.



Sector	Subsector	Potential Effects to Resources, Operations, and People
ATMOSPHERE	Greenhouse gases	Increased carbon storage where forests spread; decreased where drought causes loss of forest or where fire and permafrost release methane and CO_2 Shrub expansion into deglaciated areas and new vegetation = carbon sequestration
	Air Temperature	Air temperature increases ~1°F per decade; greatest change in the north and in winter. Average annual temps shift from below freezing to above freezing, changing freeze/thaw balance.
	Precipitation	Average annual precipitation increases. Relative amounts of snow, ice or rain change Many areas experience drying conditions despite increased precipitation. More freezing rain events affect foraging success for wildlife, travel safety, etc. Avalanche hazards increase with rising precipitation and rising winter temps
	Storms	Lightning and lightning-ignited fires continue to increase. Storm and wave impacts increase in northern Alaska where land-fast sea ice forms later
	Air quality	More smoke from longer and more intense fire seasons.
	Contaminants	Increased contaminants and shifting contaminant distribution.
CRYOSPHERE	Snow/ice	Later onset of freeze-up and snowfall + earlier spring snowmelt and break-up. Arctic snow cover declines with higher air temperatures and earlier spring thaw. Lack of snow cover leads to deeper freezing of water in the ground or rivers. Cultural resources are exposed as snow and ice patches melt and recede.
	Glaciers	Most glaciers diminish as warming continues, though a few are still advancing Glacial outwash affects aquatic productivity and forms deposits in shallow water. Glacial lakes fail more frequently, creating risk of flash floods and debris flows. Surging glaciers could block rivers and fjords, resulting in severe flooding.
	Sea ice	Less sea ice complicates travel, impacts ecosystems, and adds energy to storm surges. Seasonal reductions in sea ice increase the risk of spills contaminating coastal resources
	Ice roads	Reduced winter transportation affects opportunities for travel and subsistence.
	Permafrost	Mercury & other pollutants are released into aquatic environments as permafrost thaws.
HYDROSPHERE	Sea level	Global average sea level is predicted to rise 1-6 feet by the end of the 21st Century. Increased storm surges and permafrost erosion compound effects of change in sea level. Some coastal villages rapidly lose ground from storms, erosion and subsidence.
	Marine	Increasing sea surface temperature affects fish, seabird, and wildlife populations. Falling global phytoplankton could reduce ocean productivity and CO_2 sequestration. Freshwater influx from thawing glaciers dilutes marine waters, stressing animals Toxic marine algae & shellfish poisoning attributed to changes in water conditions. Ocean acidification affects food sources of fish, marine mammals and birds in the Arctic. Ocean acidification reduces sound absorption (by 40% by mid-century?)
	Estuarine	Coastal erosion and sea level rise increase the frequency of saltwater flooding. Some shallow water areas convert to terrestrial ecosystems with post-glacial rebound
	Freshwater	Stream flows from melting glaciers increase and then decrease over time. Ponds shrink as ground ice thaws or thermokarst drainage occurs in permafrost areas. Drainage from thawing waste and sewage dumps contaminates rural water supplies.
	Groundwater	Groundwater supplies dependent on seasonal glacial recharge become less predictable.
LITHOSPHERE	Ground level	Ground level rises in recently de-glaciated areas because of isostatic rebound.
	Ground stability	More roads and infrastructure fail or require repairs due to permafrost thaw. Landslides and mud flows increase on steep slopes. Rapid glacial retreat and permafrost thaw leave steep and unstable slopes in valleys Earthquake activity increases in recently deglaciated areas due to isostatic rebound Large and small tsunamis could result from collapse of unstable slopes in fjords. Coastal erosion claims both natural and cultural resources and constructed assets. Burials and other remains are exposed as cultural sites thaw and erode.
	Soil	Soil moisture declines due to rising soil temperature, thawing permafrost, and drainage.

Table 3. (Part 1) Southeast Alaska Network Potential Effects (*Fresco et al. 2014:57-58*)

of innovative solutions, effective adaptation, and mitigation strategies. To accomplish this goal we urgently need to expand our capacity to study the environment as an integrated system that includes the human dimension. Humans are inextricably embedded within supporting environmental systems. To understand this coupling of natural and human social systems, we must advance general concepts such as ecosystem services and describe the processes that link natural systems, from local to global scales, with human systems from individuals to collectives. (*Advisory Committee for Environmental Research and Education 2009*).

One of the communities currently at risk from the large environmental changes brought about by climate change in the Bering Sea is Newtok. The difficulties Newtok has experienced serve as an exemplar case study as to what may await numerous other rural Alaska coastal and riverine communities. Floods, erosion, and the complete encirclement of the community by the Ninglick River have turned Newtok into an island. Newtok is faced with:

- Flooding that has eroded the community's dock and crane—bulk shipments of fuel can't be delivered
- Flooding that is causing problems with sewage disposal and may have serious health consequences
- Solid waste disposal that can only be accomplished by boat
- Complete community infrastructure—school, homes, diesel storage, and clinic that are eroding

As bad as the problems presented by the physical environment are, much worse is the frustration experienced by residents as they try to adapt and move their community to higher ground (the community was originally situated in this location by edict of the BIA in the 1950s against the objections of indigenous families).

Stanley Tom of Newtok stated that one of the biggest obstacles they face in trying to relocate is the lack of a single

Sector	Subsector	Potential Effects to Resources, Operations, and People
BIOSPHERE - vegetation and fire	General	Ecological "tipping points" are likely to result in rapid change, when conditions exceed physical or physiological thresholds (e.g., thaw, drought, water temperature)
	Vegetation	Average number of frost-free days for the Arctic could increase 20-40 days by 2100. Increased agricultural production in Alaska because of longer growing season. Potential large-scale shift of tundra to shrubs, to conifers, to deciduous forests or grass. Atypical outbreaks of pests and diseases affect native species and increase fire hazards. Invasive exotic plant species and native species from other areas expand their ranges. Vegetation expands into deglaciated coastal areas, less into higher elevation areas. Tree species and vegetation classes shift as species of lower latitudes and altitudes expand.
	Forests	Black spruce may expand with warming – or contract as permafrost soils thaw and fires increase. Mature forests and "old growth" decline because of drought, insects, disease, and fire. Mature yellow cedars decline across southeast Alaska, possibly due to lack of insulating snow.
	Fire	Models show a warmer climate leads to larger, more frequent and intense fires. Wildland fire hazards increase, affecting communities and isolated property owners. Fire-related landcover and soil changes result in vegetation shifts, permafrost thaw, etc.
BIOSPHERE - wildlife	Wildlife	Changes to terrestrial and aquatic species occur as ranges shift, contract, or expand, affecting visitor experience and subsistence Parks and refuges may not be able to protect current species within their boundaries. Animals and plants expand into landscapes vacated by glacial ice. Some species will suffer severe loses. So far, the greatest losses across all parks have been rodents, bats, and carnivores. Predator-prey relationships may change in unexpected ways. Migratory routes and destinations will change (e.g., wetlands, open tundra, snow patches).
	Birds	Arctic and alpine birds' breeding habitats reduced as trees and shrubs encroach on tundra. Kittlitz's murrelet populations decline with loss of important nesting and foraging habitat. Waterfowl shifts occur as coastal ponds become more salty. Productivity of nesting shorebirds may increase if schedules change to coincide w/ insects. Predation on ground nesting birds could increase if prey (lemming) abundance declines. Coastal seabirds (e.g. Ivory Gull and Aleutian Tern) are vulnerable to climate change. Population cycles of birds and their prey could be out of sync due to higher temperatures.
	Marine Mammals	Arctic marine mammals (e.g. seals, walrus and whales) are affected by sea ice decline. Less sound absorption (ocean acidification) affects marine mammals that rely on echolocation. Polar bears may have increasing difficulty accessing prey and finding shelter.
	Caribou/ Reindeer	Caribou and reindeer health are affected by changes in weather, forage, and insects and pests. Earlier green-up could improve caribou calf survival because of more available forage. Caribou may suffer heavy losses if rain events prevent successful feeding during cold weather.
	Moose	Shifts in forests could mean less habitat for caribou, but more habitat for moose. Climate change could hinder moose calf birth success and moose calf survival.
	Small Mammals	Fire may create new burrowing habitat and forage growth to help vole populations. Less snow cover reduces survival of subnivian species, due to increased predation & cold stress.
	Fisheries	Commercial fisheries are affected by changes to ocean communities in the Bering Sea. Some marine plant and animal populations may decline with ocean acidification. New stream habitats become available for fish and wildlife as glaciers decline. Some salmon waters may become unsuitable for migration, spawning and incubation. Fish diseases increase with rising stream temperatures. Fish habitats in permafrost areas are degraded by slumps and sediment input into rivers.
	Invertebrates	Ice worm populations decline locally as glacier habitats melt. Marine intertidal environments change, may become more susceptible to exotic marine species. Exotic pests expand from warmer areas, and endemic pests expand as host species are stressed.
	Subsistence	Altered animal migration patterns make subsistence hunting more challenging. Sea ice changes make hunting for marine mammals less predictable & more dangerous. Managing new species and intensified management of native species may be needed.
OTHER	Tourism	Longer summer seasons increase tourism. Some visitor activities increase, others decline. Landscape-level changes affect visitor experiences and access, visitor use patterns shift.
	Wilderness	Large-scale physical and biological changes across broad landscapes affect abundance and condition of wilderness-associated resources (e.g., glaciers, wildlife, access routes, ..) Changing biophysical landscape affect key wilderness values such as naturalness, wild-untamed areas wtihout permanent opportunities for solitude, etc.
	TEK	Uses of traditional ecological knowledge become less predictive and less reliable.
	Devpmt	More natural resource development in Alaska with increasing global demand. Fuel and energy prices increase substantially with carbon mitigation measures. Transporting fuels to remote locations becomes more challenging and costly.

Table 3. (Part 2) Southeast Alaska Network Potential Effects (*Fresco et al. 2014:57-58*)

agency or group in charge of planning and/or response. The Alaska Department of Transportation and Public Facilities can't build an airstrip unless there is a post office; there can't be a post office without a school; and the school has to have at least 25 students. But the structures needed to house 25 students can't be built without the airstrip. These and numerous other Catch-22 situations impede an integrated, flexible, and timely response. In addition, obtaining funding for relocation has been difficult and frustrating.

A multitude of state, federal, and regional entities are responsible for delivering services to rural Alaskan villages, but specific program policies and regulatory constraints produce circumstances for conflicting directives, resulting in bottlenecks in the ability to achieve a coordinated delivery of vital services and outcomes that will enable villages and traditional culture to adapt in the face of climate change. Therefore, there is a concrete need for establishing a coordinating entity with the ability to advocate and navigate these multiple bureaucratic entities and to leverage their resources to support rural villages in emergency response, relocation, subsistence concerns, and other priorities.

For instance, in order to facilitate a possible migration to higher ground, the Newtok Traditional Council has to interact with a large number of bureaucratic entities—13 State of Alaska agencies, 10 federal agencies and over five regional entities. This is a severe burden for a small community of 300 inhabitants.

Conclusion

The NPS scenario planning initiative in Alaska serves as an exemplary model for interdisciplinary research on climate change. Single-source funding for interdisciplinary cooperation is rare. Nevertheless we must recognize and continue to advocate, as the NSF Advisory Committee (2009) notes:

> Incorporating the human component will require long-term, regional-scale research that addresses how individual behavior, demography, and social systems respond to changes in the functioning of environmental systems. While scientists from every discipline can make significant contributions, studying the components of environmental systems in isolation from each other is neither adequate nor meaningful. To address the environmental challenges that confront us we must find ways to integrate and synthesize data from diverse fields into a whole-systems perspective, taking into account the complications of interactions occurring on different spatial and temporal scales.

REFERENCES

Advisory Committee for Environmental Research and Education. 2009.
Transitions and Tipping Points in Complex Environmental Systems. http://www.nsf.gov/geo/ere/ereweb/ac-ere/nsf6895_ere_report_090809.pdf

National Park Service (NPS). 2010.
National Park Service Climate Change Response Strategy. NPS Climate Change Response Program. Fort Collins, CO: National Park Service. http://www.nature.nps.gov/climatechange/docs/NPS_CCRS.pdf

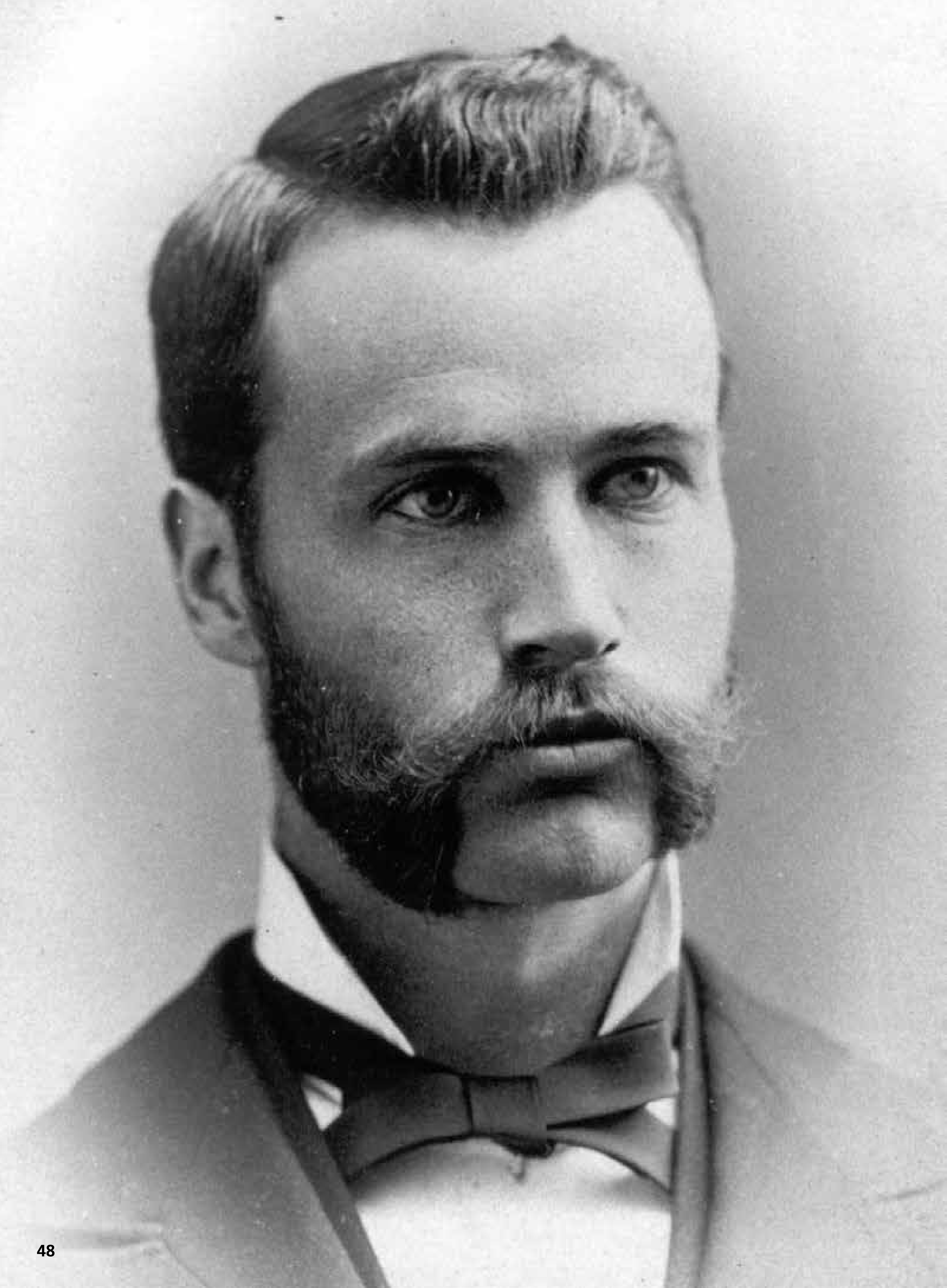
Winfree, R., B. Rice, N. Fresco, L. Krutikov, J. Morris, D. Callaway, D. Weeks, and J. Mow. 2014a.
Climate change scenario planning for southeast Alaska parks: Glacier Bay, Klondike, Sitka, and Wrangell-St. Elias. Natural Resource Report NPS/AKSO/NRR—2014/831. Fort Collins, CO: National Park Service. http://www.nps.gov/akso/nature/documents/NPS-CCSP-Report-Southeast.pdf

Winfree, R., B. Rice, N. Fresco, L. Krutikov, J. Morris, D. Callaway, D. Weeks, J. Mow, and N. Swanton. 2014b.
Climate change scenario planning for southwest Alaska parks: Aniakchak National Monument and Preserve, Kenai Fjords National Park, Lake Clark National Park and Preserve, Katmai National Park and Preserve, and Alagnak Wild River. Natural Resource Report NPS/AKSO/NRR—2014/832. Fort Collins, CO: National Park Service. http://www.nps.gov/akso/nature/climate/south-west.cfm

Winfree, R., B. Rice, N. Fresco, L. Krutikov, J. Morris, D. Callaway, J. Mow, and N. Swanton. 2014c.
Climate change scenario planning for northwest Alaska parks: Cape Krusenstern and Bering Land Bridge. Natural Resource Report NPS/AKSO/NRR—2014/830. Fort Collins, CO: National Park Service. http://www.nps.gov/akso/nature/documents/NPS-CCSP-Report-Northwest.pdf

Winfree, R., B. Rice, N. Fresco, L. Krutikov, J. Morris, D. Callaway, J. Mow, and N. Swanton. 2014d.
Climate Change Scenario Planning for Interior Arctic Alaska Parks: Noatak, Gates of the Arctic, and Kobuk Valley. Natural Resource Report NPS/AKSO/NRR—2014/833. National Fort Collins, CO: National Park Service. http://www.nps.gov/akso/nature/documents/NPS-CCSP-Report-InteriorArctic.pdf

Winfree, R., B. Rice, N. Fresco, L. Krutikov, J. Morris, D. Callaway, J. Mow, and N. Swanton. 2014e.
Climate Change Scenario Planning for Central Alaska Parks: Yukon-Charley, Wrangell-St. Elias, and Denali. Natural Resource Report NPS/AKSO/NRR—2014/833. Fort Collins, CO: National Park Service. http://www.nps.gov/akso/nature/documents/NPS-CCSP-Report-Central.pdf



Charles L. McKay, a Smithsonian Biologist at Nushagak, Alaska, 1881-1883

By John Branson

During the late 1870s and early 1880s, the U.S. Signal Service became the leading federal agency responsible for compiling meteorological data in Alaska. General William B. Hazen, chief signal officer, collaborated with Spencer F. Baird, assistant secretary of the Smithsonian Institution, in selecting young naturalists to gather data at meteorological-natural history stations. Stations were established at St. Michael, Unalaska, and Nushagak. Perhaps the most accomplished Signal Service agent was Edward Nelson, who was stationed at St. Michael between 1877 and 1881 (*Unrau 1992*).

On March 2, 1881, Baird wrote to David Starr Jordan, a professor at Indiana University, telling him of a great opportunity for "some earnest student of natural history to acquire distinction," by documenting a "vast region now unknown," to the wider world. Baird was "anxious to find a first-rate man to go as signal observer to Bristol Bay, in Alaska . . . the best locality for zoological discovery in North America . . . The ethnological field is also one of wonderful richness, furnishing an opportunity for important discoveries & collections of all kinds can be made in vast amounts." (*Baird 1881*).

The duties assigned to the observer at Nushagak were stated in a letter of March 22, 1884, by Baird to James W. Johnson, the second observer at that post. "Your primary duty at the station will be to make twice-daily observations in regard to the thermometer, barometer, rain gauge and next to that, to make collections of specimens of natural history and ethnology for the National Museum." The observer was also authorized to make purchases of trading stock from John Clark at the Alaska Commercial Company post, such as tea, sugar, pilot bread, and tobacco to barter with Natives for various artifacts and services such as guiding and paddling baidarkas on collecting trips (*Baird 1884*).

The first Signal Service observer at Nushagak was Charles Leslie McKay. He was born near Appleton, Wisconsin, on April 21, 1855. At a young age, McKay did chores on the family farm and demonstrated a great love of the natural world, in particular birds and fish. He enrolled in the Appleton Collegiate Institute and became a student of David Starr Jordan. When McKay wanted to become a naturalist like Jordan, he first went to college at Cornell University. In the late 1870s, McKay followed his mentor, Jordan, to Butler University and transferred again to Indiana University, where he was graduated in 1881 (*Mearns 1993*).

For a short time during the winter of 1881, McKay worked for the U.S. Fish Commission in Washington, D.C., where he must have come to the attention of Baird. By late winter, he had been selected to man the Signal Service station at Nushagak. McKay enlisted in the Signal Service on March 28, 1881, as a private. McKay sailed from San Francisco to Nushagak that spring.

McKay arrived at Nushagak in June, where he met Clark. Clark was an experienced Alaska hand, having been in Alaska since the late Russian America period. Clark was to be McKay's only English-speaking companion for the next two years. McKay lived in a small log house next to Clark's Alaska Commercial Company store. Twenty years later, biologist Wilfred Osgood, the second federal biologist to work in the Bristol Bay region, stayed in the same house (*Osgood 1904*).

Clark would become McKay's translator and chief local informant, sharing his knowledge of the Bristol Bay people and the locations of various natural and cultural resources suitable for museum collections. One immediate need Clark resolved was hiring local Yup'ik guides with their three-hatch baidarkas to take McKay on collecting forays around the Bristol Bay region. The pay would probably have been in trade goods, such as tea, tobacco, or gun powder. Clark loaned his own kayak to McKay, and soon McKay wrote to Baird at the Smithsonian of his need of a skin boat: "I will get a baidarka for my own use this coming season. I have been using one of the Company's baidarkas, but I cannot always have it when I want it and it sometimes puts Mr. Clark to inconvenience. It would probably cost about $15." (*Baird 1881*).

McKay began collecting as soon as he arrived at Nushagak village, Osgood wrote in *A Biological Reconnaissance of the Base of the Alaska Peninsula* (*Osgood 1904*); he collected a fox sparrow on June 6, 1881. McKay wrote in July 1881 that he went to the head of Bristol Bay. By that, he seems to have meant to the mouth of the Kvichak River. McKay went as far south as the Ugashik River, where he collected ethnographic specimens, including an elaborately beaded headdress (*Fitzhugh and Crowell 1992*). McKay hoped to go on a collecting trip to the northward of Cape Constantine, an area that was rocky (Kulukuk and Togiak) "if the weather quiets down

Figure 1. Charles Leslie McKay (1855-1883) was the first biologist to work in the Bristol Bay region. He was employed by the Smithsonian Institution and the U.S. Signal Service while stationed at Nushagak village between 1881 and his death in 1883.

Photo courtesy of the Indiana University Archives, Bloomington Indiana.

Photo courtesy of the Field Museum, 283410.

Figure 2. Biologist Wilfred Osgood (1875-1947) did more to document McKay's travels of 1882 than anyone. He was the first biologist to systematically document the ecological diversity of the Bristol Bay region in 1902.

Photo courtesy of Dennis and Lois Herrmann and the NPS.

Figure 3. John W. Clark was McKay's only English speaking friend and patron while the young biologist lived at Nushagak. Clark was the chief trader for the Alaska Commercial Company in the Bristol Bay region and one of the founders of the commercial salmon industry in western Alaska.

sufficiently this fall." It is doubtful that he ever traveled to Togiak himself, yet he might have collected specimens from that location with the aid of a Togiak resident who ran a small trading station for Clark (*Baird 1881*).

In the mid- to late-19th century, travel was difficult at best in Bristol Bay country. When the Bering Sea and the inland waters were ice-free, travel was by kayak, baidarka, or baidara. Winter travel was by dog team and was generally less laborious than travel by skin boat, yet, it too, was very physically demanding.

McKay wrote that he had "a smart young fellow . . . one of the agents of this company Alaska Commercial Company collecting for me on the other side of the bay." Unlike the better-known Signal Service agent Edward Nelson, McKay's few extant letters are often vague about locations and dates. He might have been referring to Togiak, Egegik, Ugashik, or Koggiung villages or even Igushik, west across Nushagak Bay from his home at Nushagak (*Baird 1881*).

McKay was a skilled collector, and he was able to establish a level of trust and mutual respect with Bristol Bay Natives, which enabled him to do his job of collecting natural history specimens. That would be borne out by the fact that he traveled widely in the Bristol Bay drainage collecting artifacts and specimens with Native guides and paddlers. Some of the locations he visited were Lake Aleknagik, Igushik, Ugashik, Kvichak Bay, Iliamna Lake, Lake Clark, and the Chulitna Portage, including the Swan, Koktuli, Mulchatna, and Nushagak Rivers (*Osgood 1904*).

Osgood is the best source for information on the extent of McKay's travels around much of the Bristol Bay region for several reasons. In 1902, for his wide-ranging trip around the bay, Osgood hired the same Dena'ina guide as McKay, Zackar Evanoff. Evanoff had guided McKay on the same portage from Lake Clark to the Nushagak drainage. In addition, when writing his book, Osgood had access to McKay's field notebooks to document locations of where the collections were made.

McKay did write his friends in Indiana telling them of some of his adventures, and it is clear that he also traveled by dog sled from Nushagak during the winters of 1881-1882 and 1882-1883. David Starr Jordan references the last letter McKay wrote to Spencer Baird on January 26. Osgood established that McKay went upriver during the spring-summer of 1882. It seems inexplicable that McKay did not write a lengthy letter to Baird detailing his collecting trip to the Chigmit Mountains. Yet no such letter exists in the Smithsonian Institution Archives. It seems likely, though, given that McKay wrote to Baird on January 26, 1882, describing his intention of going to the Chigmits:

> There is one section of this district, up at the head of this river [Nushagak River], among the Chigmit Mountains and inland, that is entirely unexplored and unknown. No white man has ever been there. It is very probable that many species of birds that are not found here will be found there . . . The mountain sheep and little 'chief hare' pika are very abundant there, but it is impossible to get the Natives that live around here to kill the latter as they have some superstition about it. The Natives also say that there is a goat that lives in these mountains . . . I have no doubt that if I could spend one summer in that region, I could do good work there. Looking towards that end, I have a proposition to make . . . Mr. Swain, who has been at work in Professor Jordan's laboratory remarked incidentally in one of his letters that he 'wouldn't mind spending a year with me.' If he would come, I could leave my station in his charge. The expense to the Smithsonian would only include his transportation to San Francisco and return . . . In that case, I would, of course, be without salary, but I would be perfectly satisfied with having my traveling expenses paid . . . Mr. Swain would be a very valuable aid in developing the resources of this large region. There is yet a good deal of work to do and I do not care to return under four years. (*Jordan 1883*).

Osgood was certain that McKay did reach Lake Clark, and there are several specimens in the Smithsonian's American Museum of Natural History collections attributed to McKay from the Chulitna River, a tributary of Lake Clark. Moreover, Osgood states that his guide in 1902 on the Chulitna River was Zackar. "He [McKay] also made a trip over a considerable part of the route traveled by our party," Osgood wrote. "He visited Lake Iliamna and Iliamna Village, and according to an account received from a Native, [Zackar]

Photo courtesy of the Elizabeth Butkovich Collection and the NPS.

Figure 4. Togiak men in baidarkas at Nushagak village in 1884 with Moravian missionary William Weinland in the center hatch. A fish trap or stake net is seen on the left. This is how McKay would have traveled around Bristol Bay.

Photo courtesy of Sandra Orris and the NPS.

Figure 5. Chief Zackar Evanoff (1851-1935) photographed in 1921 at Seversen's Roadhouse. In 1882 he guided McKay on the Chulitna Portage from Lake Clark to the Swan River (Nushagak River drainage). In 1902 Zackar guided Osgood on the same route over the Chulitna Portage.

Photo courtesy of the Elizabeth Butkovich Collection and the NPS.

Figure 6. A winter scene of Nushagak village and the Alaska Commercial Company buildings in the 1880s or '90s. McKay's home was the small cabin in the left foreground. Clark's store and home are in the center and right of center respectively. The church and priest's home are seen on the second level to the left.

University of Washington Libraries, Special Collections, John Cobb Collection, 4179.

Figure 7. A 1917 scene from Egegik showing four kayaks and one three-hatch baidarka on racks. McKay would have used the baidarka to travel to Iliamna and Lake Clark in 1882. He died in Nushagak Bay while paddling the more challenging kayak.

crossed the Chulitna Portage. By strange coincidence, the same Native who, as a young man accompanied McKay on his trip, went with us from Lake Clark to Swan Lake, and related to us various incidents of the trip made twenty years before, [with McKay] . . . our guide, Zackar, a very intelligent Native from Kijik village." (*Osgood 1904*).

McKay wrote another intriguing letter from Nushagak on April 14, 1882, to an unnamed friend at his alma mater, Indiana University:

> In Nushagak here, they [Natives] have adopted the European dress to a greater extent than anywhere else in the Bristol Bay region, but they still retain the parka and the moccasins or skin boots. As you go inland, however, the people dress entirely in skins. Their dishes and weapons of the chase are made just as their forefathers made them . . . The Indians of the interior . . . There is a tribe of them, living up on the Molchatria [sic] River, a branch of the Nushagak River . . . They were far more sociable than these [Yup'ik ?] people, as far as my observation went—different in features and language. In Callogamuck [Koliganak] I saw one huge squaw [sic] with a face as big and round and expressive as the full moon. (*McKay 1882*).

McKay's Bristol Bay life was described by the editor of *The Indiana Student*:

> If space permitted, we should be glad to add many other interesting extracts from Mr. McKay's long and interesting letter. His experiences in that strange far-away land, with fish, fowl, men and ferocious mammals, among mountains and fleas, and in the wilderness with spruce boughs for a bed, the sky for a coverlet, and a thermometer marking 29 below zero for a bed-fellow, are altogether as interesting reading as can be found in any books of travel. (*Anonymous 1882*).

The spring-summer of 1882 saw McKay travel with Yup'ik guides and paddlers by baidarka from Nushagak around Etolin Point into Kvichak Bay upstream on the Kvichak River and eastward across Iliamna Lake to Old Iliamna village, where he likely secured two Dalls sheep horn spoons from the Dena'ina. The sheep horn specimens came from the Chigmit Mountains. Osgood believed McKay obtained the sheep specimens at the Dena'ina village of Old Iliamna. But Osgood felt the Iliamna Dena'ina probably obtained the sheep parts from their kinfolk on Lake Clark, because, based on his 1902 visit, Dall sheep were not known to commonly inhabit the mountains around Iliamna Lake. In addition, McKay's accession records from 1883 list "Clothing of Kenai Indians," that he could have collected himself at Old Iliamna during his 1882 visit or from one of the Mulchatna villages he perhaps visited during the winter of 1882 or 1883 (*Osgood 1904*).

McKay collected a pika in the Chigmit Mountains and noted, "Indians in their vicinity have a superstitious dread about killing them, and cannot be hired to do so." (*Jordan 1883*).Osgood said "McKay was unquestionably a careful and enthusiastic collector, and his accidental death at an early age was a distinct loss to science." (*Osgood 1904*). On May 19, 1883, about a month after McKay died in Nushagak Bay, Baird, not knowing of his death, wrote him saying the collections he sent back to the Smithsonian had "extreme value" and "great importance." (*Baird 1883*).

As late as 1882, the Iliamna-Lake Clark region had rarely seen a Euro-American traveler. Perhaps Alphonse Pinart, the French ethnographer-linguist, was the first non-Russian white man to see Iliamna Lake when, in 1871, he and Yup'ik guides paddled baidarkas up the Kvichak River to the lake's outlet and then returned to Bristol Bay. It is very likely that McKay was the first documented American to see the lake north of Iliamna Lake, which the

Dena'ina called Qizhjeh Vena, before it was named Lake Clark in February 1891 by New York City writer-explorer Albert B. Schanz (*Haakanson and Steffian 2009*).

The Demise of McKay and His Legacy of Scientific Inquiry

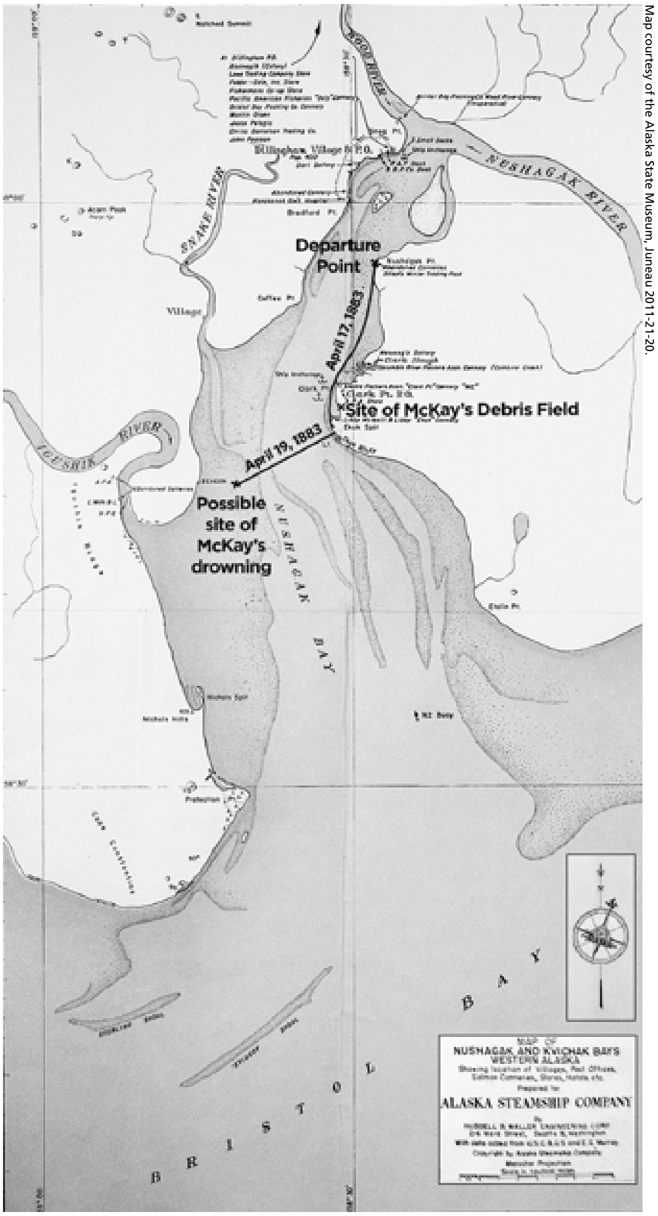
> It is my sad duty to inform you that your son left this place on the 17th of April, to make a short trip for the purpose of making collections, and that he never returned. He left in company with a Native, each of them in a single canoe and passed the night in an Indian village, sixteen miles from the station. The following day was very stormy and they lay over in the village. On the morning of the third day it being calm weather, they left the village to cross over the bay, a distance of twelve miles. They were accompanied from the village by three other Native canoes. When about two thirds of the way across a strong adverse wind sprang up. In some manner, he was left behind and that was the last that was seen of him. On the 22nd the report reached me and the same day we began to search for him. We found broken pieces of his canoe, a gun, his rubber boots, hat and various little articles on the beach about a mile on this side of the village they left that morning. We continued the search for over three weeks, but could not find the body. Such is a brief account of all that is at present known of the manner in which he was lost. I can readily understand with what feelings you will receive this letter, and believe me that if the sympathy of a stranger can serve to mitigate your grief in the slightest degree, you have mine. Being my sole companion for two years, I had learned to appreciate him and to esteem his manly, upright character. Your very obedient servant, John W. Clark. (*Clark 1883*).

McKay seemed to foretell the cause of his own demise when he wrote Baird about the dangers of kayak travel on the waters of Bristol Bay. In a September 1881 letter to Baird, McKay wrote: "It has to be pretty quiet down on the coast or there is no getting the Indians [Yup'iks] to venture out. On the last trip I wanted to go out fishing, but the Indians would not stir as it happened to be a little rough . . . I believe that I will get a baidarka for my own use this coming season." (*Baird 1881*).

Another letter, written by Nelson Groom of the Signal Service in San Francisco to General Hazen on July 19, 1883, tells of a letter from an unnamed Alaska Commercial Company agent at Unalaska. Groom wrote: "I regret to inform you of the drowning April 19 of Charles L. McKay . . . who had left Nushagak on the breaking up of the river to go with a party to Cape Constantine on a collection tour and on his return the accident occurred; his party was ahead and a very strong gale blowing at the time, and did not see him capsize, but from the finding of his gun and a portion of the wreck of his baidarka, concluded it must have happened by his trying to make a landing on the ice. His body was not recovered." (*Groom 1883*).

McKay's mother, Sarah A. McKay, wrote to Baird on September 14, 1883, enclosing a copy of Clark's letter. She stated that Clark's letter "differed in some respects from the one sent by you [Baird] to us from the department. You will notice that it was three days after the accident occurred before they got word to Mr. Clark. In a letter written the first of April Charles told of making the same trip and back in the same day."

In a post script, Mrs. McKay reflected both her maternal grief and a widespread, 19th-century Euro-American bias against Native Americans: "It seems to me that the Natives must know more of the matter than they choose to tell. Perhaps an investigation of the other side of the Bay might reveal something. No one can tell a Savages [sic] motive for what he may do. I have just read of Alaska Indians killing white men." (*McKay, S.A. 1883*).



Map courtesy of the Alaska State Museum, Juneau 2011-21-20.

Figure 8. A map of Nushagak Bay showing the possible kayak routes taken by McKay on April 17 and 19, 1883, that led to his death. "Map of Nushagak and Kvichak Bays, Western Alaska." Prepared for the Alaska Steamship Company by Hubbel W. Waller Engineering Corporation, Seattle, 1946.

Painting courtesy of the author

Figure 9. An imaginative oil painting by L. Bowman of McKay on the Chulitna Portage in 1882 nearing the Nushagak drainage guided by Lake Clark Dena'ina, resident Zackar Evanoff.

Rumors persisted into the 20th century of foul play in McKay's death. Sarah McKay's sentiments indicated she felt her son's death might have been the responsibility of his Yup'ik companions. The implication of Mrs. McKay's letter was that perhaps some Nushagak people resented McKay collecting artifacts and natural history specimens, and somehow caused his death. In 1904, Osgood wrote, "rumor at Nushagak still persists to the effect that the drowning of McKay was brought about by foul means." However, later Osgood wrote that McKay's "accidental death at an early age was a distinct loss to science." Yet there is no evidence to suggest that McKay's death was anything but a tragic accident, albeit one exacerbated by extenuating circumstances (*Osgood 1904*).

Perhaps the genesis of rumors of foul play was propagated by the next visitor to Nushagak to leave a written record. On April 30, 1883, Danish ethnographer and collector Johan Adrian Jacobsen arrived near the scene of the accident 12 days after McKay drowned. He made no reference to criminal behavior in reference to McKay's death, but he did excoriate the behavior of McKay's Yup'ik traveling companions. Jacobsen and his four Togiak guides traveled in three small craft, probably two baidarkas and one kayak, paddling around Cape Constantine and crossing Nushagak Bay to Clark's trading station:

> We reached the village of [Ekuk] where I [met] young Kasernikoff (whose father was murdered by the Indians in Nulato 2 years ago)—he was busy searching for the body of the young signal service officer Mr. McKy [sic], who capsized in a snowstorm about [twelve] days ago on a hunting and collecting expedition, and drowned. There were several Eskimos with him and he was abandoned by these cowards when the storm came—they have found his gun and almost all things but not his body . . . This station [Nushagak] was unfortunately without an occupant because Mr. Mackay [sic], who had been there, was drowned during a hunting expedition . . . It was not possible for me to find anything at this place because Mr. Mackay [sic] had bought everything the Natives possessed for the Smithsonian Institution. . . . Here is a signal station . . . and the present observer [McKay] has plundered the entire area . . . and has in his collection a few nice things. The Eskimo are now annoyed that they have sold all of their stone axes and knifes etc. to him because I promised them higher. But it is too late because everything has been sold . . . the signal officer here lost his life a few days before I arrived because he went to hunt with some Natives and was shamefully left behind by the Eskimo in a snow storm when his kayak was cut in two by the ice and he drowned. (*Jacobsen 1883*).

Neither Clark nor the other two informants mentioned foul play as a possibility in McKay's death. There was never any official government investigation of McKay's death, nor did any documented contemporary account of his demise offer any credible evidence of foul play. Surely, if Clark had any suspicions of foul play in the death of his young friend, he would have informed the U.S. Signal

Service. McKay's successor, James W. Johnson, who arrived at Nushagak the summer of 1884, apparently never asked his superiors in San Francisco and Washington, D.C., to open an investigation into McKay's death.

Patience and deference to the forces of nature were part of the Yup'ik culture, coupled with broad experience on the water. When the weather turned bad, Yup'ik men, who had life-long experience in skin boats on the Bering Sea, were far better prepared to deal with adverse weather than a young man who had only been in Alaska two years. McKay had little experience on Nushagak Bay, with its fearsome, 25-foot tides, spring ice floes, and sudden snowstorms with accompanying gale force winds. When the going turned very bad, perhaps it was every man for himself; McKay's kayak was disabled, and he could not keep up with his Yup'ik companions.

As tragic as McKay's death was, his legacy of work in the Bristol Bay region as the first resident scientist was considerable. Captain J.N. Mills of the U.S. Signal Service sums up the value of McKay's contributions: "the . . . service has lost a faithful, intelligent and efficient member and that his service in connection with meteorological work of this office in Alaska has been highly appreciated . . . I am informed by Professor Baird that he had rendered extremely important service to the Smithsonian Institution and National Museum." (*Jordan 1883*). In addition, McKay is considered to be the first documented Euro-American to see Lake Clark.

The tangible results of McKay's few years of collecting at Nushagak include about 363 mammal and bird specimens and 123 plant species. He also collected mineral and important ethnographic specimens. His collection of Dena'ina and Yup'ik skin clothing is important to better understand the material culture of the Native people of Bristol Bay. In recognition of his excellent service, McKay's Bunting, *Plectrophenax hyperboreus*, a rare passerine bird, was named after him (*Mearns 1993*).

REFERENCES

Anonymous. 1882.
The Indiana Student. Volume IX, No. 1.

Baird, S. 1881.
Letter to David Starr Jordan. Cecil Green Library, Department of Special Collections and University Archives. Stanford University.

Baird, S. 1883.
Letter to Charles L. McKay. Record Unit 33, Volume 142, 113-117. Washington, D.C.: Smithsonian Institution Archives.

Baird, S. 1884.
Letter to James W. Johnson. Record Unit 33. Volume 160, 448-449, 467-470. Washington, D.C.: Smithsonian Institution Archives.

Clark, J. 1883.
Letter to H. McKay. Record Unit 30, Office of the Secretary Correspondence, 1882-1890. Washington, D.C.: Smithsonian Institution Archives.

Groom, N. 1883.
Letter to W. B. Hazen. Record Unit 30, Box15, Folder 10. Washington, D.C.: Smithsonian Institution Archives.

Haakanson, S. Jr., and A. Steffian. 2009.
Giinaquq, Like a Face. Fairbanks: University of Alaska Press.

Jacobson, J. 1977.
Alaskan Voyage 1881-1883: An Expedition to the Northwest Coast of America. Trans. Erna Gunther. Chicago: University of Chicago Press.

Jordan, D. 1883.
Charles Leslie McKay. *The Indiana Student*. Volume X, No.1.

Jordan, D. 1883.
Quoting letter of J. N. Mills in *The Indiana Student.* Volume X, No. 1. Letter to S. Baird. Office of the Secretary Correspondence, Record Unit 7002, Accession No. 11460.

McKay, C. 1882.
Letter to the Editor of *The Indiana Student.* Volume IX, No. 1.

McKay, S. 1883.
Letter to S. Baird. Office of the Secretary 1882-1890. Record Unit 30, Box 8, Folder 8. Washington, D.C.: Smithsonian Institution Archives.

Fitzhugh, W., and A. Crowell. 1988.
Crossroads of Continents, Cultures of Siberia and Alaska. Washington, D.C.: Smithsonian Institution Press.

Mearns, B., and R. Mearns. 1993.
McKay of McKay's Bunting: A Native of Appleton, Wisconsin. *The Passenger Pigeon*. Volume 55, No. 2, Summer 1993.

Osgood, W. 1904.
A Biological Reconnaissance of the Base of the Alaska Peninsula. *North America Fauna,* 24. Washington, D.C.: Government Printing Office.

Unrau, H. 1992.
Lake Clark National Park and Preserve, Alaska: Historic Resource Study. Draft. Anchorage: U.S. Department of the Interior.

ALLY

At the Roots of Alaska Science: Practicing Natural History along the Noatak River

By Michael Gaige and Lee James

Introduction

"Look, a fox!" a student announces. Instantly, ten pairs of binoculars rise, scanning the ground below. We are standing on a pingo, a 15-minute walk through scattered willows from the Noatak River. The animal is approximately 100 yards (91.4 meters) away and has not yet noticed us. "It's not a fox. It's a wolf pup!" another student concludes. Our lesson on permafrost features has been pleasantly interrupted.

Over the course of the next hour, eight students and two instructors observe a pack of wolves with dedicated attention. The wolves do the teaching. Our students all capture the moment that evening in their field journals. As one student describes it:

> We froze, to hear the sounding of the wolves, who were obviously watching us, from who knows where. Normally, one only hears about the howl of the wolf. But we were hearing much different words. The wolves were barking and then would let a howl off. But it was amazing to me to hear the barking! It made me wonder: what other types of communication do wolves have? Also it made me wonder: how many wolves have surrounded us at this moment? (*S. Lewis, unpublished field journal, 2012*).

We counted seven wolves in the end, some of which we saw, and others we only heard. During that hour everyone was keenly observant of the moment. And the intensity with which we observed the wolves was reciprocal:

> Finally we saw an adult wolf making its way toward us from the direction of the calls. I was expecting it to go toward the pups, but it kept trotting toward us. Then, all of the sudden, way to our left it stood in an opening and slowly made its way closer yet, totally focused on us, and maybe within 50 yards. Even without binoculars it was easy to see the curiosity with which it moved forth. (*S. Lewis, unpublished field journal, 2012*)

Natural History

People have been practicing natural history in the Noatak region for at least 11,000 years. As described by Fleischner (*2011*), natural history is "a practice of intentional, focused attentiveness to the more-than-human world, guided by honesty and accuracy." Barry Lopez (*1989*) described natural history as being "as old as the interaction of people with landscape" and a "patient interrogation of the landscape" (*Lopez 1986*). Though today natural history often takes the form of an objective inquiry and description of the natural world, over the preceding millennia, the people of the Noatak region and throughout the world depended—and still depend—on a practice of natural history for their survival, as well as their culture. Through direct observation, they understood the ways of the animals, the weather, and the seasons.

The first European to practice natural history in what is now Alaska was Georg Wilhelm Steller in 1741. As the naturalist (and physician) on Vitus Bering's voyage, Steller observed and documented a variety of animals and plants unknown to western science at the time. Because of his careful attention, we have descriptions of Alaska fauna, such as the Steller's sea cow, that have since gone extinct.

In time, other explorer-naturalists arrived and continued the inquiry into Alaska's unique landscape. John Muir plied the coast of Alaska beginning in 1879 making observations of glaciers and contributing significantly to the emerging science of glaciology. William Dall, active in Alaska soon after its purchase from Russia, was commissioned to survey the territory's interior and coastal regions. He had a passion for natural history and reported detailed descriptions of Alaska's flora, fauna, and people. After dedicated observation (and hunting) of sheep in the Alaska Range, Charles Sheldon (*1930*) described his observations and later advocated successfully for the establishment of Mount McKinley National Park. And Adolph Murie, like us, observed and described wolves. His efforts resulted in a new understanding of predator-prey relationships (*Murie 1944*) and in the establishment of additional conservation lands.

The first western naturalist-explorer to venture into the Noatak region was Samuel McLenegan of the Corwin expedition in 1885. McLenegan was commissioned to explore the river in a geographical sense, as this part of the territory remained unexplored. In his report (*Healy et al. 1887*), McLenegan describes the country and speculates on natural processes such as the limits to tree growth and the causes of folds in geologic strata. The list of observed birds he generates is particularly impressive considering the purpose of his expedition and the harrowing conditions he met.

Our Noatak expedition follows this great tradition of exploration and direct observation to describe and understand an unknown landscape. We encourage students to engage deeply, enter with broad open-mindedness, and be willing to speculate and generate questions. *This landscape rewards attention*, we tell them. Similarly, through description, comparison, and questioning, contemporary

Figure 1. We use Ally folding canoes for the 26-day expedition.

Photo by M. Gaige.

researchers in disciplines such as geology, biology, atmospheric science, and ethnography use the foundation of natural history to further our collective understanding. Natural history forms the root of all Alaskan science.

The Course

Our Arctic river expedition is an upper division undergraduate course at Prescott College (Prescott, Arizona). The course began in 2004 driven by personal experiences of rivers in Alaska's Brooks Range. Transformational encounters with landscape and wildlife and the awe and wonder they inspire have been a consistent theme ever since. The structured study of natural history fosters an opening to detail, nuance, and inter-relationships that deepens that experience.

This is not a guided trip. Students are responsible for expeditionary planning; they generate an equipment list and plan their own food ration for the entire 26-day expedition. Some students arrive having never paddled a canoe. But


Photo by M. Gaige.

Figure 2. An observant student unraveling ecological processes through his field journal.

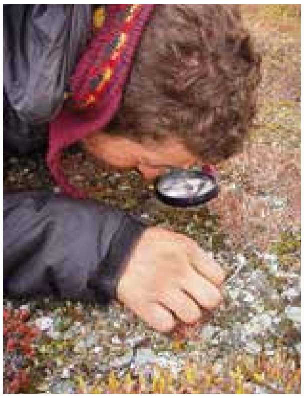


Photo by L. James.

Figure 3. Looking closely at tundra lichens.


Photo by M. Gaige.

Figure 4. A student paints a scene from the Noatak headwaters. We strongly encourage students to engage with the landscape artistically, as this hones their observational detail.


Photo by M. Gaige.

Figure 5. A student presents a natural history lesson at the Cutler River confluence. Students are each responsible for presenting three lessons.


Photo by M. Gaige.

Figure 6. The flight to the headwaters in Coyote Air's Beaver aircraft allows students to get a broad overview of the landscape in which they will spend the next 26 days.


Photo by M. Gaige.

Figure 7. Exploring the landscape away from the river is equally important, such as here on the alpine ridges near 12-Mile Creek.


Photo by M. Gaige.

Figure 8. A formal lesson on Brooks Range geology.


Photo by M. Gaige.

Figure 9. Students are responsible for navigation, and map reading is a frequent activity.

by the time we reach Noatak Village, some 370 miles downstream, they are competent in expeditionary canoe travel in the challenging arctic environment (*Figure 1*).

In addition to expeditionary planning, students have other academic responsibilities. Each student maintains a natural history field journal to record his or her observations (*Figure 2*). This is the primary means by which they document their engagement with the landscape. Field journals can be used in many ways (*Farnsworth et al. 2014*) though we emphasize two points: (1) use the journal as an objective inquiry into the external landscape; and (2) vary the subject matter and scale—be attentive to mosses and lichens (*Figure 3*) as well as to landforms, wildlife, and the shape of the river as it winds through vast expanses of tundra. We strongly encourage students to draw that which they observe (*Figure 4*) as this engages additional modalities of learning (*Ainsworth et al. 2011*). Each student also presents three brief natural history lessons on a bird, mammal, and plant family (*Figure 5*). In addition to the required text—*Arctic Dreams*, by Barry Lopez (*1986*)—we carry an extensive library of field guides and maps.

On the River

The Noatak River begins in the western Brooks Range, its headwaters rising in Gates of the Arctic National Park and Preserve. The bulk of the river and its watershed occur above treeline in Noatak National Preserve. The entire region was affected by previous glaciations, evidenced by glacially carved landscapes in the mountains, and glacial lakebed sediments in the basin (*Hamilton 2010*). After a 90-minute flight—a natural history experience in its own right—pilot Dirk Nickisch sets us down on a gravel bar within sight of Mount Igikpak, in the Noatak River headwaters (*Figure 6*).

If a group paddled each day, the trip to Noatak village could be completed in less than 10 days. We allow 26 days to accommodate hikes (*Figure 7*), formal classes (*Figure 8*), rest days, and a pace that facilitates digging in and experiencing the country.

Once on the river, students are responsible for navigation (*Figure 9*). Standard topographic maps are a luxury early explorers did not have. We stop regularly throughout each paddling day to climb the bluffs and scan the landscape. One never knows what will emerge, but something always does: caribou, musk ox, bears, birds, or a rich patch of blueberries. As one student discovered:

Photo by M. Gaige.

Figure 10a. Standing at a small refugia days after a July 2010 fire at Okak Bend.

Photo by M. Gaige.

Figure 10b. The same area of Okak Bend in September 2014. Students look for evidence of the fires.

> The whiny call of a Falcon—eee eee eee—sounds across the tundra. Looking over, my first thought is a Snowy Owl sporting the flat head and inexistent shoulders. As the wings shift and the bird banks, I can see a more defined head—stout with a large hooked bill, and dark lightning bolt streaks on the white chest and underwings. This is a Gyrfalcon! As I scan to the east another falcon enters the field of view. This one, smaller and darker all around, is also a Gyrfalcon. These two birds circle each other for the next fifteen minutes. They behave like opposed pendulums. One banks too close, the other repositions a few feathers and soars away using present energy. They fly like fish move underwater—masters of their third dimension—a simple wing flick can put a bird over on its back, backwards and upside-down, to flash a talon and send off the other pendulum. (*S. Williams, unpublished field journal, 2010*)

Observing Landscape Change

"*You can't step in the same river twice.*" Heraclitus

Though the Noatak is new and foreign country for students each year, it has become a familiar landscape to us. We revisit areas that, in less than a decade, show clear signs of change. In 2010, for example, we observed the smoldering remains of many tundra fires that occurred in the preserve that year (*Higuera et al. 2011*). On subsequent years we have been able to revisit these sites to witness the tundra's recovery (*Figures 10a and 10b*). Rather than measure and quantify change, we encourage students to observe, describe, and question the processes taking place and their repercussions.

Near Akikuchiak Creek, in the Grand Canyon of the Noatak, we explore an active thermokarst slurry. We have witnessed this rapidly melting and eroding slope expand from less than 2 acres (0.8 hectares) in 2008 to an estimated 10 acres


Photo by M. Gaige.

Figure 11a. Thermokarst slurry in 2008.


Photo by M. Gaige.

Figure 11b. The same thermoskarst slurry in 2014.


Photo by M. Gaige.

Figure 12. Drifting toward a small herd of migrating Western Arctic caribou.


Photo by M. Gaige.

Figure 13. Student Jeff Glessing with a remarkable find of a fully intact mammoth tooth.


Photo by M. Gaige.

Figure 14. Student Lauren Twohig inspects a caribou bone fragment fallen from a midden exposed by an eroding bank.

(4 hectares) in 2014 (*Figures 11a and 11b*). Each year we stand at the retreating wall of frozen sediment and listen to melting ice, mud, and falling stones. Because of our own repeated observations we're able to pose questions to students regarding how such change occurs and what the ramifications may be.

Our encounters with wildlife are never the same from year to year (*Figure 12*). One year we observed over 50 rough-legged hawks. During the same month the following year we saw none. In 2014 we observed a congregation of 17 grizzly bears working the chum salmon run at the confluence with Kugrak River—the highest density of bears we've ever seen. We're as interested in raising questions and speculating about the factors behind this variation as we are in specific answers. The questions inspired by observation are at the heart of natural history and the field journal process. On our most recent trip, a student found a fully intact mammoth tooth (*Figure 13*); discussions of Pleistocene megafauna moved from the theoretical to the observable!

The Cultural Landscape

Though Gates of the Arctic National Park and Preserve and Noatak National Preserve together form one of the largest wilderness areas in the world, the region is not without people. Depending on the year we occasionally meet other paddlers, some from as far away as Australia and Norway. We also encounter outside sport hunters, often astute naturalists in their own right. And our interactions with the residents from Noatak Village, who we typically begin meeting 100 miles upriver from the village, are always welcome and memorable. They share with us their intimate knowledge and experience of the landscape and its animals. At the end of our most recent trip, a generous family in Noatak treated us to a caribou and salmon dinner in their home.

We have also found evidence of human habitation from long ago. On a small tributary stream we discovered house pits and a midden (*Figure 14*) in an eroding bluff that we subsequently learned was approximately 500 years old (*S. Shirar, personal communication*). This was a powerful experience for students. For three weeks they had been meeting the challenge of finding good tent sites to avoid wind and to have access to higher ground. Here, they were seeing someone else's interpretation of a good site. As one student wrote in her field journal:

> The location of the house pits was in a perfect spot next to a smaller river leading into the Noatak. They had the pits in a lower protected area and not in direct sight of the river. They were located at the base of a large bluff that had a perfect 360° view of a large stretch of river and the area surrounding their camp. Perfect to look at who or what

is surrounding them, where animals are, and who is coming down the river. (*L. Twohig, unpublished field journal, 2014*)

The Value of Natural History Field Expeditions

Perhaps one doesn't need an hour with a wolf pack to learn something about wolves. Maybe it doesn't take a month-long canoe trip down one of America's most remote rivers to learn about the Arctic. But we believe that in a world where people spend less and less time engaged with plants, animals, fresh air, and wildness, that intentional immersion and focused attention to the natural world can have strong positive outcomes.

Learning from the land forges a connection with it. The understanding of Alaska's wild landscape that comes from spending weeks with it develops informed, emotionally engaged citizen-advocates who can speak wisely on behalf of Alaska's parks and wildernesses. Place-based natural history education can foster abiding connection to, and concern for, the land.

Practicing natural history helps cement academic concepts in natural sciences. After a month on the Noatak River, matters such as salmon migration, the diet of grizzly bears, and the rapidly changing Arctic become real, observable phenomena. The hour we spent with wolves that year left students (and instructors) a lasting understanding of the species' behavior that cannot be replicated in a classroom. As the great Japanese poet Matsuo Bashō said, "Go to the pine if you want to learn about the pine."

Engaging learners with the natural world is important also because we still have things to learn that come from close observation of natural phenomena in the field. Though today much emphasis in natural sciences is on predictive models and statistical analyses, direct observation allows an unfiltered window into the natural world forming a foundation upon which quantitative studies can be built. Recently, Tewksbury and colleagues (*2014*) outlined the importance of natural history to science and society in the 21st century.

Finally, though we emphasize the importance of detached observation, sometimes the power of the landscape overwhelms one's ability to objectively describe it. These moments are likely more enduring than our formal classes. These moments are what we are hoping for. As one student wrote:

Climbed the cliff upstream of camp. The colors here are stunning. Reds, greens, and grays of the mountains matched by red, green, and gray in leaves, needles, stems. You lose yourself in the shades of lichens and mosses, looking up to grey clouds turned pink with the setting sun. Pale orange glows in clear skies on the northern horizon.

A few lines, a few words, a few sounds. Ultimately, nothing can do this land justice like spending a long stretch of time with it. Enough time to drift in and out of the present so many times that you realize there's nowhere else you'd rather be. Here. Now. No chance to record, just experience. (*C. Kulfan, unpublished field journal, 2014*)

Acknowledgments

We thank the many students who, over the years, have shared in the Noatak River with us. Special thanks also to the National Park Service, the people of Noatak Village, Scott Shirar at the UAF Museum of the North, and Tom Fleischner of Prescott College and one additional reviewer.

REFERENCES

Ainsworth, S., V. Prain, and R. Tytle. 2011.
Drawing to learn in science. *Science* 333:1096-1097.

Farnsworth, J., L. Baldwin, and M. Bezanson. 2014.
An invitation for engagement: assigning and assessing field notes to promote deeper levels of observation. *Journal of Natural History Education and Experience* 8:12-20.

Fleischner, T., ed. 2011.
The mindfulness of natural history. *The Way of Natural History.* San Antonio: Trinity University Press.

Hamilton, T. 2010.
Surficial geologic map of the Noatak National Preserve, Alaska. U.S. Geological Survey Scientific Investigations Map 3036.

Healy, M., J. Cantwell, S. McLenegan, and C. Townsend. 1887.
Report of the Cruise of the Marine Steamer Corwin in the Arctic Ocean in the Year 1885. Washington, D.C.: Government Printing Office.

Higuera, P., J. Barnes, M. Chipman, M. Urban, and F. Hu. 2011.
The burning tundra: a look back at the last 6,000 years of fire in the Noatak National Preserve, northwestern Alaska. *Alaska Park Science* 10(1):36-41. Anchorage: National Park Service.

Lopez, B. 1986.
Arctic Dreams: Imagination and desire in a northern landscape. New York: Charles Scribner's Sons.

Lopez, B., and E. Wilson. 1989.
Dialogue One: Ecology and human imagination. *Writing Natural History: Dialogues with Authors.* Ed. Edward Lueders. Salt Lake City: University of Utah Press.

Murie, A. 1944.
The Wolves of Mount McKinley. Washington, D.C.: Government Printing Office.

Sheldon, C. 1930.
The Wilderness of Denali: Explorations of a Hunter-naturalist in Northern Alaska. New York: Charles Scribner's Sons.

Tewksbury, J., J. Anderson, J. Bakker, T. Billo, P. Dunwiddie, M. Groom, S. Hampton, et al. 2014.
Natural history's place in science and society. *Bioscience* 64:300-310.

Understanding Visitors' Commitment to Grizzly Bear Conservation at Denali National Park and Preserve

By Rose I. Verbos, Matthew T.J. Brownlee, and Jeffrey C. Skibins

Introduction

Denali National Park and Preserve (DENA) receives more than 400,000 visitors annually and studies have shown that grizzly bears are the most sought after species to observe (*Skibins et al. 2012*). More than 80 percent of visitors surveyed report that seeing a grizzly bear and that their satisfaction with the viewing experience fosters a favorable view of on-site conservation plans (*Anderson et al. 2010; Skibins et al. 2012*). Skibins, Powell, and Hallo (*2013*) found evidence linking wildlife viewing experiences and interpretive programs to an increase in visitors' on-site pro-conservation behaviors. Given the volume of visitation, high likelihood of seeing a grizzly bear, and the potential link between the viewing experience and support for conservation, this represents a tremendous untapped potential to bolster wildlife conservation at DENA.

Locations such as DENA rely on the link between visitors' wildlife viewing experiences and subsequent support for conservation. However, park managers and interpreters often need empirical data to identify visitors' perceptions towards conservation issues. Park management and interpretation often relies on understanding an audience's perceptions and experiences, particularly related to site-specific resources, such as grizzly bears at DENA (*e.g., Beck and Cable 2011; Manning, 2011*). Similar to interpretation, many public outreach initiatives use an audience's existing perceptions and experiences as a foundation to design strategic pro-conservation messages (*Center for Research on Environmental Decisions 2009*). Environmental policy decisions also require an understanding of constituents' underlying perceptions (*Jacobson 1999*). Without understanding visitors' grizzly bear viewing experiences and levels of caring about the grizzly bears, wildlife interpretation and management decisions may be misinformed.

Therefore, during the summer of 2013, researchers investigated DENA visitors' commitment to grizzly bear conservation to inform park management, interpretation, and outreach. Specifically, researchers and managers sought insight into (a) the emotional impact of the grizzly bear viewing experience, (b) visitors' levels of conservation caring, and (c) their willingness to engage in on-site pro-conservation behaviors towards grizzly bears at the park. These constructs and their measurements are discussed in the following section.

Figure 1. Visitors to Denali National Park and Preserve observe a grizzly bear on the park road.

NPS Photo by Robert Winfree

Methods

On-site questionnaires were administered to DENA visitors in the summer of 2013. Visitors were approached at the Wilderness Access Center and asked to complete the questionnaire after finishing their bus tour on the Denali Park Road. Researchers used a stratified random probability sampling approach diversifying across types of bus tours (e.g., distance, price, time spent) to ensure a representative sample.

The questionnaire assessed visitors' perceptions of grizzly bears including the emotional impact of the grizzly bear viewing experience, willingness to engage in on-site pro-conservation behaviors towards grizzly bears at the park, and their levels of conservation caring towards grizzly bears as a species (see Table 1 for items used to measure these constructs). The emotional impact of the grizzly bear viewing experience captured the on-site experience and its contribution to visitors' emotional connections to grizzly bears. Visitors' willingness to engage in on-site pro-conservation behaviors towards grizzly bears at the park was measured using questions evaluating visitors' likelihood to engage in park-specific conservations actions. Conservation caring was evaluated by asking visitors' to report their level of affective (i.e., care about) and cognitive (i.e., care that) connection to grizzly bears as a species. Conservation caring differs from the emotional impact of the grizzly bear viewing experience because conservation caring measured the level of visitors' connection to grizzly bears as an entire species and the impact of the grizzly bear viewing experience captured the contribution of on-site experiences to visitors' emotional connection to DENA grizzly bears. All responses were measured on a nine-point scale, with higher responses (i.e., 7, 8, 9) indicating (a) a more emotionally impactful grizzly bear viewing experience, (b) a higher willingness to engage in on-site pro-conservation behaviors towards grizzly bears at the park, and (c) a higher level of conservation caring.

After standard data cleaning and validating the measurements, descriptive statistics were calculated for each construct (*Byrne 2008*). Next, a K-means cluster analysis (*Wu 2012*) was used to group individual cases of visitors with similar patterns of responses to create manageable and highly homogeneous clusters that were statistically different from each other. For this study, visitors were categorized based on their levels of conservation caring and willingness to engage in on-site pro-conservation behaviors towards grizzly bears at the park. Following this segmentation, researchers evaluated if these distinct groups of visitors differed in their emotional impact from the grizzly bear viewing experiences.

Results

Description of the Sample

A total of 472 visitors completed the questionnaire (89 percent response rate). The sample was evenly split between males (51.3 percent) and females (48.7 percent). The majority of the visitors (70 percent) reported a four-year college degree or graduate/professional degree. The visitor population at DENA was found to be fairly homogeneous in that white visitors comprised 83 percent of the sample. Fifty percent of the visitors reported more than $75,000 in annual household income. Approximately 18 percent of the sample was from Alaska, 68 percent of the sample was split between the remaining U.S. Census regions, and 13 percent were international visitors.

Visitors' Levels of Conservation Caring, Willingness to Engage in On-Site Pro-Conservation Behaviors, and Grizzly Bear Viewing Experiences at the Park

The psychometric properties for conservation caring, willingness to engage in on-site pro-conservation behaviors, and the emotional impact from the grizzly bear viewing experience achieved desirable and acceptable levels, indicating that these constructs were measured appropriately (*Table 1*). The majority of visitors (67.3 percent) reported high levels of conservation caring (*Figure 2*). In contrast, 76 percent of visitors reported a low willingness to engage in on-site pro-conservation behaviors. Visitors' emotional

Constructs and items [a]	Mean (SD)	λ
Conservation caring	**6.21 (1.92) [a]**	-
Ensuring grizzly bear survival is my highest priority.	5.66 (2.27)	0.75
My emotional sense of well-being will be severely diminished by the extinction of grizzly bears.	5.39 (2.51)	0.81
My connection to grizzly bears has increased my connection to all wildlife.	4.85 (2.40)	0.79
I will alter my lifestyle to help protect grizzly bears.	4.62 (2.36)	0.85
I need to learn everything I can about grizzly bears.	4.55 (2.21)	0.85
Model fit: CFI = 0.99; NNFI = 0.98; SRMR = 0.02; RMSEA = 0.06; RHO = 0.91; SBχ2 (df) = 23.23*	-	-
Willingness to engage in on-site pro-conservation behavior	**3.95 (1.78) [a]**	-
I would support entrance fees at Denali being $10 - $25 higher, if the extra money was used for the management of grizzly bears.	5.02 (2.37)	0.75
I would write a letter/sign a petition to a government official supporting grizzly bears at Denali.	4.10 (2.92)	0.71
I will donate up to $75 to help purchase bear-proof trash cans around Denali.	3.41 (2.25)	0.80
I will provide on-going financial support to Denali.	3.02 (2.26)	0.87
I will contribute up to $150 to support the on-going research of grizzly bears at Denali.	2.99 (2.15)	0.80
Before my visit is over, I will sign up for a mailing/email to receive updates about grizzly bears at Denali.	2.84 (2.26)	0.80
I will become a member of an organization committed to protecting grizzly bears at Denali, within the next 6 months.	2.72 (2.04)	0.87
Model fit: CFI = 0.97; NNFI = 0.95; SRMR = 0.04; RMSEA = 0.08; RHO = 0.91; SBχ2 (df) = 92.18*	-	-
Impact of the grizzly bear viewing experience	**4.04 (2.08) [a]**	-
I spent time discussing grizzly bears with others in my group.	4.44 (2.71)	0.78
I understood their (grizzly bears) behaviors.	4.18 (2.57)	0.81
I understood their emotions.	3.31 (2.41)	0.96
I felt empathy for them because of their emotions.	3.20 (2.35)	0.81
Model fit: CFI = 0.99; NNFI = 0.98; SRMR = 0.03; RMSEA = 0.08; RHO= 0.84 ;SBχ2 (df) = 7.43*	-	-

Table 1. Measurement performance and items for conservation caring, willingness to engage in on-site pro-conservation behaviors, and the grizzly bear viewing experience at Denali National Park and Preserve (DENA). Notes: All items rated as agreement on nine-point scale; 1 = completely disagree; 9 = completely agree; a = estimated construct mean; all fit indices derived from robust statistics; CFI = comparative fit index; λ = standardized factor loading; NNFI = non-normed fit index; RHO = adjusted Cronbach's alpha; RMSEA = root mean square error of approximation; SB χ2 = Satorra-Bentler Scaled Chi-Square; SRMR = standardized root mean squared residual;* $p < 0.05$. Each of the model fit indices has acceptable levels of good fit: CFI > 0.90; NNFI > 0.90; RMSEA < 0.08; RHO > 0.70; SRMR < 0.1; (*Byrne 2006; Kline 2011*).

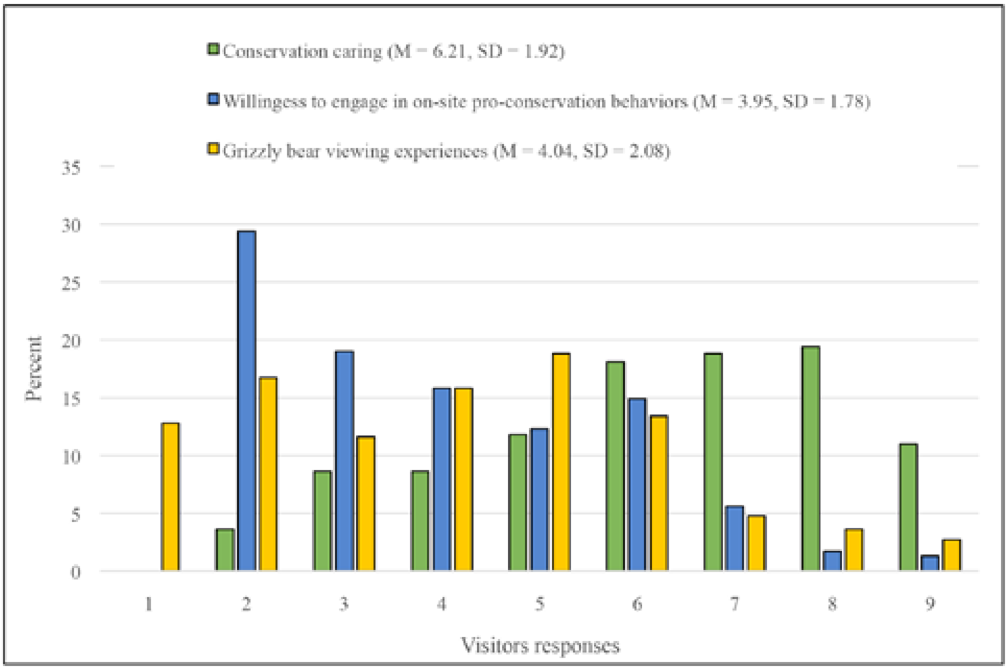


Figure 2. Visitors' conservation caring, willingness to engage in on-site pro-conservation behaviors, and grizzly bear viewing experiences at Denali National Park and Preserve. Measured on a nine-point scale using multiple responses (see Table 1 for items); conceptually, 1 = low levels of conservation caring, willingness, and emotional impact from the viewing experiences; 9 = high levels of conservation caring, willingness, and emotional impact from the viewing experiences; M = mean; SD = standard deviation.

impact from a grizzly bear viewing experience was moderate and relatively dispersed across response categories (*Figure 2*).

K-Means Cluster Analysis and Visitor Segmentation Groups

To identify different groups of visitors with similar perceptions, the researchers combined the measures for conservation caring and willingness to engage in on-site pro-conservation behaviors into a single model. Results indicate five significantly distinct groups of visitors exist based on their (a) levels of conservation caring, and (b) willingness to engage in on-site pro-conservation behaviors. The largest group of visitors with similar perceptions (38.3 percent) is described as "Caring but Unwilling." These individuals are characterized by a moderate level of conservation caring while also reporting limited willingness to engage in on-site pro-conservation behaviors (*Figure 3*).

The next largest group, which comprised 20.5 percent of the sample, is described as "Low Caring and Unwilling." This group is characterized by low levels of conservation caring and a low willingness to engage in on-site pro-conservation behaviors. Next, the "High Caring but Neutral" group reported a high level of conservation caring and neutral levels of willingness to engage in on-site pro-conservation behaviors. This group represents approximately 18.7 percent of the sample.

The "Caring and Willing" group comprised 14.4 percent of the sample and report moderate levels of conservation caring as well as moderate levels of willingness to engage in on-site pro-conservation behaviors. The smallest group of visitors is described as "High Caring and Very Willing" (8.2 percent of visitors), which is characterized by high levels of conservation caring, and high levels of willingness to engage in on-site pro-conservation behaviors.

These five visitor segmentation groups do not differ significantly in their past visitation to the park, age, gender, income, residence location, or education. However, these groups do differ significantly in respect to the emotional impact from their grizzly bear viewing experiences.

The Emotional Impact from the Grizzly Bear Viewing Experience

The emotional impact from the grizzly bear viewing experiences was found to be generally moderate and significantly different between the five segmentation groups (*Figure 4*). Visitors in the "High Caring and Very Willing" group reported the highest emotional impact from the grizzly bear viewing experience. Visitors who report a higher emotional impact from a grizzly bear viewing experience also report higher levels of conservation caring and higher levels of willingness to engage in on-site pro-conservation behaviors (*Figure 4*). However, this represents only 8.2 percent of the total sample. Conversely, the "Caring but Unwilling" group represents the largest segment of the visitor population (38.3 percent) and visitors in this group report a moderate to low emotional impact from their grizzly bear viewing experience. These data suggest one of two things. First, visitors' levels of conservation caring and willingness to engage in on-site pro-conservation behaviors are partially a function of the emotional impact born from the grizzly bear viewing experience. Alternatively, visitors who already have higher levels of conservation caring and willingness to engage in on-site pro-conservation behaviors before their DENA visit are more likely to have emotionally meaningful grizzly bear viewing experiences. Regardless, on-site wildlife viewing experiences with charismatic megafauna (e.g., grizzly bears) are potentially quite important

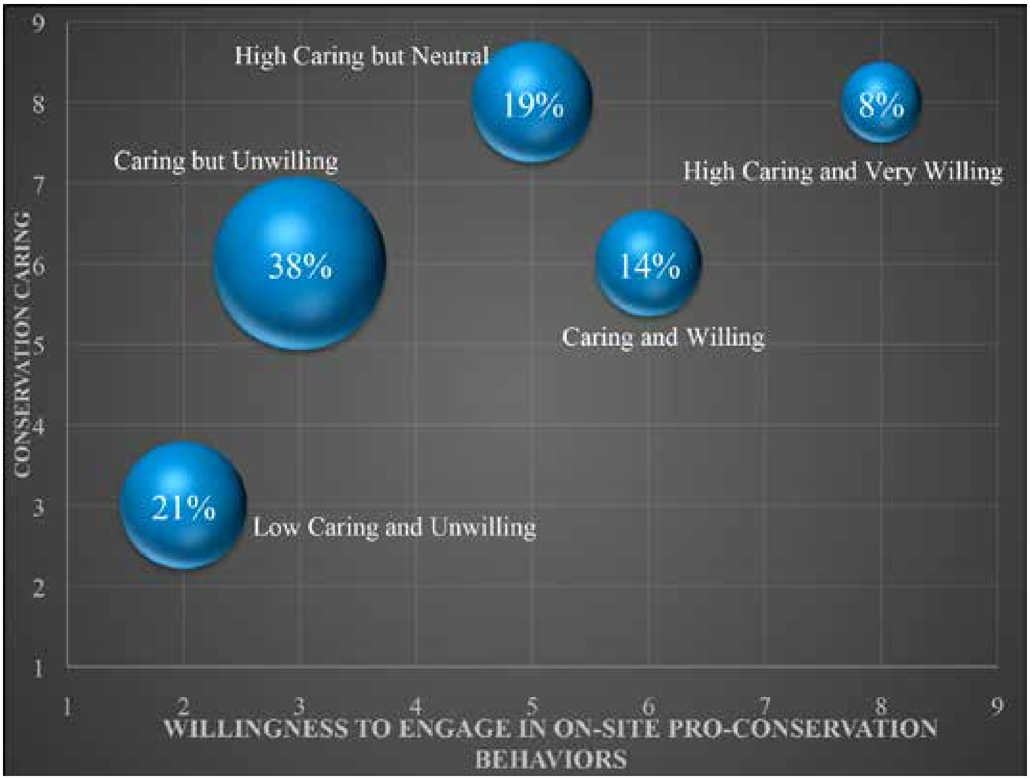


Figure 3. Results of a K-means cluster analysis to segment Denali National Park and Preserve visitors (n = 472) based on their levels of conservation caring and willingness to engage in on-site pro-conservation behaviors; both measured on a nine-point scale using multiple response items; % = percent of sample; 1 = low levels of conservation caring, and willingness; 9 = high levels of conservation caring and willingness.

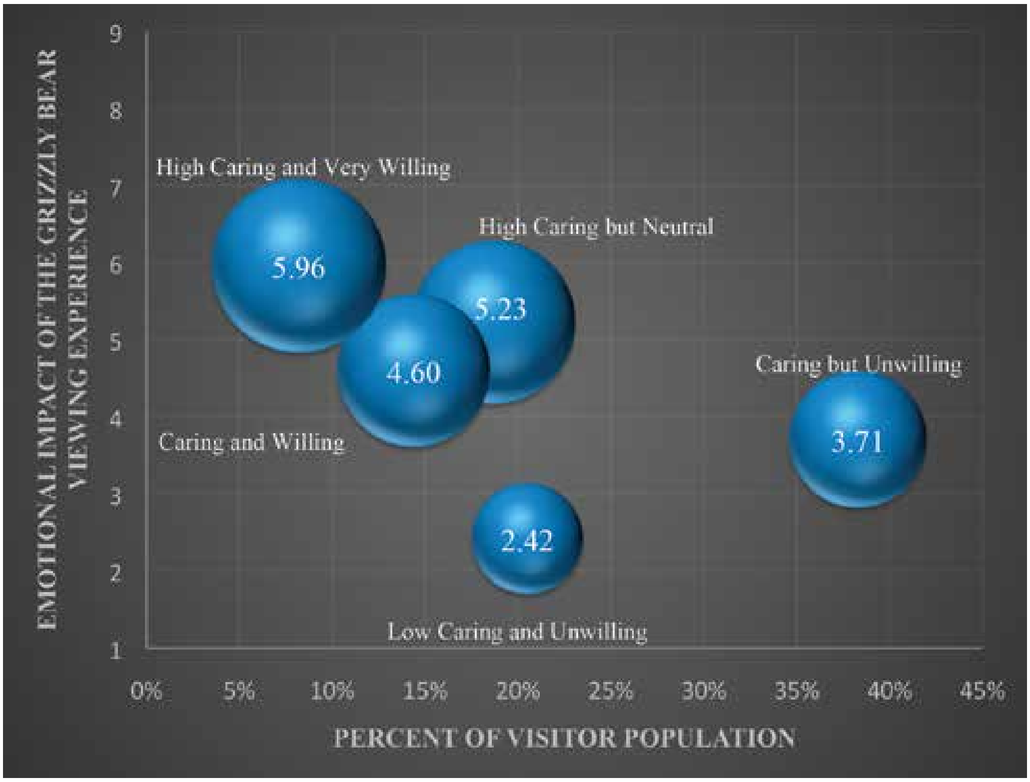


Figure 4. Emotional impact of the grizzly bear viewing experience across visitor segments; mean values of the impact of the grizzly bear viewing experience are displayed inside each sphere; viewing experience measured on a nine-point scale and 1 = low emotional impact from the viewing experience; 9 = high emotional impact from the viewing experience.

when considering visitors' willingness to engage in on-site pro-conservation behaviors towards grizzly bears at DENA.

Discussion and Management Implications

The purpose of this study was to gain insight into visitors' grizzly bear viewing experiences, levels of conservation caring, and willingness to engage in on-site pro-conservation behaviors towards grizzly bears at Denali National Park and Preserve. Results indicate that visitors have high levels of conservation caring but low levels of willingness to engage in on-site pro-conservation behaviors. Furthermore, visitors with high levels of conservation caring and a high willingness to engage in on-site pro-conservation behaviors also report emotionally impactful viewing experiences.

Implications for these results are two-fold and affect visitor management as well as interpretation at DENA.

DENA visitors report low levels of willingness to engage in on-site pro-conservation behaviors, which is potentially influenced by visitor management transportation policies related to use of the Denali Park Road (e.g., providing no public vehicle access, with the exception of designated overnight campgrounds). The transportation policies protect important resources and provide unique visitor experiences by requiring visitors to take a bus tour, walk, or bike the park road. The majority of visitors tour DENA on buses traveling into the park daily and hourly during peak season. The bus tours vary from four to eight hours, and visitors are typically arriving directly before and departing immediately after their bus tour—potentially providing limited time and schedule flexibility to consider engaging in on-site pro-conservation behaviors. This bus tour experience and consequential constraints potentially lead to low levels of willingness to engage in on-site pro-conservation behaviors. Additionally, an information deficit could exist whereby visitors' are unclear about opportunities to financially contribute or join an organization to support on-site pro-conservation towards grizzly bears at the park. Information deficits, constraints on time, and schedule flexibility may contribute to visitors reporting low levels of willingness to engage in on-site pro-conservation behaviors. Interpretation, however, could highlight how on-site pro-conservation behaviors are mutually beneficial to grizzly bears and the visitor experience, as a possible solution.

DENA may be ideally positioned to provide links from conservation caring to on-site pro-conservation behavior because visitors' report relatively high levels of conservation caring, and conservation caring has been shown to be a strong predictor of pro-conservation behaviors (*Skibins and Powell 2013*). Interpreters and park staff could strive to inform visitors through campaigns focused on understanding the importance of participating in on-site pro-conservation behaviors. Information could be tailored to each group (*Figures 3 and 4*) describing how to contribute to grizzly bear protection in DENA and why it is important. For example, it may be advantageous to design specific messages to target the "Low Caring and Unwilling" (21 percent of the sample). For this group, interpretation messages can stress the importance of conservation caring and on-site pro-conservation behaviors through providing specific behavioral outcomes such as organizations to join, volunteer openings, and adoption opportunities. Although it may be difficult for park staff to quickly identify which visitors arriving at the park belong to a specific segmentation group, park staff can design specific messages that may attend to each group's characteristics derived from this study.

Grizzly bear conservation at DENA may be fostered by drawing on specific elements of the grizzly bear viewing experiences. The majority of visitors (71 percent) are in three of the five segmentation groups that report moderate to high levels of conservation caring. For grizzly bear conservation,

NPS photo by Robert Winfree

Figure 5. Grizzly bear along the Denali Park Road.

this means visitors' report relatively high levels of affective and cognitive connection to grizzly bears as a species. The results from this study specifically link visitors' high levels of conservation caring with high levels of emotional impact during grizzly bear viewing experiences. Therefore, by fostering emotional connection with grizzly bears during viewing experiences, DENA may be able to increase overall levels of conservation caring for grizzly bears in the park.

It is important for interpretation to nurture environments whereby visitors can connect with grizzly bears at an emotional level through safe and sustainable on-site viewing opportunities (e.g., avoiding human-bear conflict and providing visitor education). According to Manfredo (*2008*), "from an applied perspective, it is important to realize that emotional responses are at the heart of human attraction to, and conflict over, wildlife." The results of this study suggest visitors emotionally connect most with grizzly bears at DENA when they have spent time discussing grizzly bears with others in their group, feel that they understand grizzly bear behaviors and emotions, and feel empathy for grizzly bears. Therefore, interpretation can help visitors explore, understand, and connect to DENA grizzly bears by connecting bear and human behavior and emotion. For example, many grizzly bear behaviors viewed during a visit may be similar to the human experience, and interpretation could highlight emotionally laden topics, such as the role of mothering in an offspring's success. In practice, when viewing a sow with her offspring, time spent interpreting animal behaviors and connecting the observations to visitors' lived experiences could increase levels of conservation caring and a connection to grizzly bears. Such increases may stimulate visitors' willingness to engage in on-site pro-conservation actions and consequentially targets the visitors (71 percent) who report moderate to high levels of conservation caring but low to moderate levels of willingness to engage in on-site pro-conservation behaviors.

Photo by Rose I. Verbos

Figure 6. A visitor to Denali Park fills out a survey.

Denali National Park and Preserve, with more than 400,000 visitors annually, has a unique opportunity to proactively link interpretation and park management to on-site grizzly bear conservation. A prerequisite for effective wildlife interpretation and management decisions is knowledge of an audience's existing perceptions and connections to particular species (*Manfredo 2008*). DENA has the prospect to improve conservation efforts by expanding on-site opportunities for visitor-based actions thereby bolstering grizzly bear conservation on public lands, provided there is an understanding of audiences' perceptions of grizzly bear viewing experiences. Without fully evaluating the grizzly bear viewing experience and visitors' perceptions, funds and management options may be ineffectively applied to grizzly bear viewing and grizzly bear interpretation strategies.

Author Note

The authors acknowledge and thank the Global Change and Sustainability Center at the University of Utah and the David C. Williams Fellowship for supporting this research. Additionally the authors thank Denali National Park and Preserve for their non-monetary support and assistance.

NPS photo by Robert Winfree

Figure 7. Grizzlies roam throughout Denali Park; private vehicles are allowed only on the first few miles of the park road. Options beyond that are to travel by bus, bicycle, or on foot.

REFERENCES

Anderson, L., R. Manning, W. Valliere, and J. Hallo. 2010. Normative standards for wildlife viewing in parks and protected areas. *Human Dimensions of Wildlife* 15(1):1-15.

Beck, L., and T. Cable. 2011. *The Gifts of Interpretation.* Champaign, IL: Sagamore.

Byrne, B. 2008. *Structural equation modeling using EQS.* New York: Psychology Press.

Center for Research on Environmental Decisions. 2009. *The Psychology of Climate Change Communication: A Guide for Scientists, Journalists, Educators, Political Aides, and the Interested Public.* New York: Center for Research on Environmental Decisions.

Jacobson, S. 1999. *Communication skills for conservation professionals.* Washington: Island Press.

Manning, R. 2011. *Studies in Outdoor Recreation: Search and Research for Satisfaction.* Corvallis, OR: Oregon State University Press.

Manfredo, M. 2008. *Who cares about wildlife: Social science concepts for exploring human-wildlife relationships and conservation issues.* New York: Springer.

Skibins, J., J. Hallo, J. Sharp, and R. Manning. 2012. Quantifying the role of the Denali “Big 5” in visitor satisfaction and awareness: conservation implications for flagship recognition and resource management. *Human Dimensions of Wildlife* 17(2):112-128.

Skibins, J., R. Powell, and J. Hallo. 2013. Charisma and conservation: Charismatic megafauna’s influence on safari and zoo tourists’ pro-conservation behaviors. *Biodiversity and Conservation* 22(4):959-982.

Wu, J. 2012. *Advances in K-means Clustering.* New York: Springer.

Zinn, H., M. Manfredo, and D. Decker. 2008. Human conditioning to wildlife: steps toward theory and research. *Human Dimensions of Wildlife* 13(6):388–399.

Alaska Park Science

National Park Service
Alaska Regional Office
240 West 5th Avenue
Anchorage, Alaska 99501

www.nps.gov/akso/AKParkScience/akparkarchives.html

Photo by D. Klein

Murres