Appendices

Appendix 1

Terrestrial Ecosystems Scoping Workshop Notebook

Dear Colleague,

Thank you for agreeing to participate in the Arctic Network (ARCN) Terrestrial Ecosystems Scoping Meeting for the NPS Inventory and Monitoring Program. This is the third ARCN scoping meeting in a series of four, and we have developed a workshop process that works well. I use this cover letter to orient you to this process. Again, thanks for your interest and I look forward to seeing you!

Using yours and others' expertise in a series of small working group sessions, the overall objectives of the meeting are to: (1) develop a comprehensive list of potential monitoring questions; (2) identify potential ecosystem attributes ("vital signs"); and (3) determine possible measures of those "vital signs." This workshop is designed to help NPS staff design a statistically sound, ecologically based, management relevant, and affordable monitoring program to inform us over the next 20 to 60 years. For example, monitoring questions from the Coastal Ecosystems Scoping Workshop included such specific questions as: How are nutrients cycled in lagoon systems in the Arctic Coastal Parks? Are nutrient levels changing? (With nitrogen and phosphorus as the relevant vital signs.) What are the sources and levels of contaminates in lagoon systems in the Arctic Coastal Parks? (With trace element and persistent organic pollutant loads in water, air and benthic and pelagic organisms as the vital signs.)

We will spend the first afternoon and following morning in a large group gaining background on the specific ecosystem components (e.g., birds, soils, vegetation) as well as some "drivers" that impact them (e.g., climate, fire, visitor impacts, adjacent North Slope development). On this day, we'll also get as clear as we can about the workshop agenda and the terminology we'll be using, both of which, I assure you, allow some flexibility.

Just prior to lunch on the second day, we'll start with presentations and some discussion of proposed ecosystem and potential stressor models. Then, divided into small groups of 8 to 12, you are asked to comment on, revise or replace these models as needed for thoroughness, accuracy, descriptive quality, etc.

On the final day, in small groups and with the terrestrial ecosystem models in mind, you are asked to develop monitoring questions and propose some "vital signs". Each small group will have an assistant entering the questions into a database, the report from which will help each group share its results with the larger group. In the second small-group work session of this day, having heard everyone else's proposed monitoring questions, you are asked to identify your group's highest priority questions—what we absolutely *must* know over the coming five or six decades to understand what's happening to the parks' terrestrial ecosystems.

By the end of the third day, we'll be plenty tired *and* we should have a comprehensive list of monitoring questions, as well as a good idea of what to measure in order to answer them. This workshop process is laid out graphically on page 10 of this notebook.

Remember, this is only an overview. Many questions remain. What makes a particularly good monitoring question? Should we consider sampling size and cost? Do we care only about those changes to ecosystems that we can *do* something about—the "management relevance" question. We'll have some time to get as clear as possible, though I'm sure debate on how best to do this will continue throughout the three days. It's quite an undertaking, so, again, thank you so much. It should be fun!

For background information about the Arctic Network of parks, see the network web site at http://www1.nature.nps.gov/im/units/arcn/index.cfm. The website for the workshop itself is at http://www1.nature.nps.gov/im/units/arcn/temp/terrestrial_workshop/.

Sincerely,

Diane Sanzone
Arctic Network Coordinator

TERRESTRIAL ECOSYSTEMS MONITORING SCOPING WORKSHOP

Arctic Network, National Park Service

Purpose of the Workshop

The purpose of this workshop is to provide a forum for NPS resource managers and scientists to discuss ideas for building a statistically sound, ecologically based, management-relevant, and affordable monitoring program for the Arctic Network (ARCN) of parks. The information gleaned from this Terrestrial Ecosystems Workshop will be used to form the basis for drafting a long-term monitoring plan for the Arctic Network. All sections of this notebook are in draft form and will be revised after input from participants is received.

Objectives for the Scoping Workshop

1. Create conceptual ecosystem models and determine general monitoring framework
2. Develop working groups' highest priority candidate questions for terrestrial ecosystem monitoring
3. Identify potential attributes ("vital signs") for highest priority monitoring questions

Terrestrestrial Ecosystems Monitoring Scoping Workshop

April 26–28, 2005
Fairbanks, Alaska–Westmark Hotel

Preliminary Agenda

Tuesday, 26 April

Objectives for Day One

1. Gain familiarity with ARCN monitoring goals
2. Overview of terrestrial ecosystems of Arctic Network
3. Overview of the workshop

Arctic Network
Terrestrial Ecosystems Monitoring
Scoping Workshop

Wednesday, 27 April

Objectives for Day Two

1. Gain familiarity with terrestrial ecosystems of the Arctic
2. Create conceptual models for terrestrial-influenced ecosystems

8:00 Arrival and Continental Breakfast

8:30: Continuing Presentations by Guests (20 minutes each with questions)

- Monitoring bird populations and predicting effects of anthropogenic change in the Arctic National Wildlife Refuge: David Payer
- Using remote sensing to assess large scale habitat quality for ungulates: Brad Griffith
- Top down effects of large mammals on ecosystems: Dave Klein
- A Changing Arctic: The Past and Possible Future: Marc Stieglitz
- Contributions of Local Communities to Ecosystem Monitoring: Gary Kofinas

10:10 —BREAK—

10:30 Continuing Presentations by Guests (20 minutes each with questions)

- North Slope Development: Harry Bader
- Arctic Contaminates: Linda Hasselbach (by phone)

11:10 Conceptual Models from previous workshops: Torre Jorgenson

11:40 Draft Terrestrial Conceptual Models: Diane Sanzone

12:00 Overall sample design for monitoring (an example from SWAN): Bill Thompson

12:30 —LUNCH—

1:30 Reconvene Together for Instructions to Working Groups for Day

1:45 Working Groups: Each working group will revise the draft conceptual ecosystem models. Each group can revise the model(s) as much or as little as they see fit. Creation of additional ecosystem models is encouraged. A leader for each group must report back to the larger group on revised or new model(s). Laptops, large sheets of paper, and overhead copies of the models will be available for this purpose.

3:45 —BREAK—

4:00 Reports from working groups on revised conceptual ecosystem models (15 minutes per group, with questions)

5:00 RECESS

6:00 Meet at Pike's for dinner. Host: Jim Lawler

Arctic Network
Terrestrial Ecosystems Monitoring
Scoping Workshop

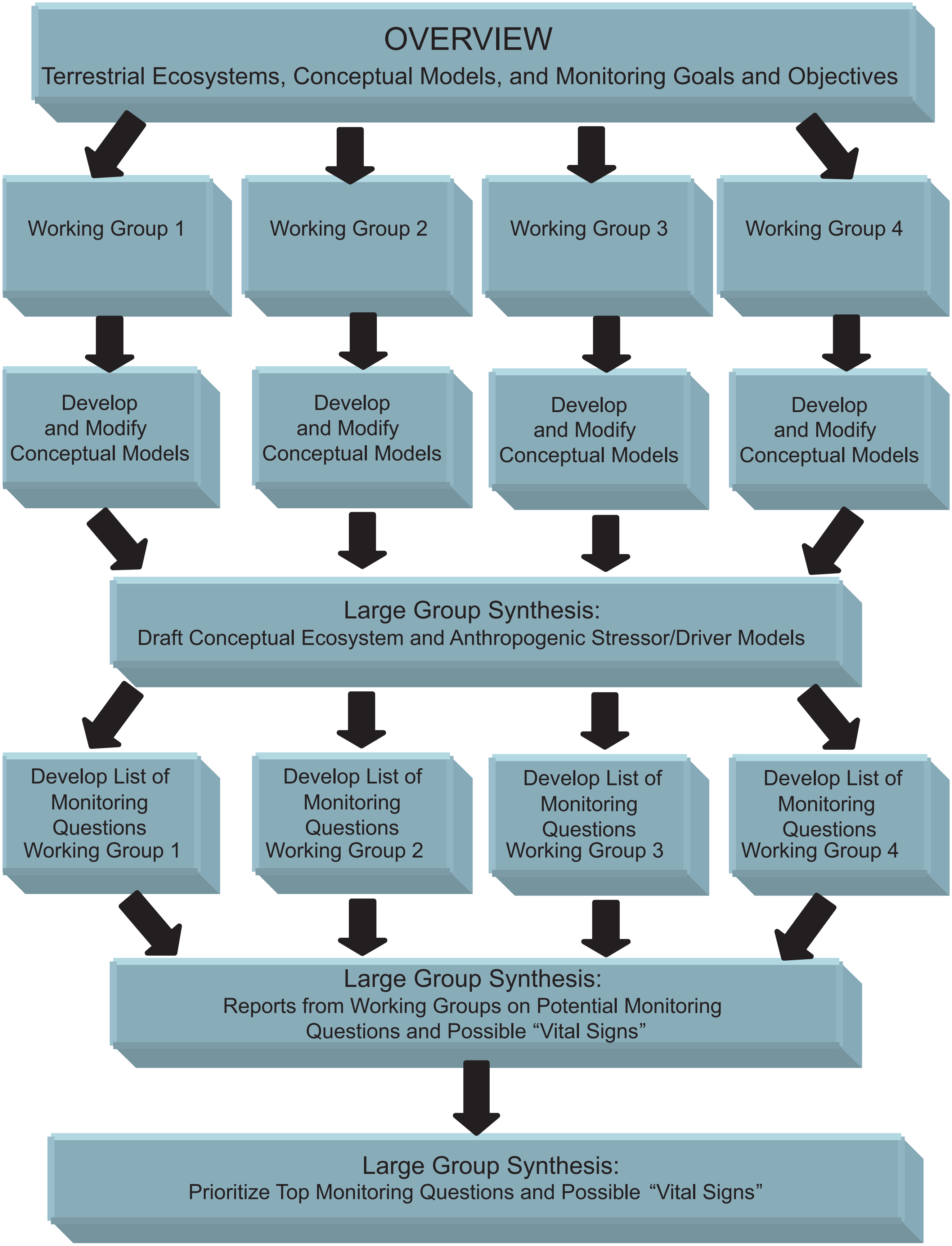
Thursday, 28 April

Objectives for Day Three

1. Identify potential monitoring questions for terrestrial-influenced ecosystems
2. Develop list of priority monitoring questions for terrestrial-influenced ecosystems
3. Identify possible attributes (“vital signs”) for monitoring terrestrial-influenced ecosystems

8:00	Arrival and Continental Breakfast
8:30	Review Agenda and Instructions to Working Groups: April Crosby and Scott Miller
8:45	Working Groups: Each working group will develop a comprehensive list of potential monitoring questions, organized by sections on the electronic worksheet provided. A recorder for each group must type the questions into the worksheet on the laptop, and a working group member must be prepared to review questions with the whole group.
10:45	—BREAK—
11:15	Reports from working groups on potential monitoring questions for each ecosystem (15 minutes for each group, with questions)
12:15	Large Group Discussion: Are we missing anything?
12:30	—LUNCH—
1:30	Reconvene in Working Groups: Develop from the list of monitoring questions the five highest priority candidates for monitoring and an exhaustive list of potential “vital signs” for each of them.
2:30	—BREAK—
2:50	Reports from working groups on priority monitoring questions and a list of potential vital signs (15 minutes for each group, with questions)
3:50	Large Group Discussion: The whole group will identify the highest priority monitoring questions and possible “vital signs” for monitoring.
4:50	Final and summary thoughts from workshop participants for Diane and the Technical Committee as they go forward in designing the monitoring program.
5:15	Adjourn

Flowchart of Workshop Strategy



Name: ______________________________

Worksheet A (Please Complete Before the Workshop)

1. Please state any initial thoughts and/or comments about the general monitoring strategy we have laid out in this notebook.

2. Please comment on our draft conceptual models.

3. Terrestrial Ecosystems of the Arctic Network:
    a. Please provide examples of key ecosystem components or processes important to arctic terrestrial ecosystems from your field of expertise.
    b. Please list the major anthropogenic stressors for each of the above ecosystem components or processes.
    c. Please think about what key ecosystem components or processes you might monitor to study the effects of the above stressors and how.

Name: ______________________________

Worksheet B (Day 2)
Working Group Session I

Conceptual Ecosystem Models

Session instructions: Each working group will revise draft conceptual ecosystem models. Each group can revise the model(s) as much or as little as they see fit. Creation of additional ecosystem models is encouraged. Use this space to capture your ideas.

Name: ______________________________

Worksheet C (Day 3)
Comprehensive List of Potential Monitoring Questions

Session instructions: The goal of this working group session is to create a comprehensive list of possible monitoring questions/objectives for each area of interest.

You have each been given copies of our initial anthropogenic stressor models. By now you should have a good understanding of some of the natural resources in the five parks and the enabling legislation that was important in creating them. We hope you have also had time to think about key stressors important to arctic coastal ecosystems, and more specifically, to the parks.

You are divided into working groups by subject area expertise. Your group's list of questions should identify those ecosystem attributes that, when studied, provide reliable signals regarding the condition of the ecosystem.

We have prepared a spreadsheet on the laptop that includes the following subsections to help your group develop questions:

1. Working group designation: (1) biogeochemistry, (2) biodiversity, (3) landcover/land change, and (4) migratory and invasive species

2. List of potential monitoring questions

3. Key ecosystem attributes ("vital signs") to address the above questions

4. List of major anthropogenic stressors affecting each of the above ecosystem attributes (an attribute can be a component or process)

Name: ____________________

Worksheet D
Use Your Ecological Knowledge to Win Big Prizes!

We need your help! The Arctic Network is currently compiling a knowledge base of research done in the arctic parks through a process called "data mining." The job is big and we can't do it alone. To encourage your participation, **we are offering prizes** (see below)!

We have exhaustively searched all research databases and assembled a bibliography of thousands of publications. Now we need help determining which datasets are the most essential for understanding arctic ecosystems.

Participants for this workshop were chosen not only for their knowledge of the arctic ecosystem but also their familiarity with the vast body af arctic literature and datasets. With this in mind, please answer the following questions for your area of expertise:

What are the seminal publications related to the arctic parks?

What datasets do you rely on, time after time, in your arctic research?

Are there high quality datasets that you know of—regardless of age, condition, and whether they are published or not—that we should pursue and potentially enhance?
(Continue on the reverse side, if you need to.)

We are interested in long-term or wide spatial-scale projects, especally those that can be revisited and remeasured, but any information that you can provide about any dataset will be greatly appreciated.

Prizes will be given out the last day of the workshop!

If you fill in your contact information and drop this sheet in the collection bucket provided in the conference room, **you could win big prizes!**

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Cathy Cahill	Dave Klein	Bill Manley	Enoch Shiedt
Knut Kielland	Kyle Joly	Harry Bader	Paul Matheus
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Amy Larsen (database)	Peter Neitlich (facilitation)	Scott Miller (database)	Chris McKee (database)
	Lois Dalle-Molle (database)		

National Framework for the Inventory and Monitoring Program of the National Park Service

The funding for this workshop comes from the Inventory and Monitoring (I&M) Program of the National Park Service (NPS). Established in 1992, the purpose of the I&M Program is to "develop scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems." In order to accomplish this mission the I&M program set out to: (1) provide a consistent database of information about our natural resources, including species diversity, distribution, and abundance (12 basic inventories); and (2) determine the current condition of our resources and how they are changing over time.

Vital Signs Monitoring

The I&M Program is vital to fulfilling the NPS's mission of protecting and preserving the natural resources of the national park system unimpaired for the use and enjoyment of current and future generations. The National Park Service Organic Act of 1916 clearly states that NPS lands will be managed:

> *to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as to conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.*

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the national park system. The act charges the secretary of the interior to: "continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System," and to "assure the full and proper utilization of the results of scientific studies for park management decisions."

The lack of scientific information about resources under NPS stewardship has been widely acknowledged as inconsistent with NPS goals and standards. In 1992, the National Academy of Science recommended that, "if this agency is to meet the scientific and resource management challenges of the twenty-first century, a fundamental metamorphosis must occur."

Congress reinforced this message in the text of the FY 2000 Appropriations Bill:

> *The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data.*

The nationwide Natural Resource Challenge program was put in place to revitalize and expand the natural resource program of the National Park Service. This effort increased funding to the I&M Program to facilitate improved baseline and long-term trend data for NPS natural resources. To efficiently and fairly use the funding available for inventories and monitoring, the 270 National Park Service units with significant natural resources managed by the service were organized into 32 biome based networks (Figure 1). Four networks were established in Alaska, clustering park units that share similar ecosystems and mandates (Figure 2). These networks have been designed to share expertise and infrastructure for both biological inventories and development of long-term ecological monitoring programs. The ARCN is the northernmost and westernmost unit in Alaska.

In order for this program to be highly accessible and useful to park managers, each network was advised to establish a board of directors and technical advisory committee to help plan and implement the monitoring program (Figure 3). The ARCN board of directors consists of three superintendents representing the park units, the Alaska regional Inventory and Monitoring (I&M) coordinator, the ARCN I&M coordinator, and the Alaska regional science advisor. The nine-member technical committee consists of the chiefs of resource management from each park unit, two natural resource scientists from each park unit, the ARCN I&M coordinator (chair), the Alaska Region I&M coordinator, and a USGS-Alaska Science Center liaison. Consultation with scientific experts and peer review are also encouraged in the development of this program.

Figure 1. National map of inventory and monitoring networks, including the four Alaskan networks.

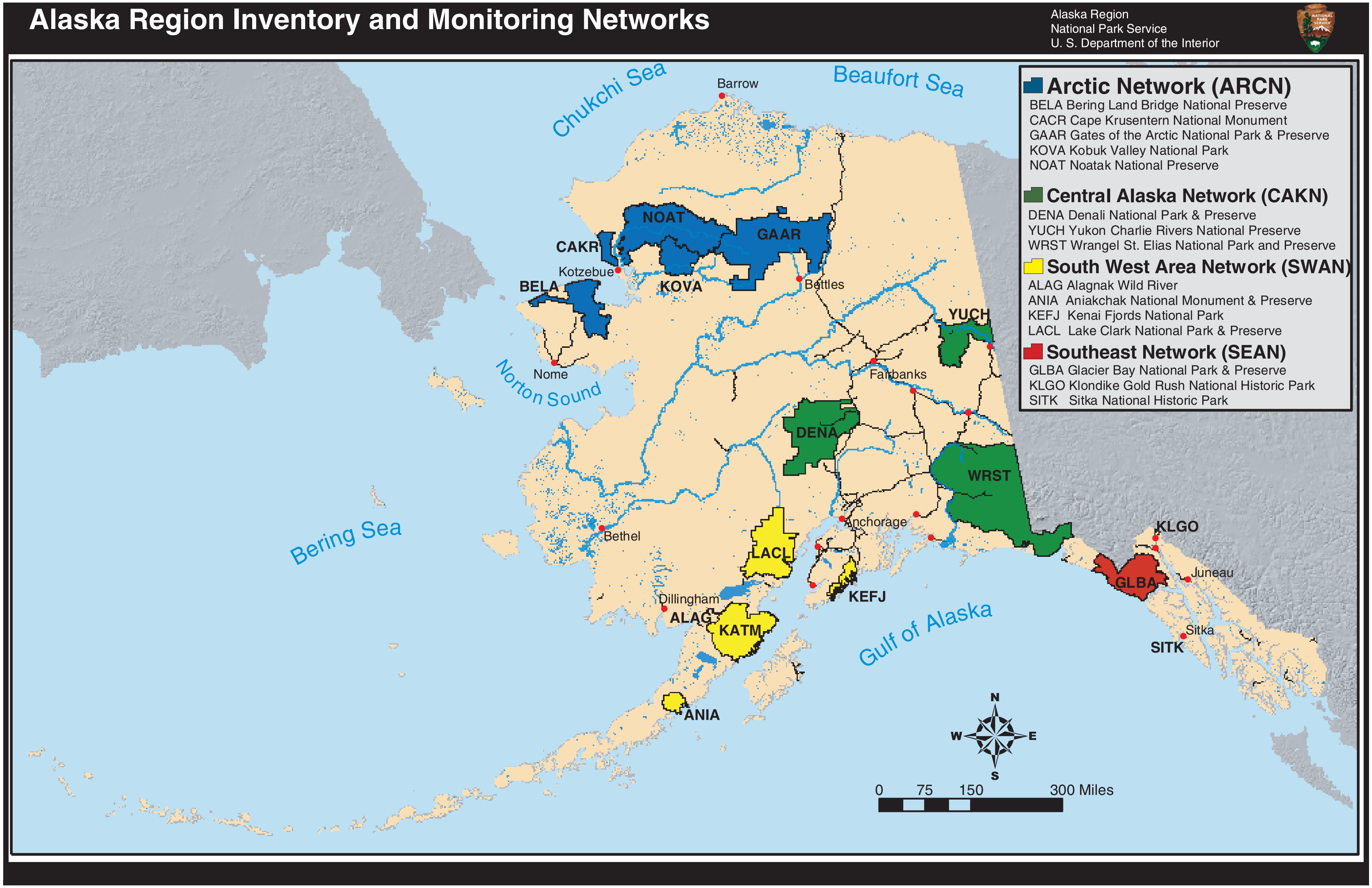

Figure 2. Alaska Region I&M networks

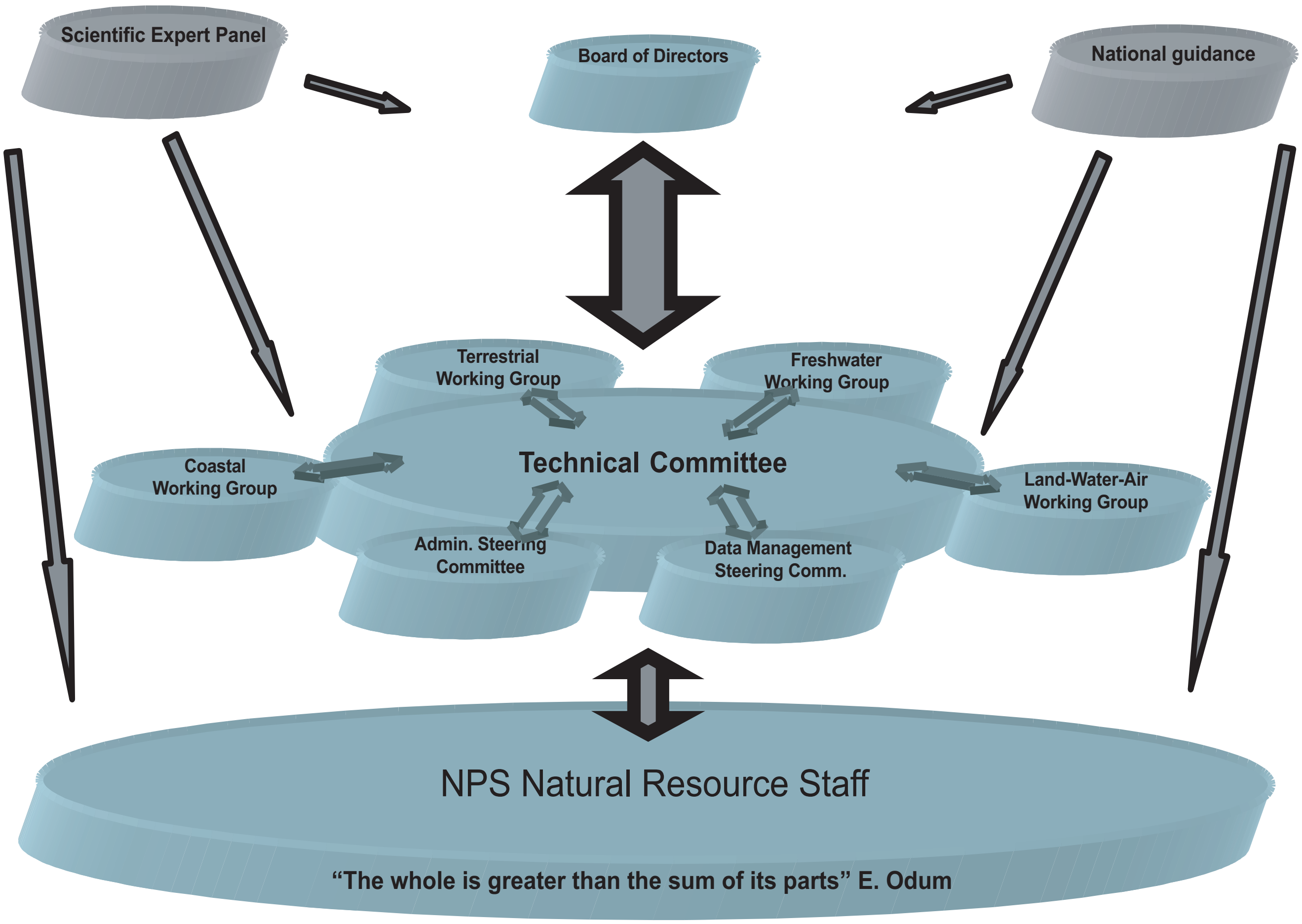

Figure 3. *ARCN network structure and function*

The Arctic Network

The Arctic Network (ARCN) includes five NPS system units (Figure 4):

- Bering Land Bridge National Preserve (BELA),
- Cape Krusenstern National Monument (CAKR),
- Gates of the Arctic National Park and Preserve (GAAR),
- Kobuk Valley National Park (KOVA), and
- Noatak National Preserve (NOAT).

Collectively these units represent approximately 19 million acres, or roughly 25% of the land area of NPS-managed units in the United States. GAAR, KOVA, and NOAT are contiguous and encompass a large expanse of mostly mountainous arctic ecosystems at the northern limit of treeline. Immediately to the west of these units lie CAKR and BELA, which border Kotzebue Sound, the Bering Strait, and the Chukchi Sea. BELA and CAKR are similar with respect to their coastal resources and strong biogeographic affinities to the Beringian subcontinent—the former land bridge between North America and Asia. The ARCN park units are not connected to the road system. Much of the ARCN is designated or proposed wilderness.

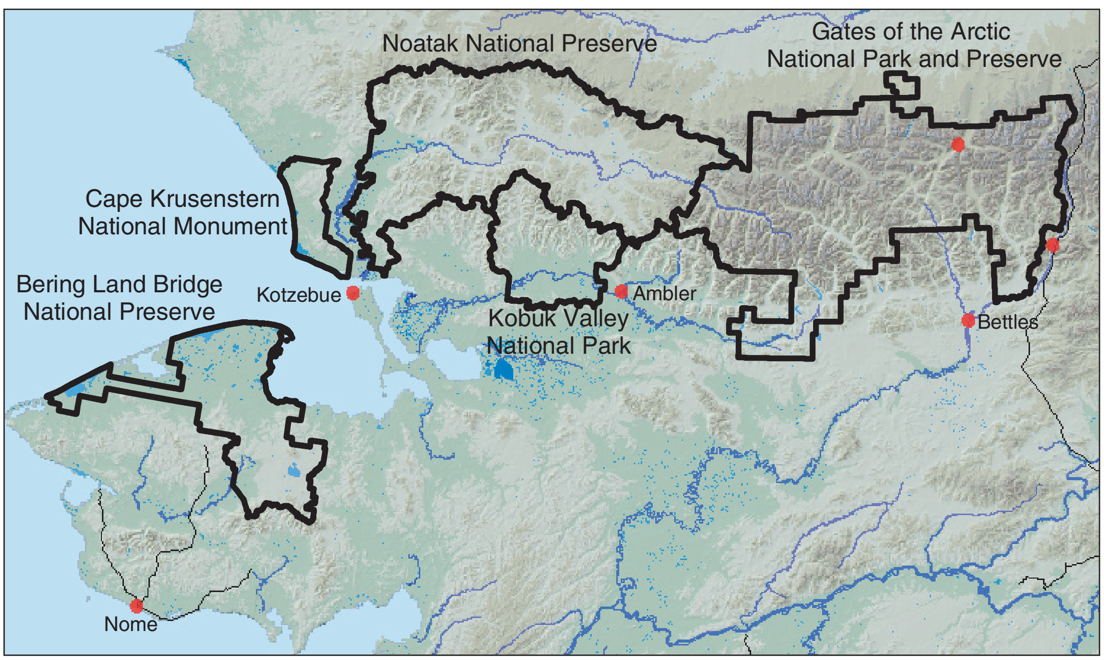

Figure 4: *Arctic Network (ARCN) of the National Park Service's I&M Program*

All of the NPS units within the ARCN parks are relatively recent additions to the National Park System. Portions of BELA, CAKR, and GAAR were initially created by presidential proclamation in 1978. All five units were redesignated or created with their present boundaries by the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. The recent origin of these remote and difficult-to-access units, coupled with limited natural resource staffing levels, has left the natural resources in these units relatively unstudied.

Terrestrial Ecosystems of ARCN

The ARCN parks contain a broad array of the ecosystems typical of the subarctic (boreal forest or taiga), and arctic (tundra) biomes of northwestern North America. The boundary, or ecotone between these two biomes is also represented in many different phases. Because these parks encompass large areas of mountainous terrain, including a major portion of the Brooks Range, they also include examples of virtually every type of alpine situation to be found in northern Alaska.

The nature of boreal and arctic ecosystems is often profoundly influenced by climate, especially whether and to what degree the climate is maritime or continental. The climate of the ARCN parks varies from the extreme continentality of interior Alaska to the more maritime coastal areas of the parks bordering the Chukchi Sea. This maritime climate is, however, somewhat modified by the presence of pack ice, which minimizes the moderating effect of the sea during the six to nine months it is present. Thus winters, even in coastal areas, are intensely cold and have relatively moderate precipitation and snow cover.

Overview of Terrestrial Vegetation

As is discussed in the following section ("The Biomes"), the most conspicuous feature of the vegetation in northwestern Alaska is the treeline, or northward or coastward limit of conifer forest. The forest reaches its northwesternmost limit in North America in the vicinity of the eastern border of Cape Krusenstern and the western edge of the Noatak Preserve (Young 1974) but treeline forms a complex and convoluted boundary through much of the three more eastern parks. A number of other organisms have ranges strongly associated with the presence of conifers: red squirrels, porcupines, certain typically understory plants, some tree-nesting birds, and some epiphytic lichens are examples. Overall, though, the presence or absence of conifer forest has relatively little effect on the composition of the vegetation and, especially, the flora (Young 1989).

Vascular Plants

Western and northwestern Alaska has long been recognized as having the richest array of vascular plants of any region in the circumpolar north (Hulten, 1937, 1968). This is due to a number of factors, the most important of which are as follows. First, the area was never totally glaciated during the later Pleistocene. This means that populations of many species of plants were presumably able to survive *in situ* throughout the period that most of the rest of northern North America was repeatedly glaciated (e.g., Hopkins et al. 1982). It also means that soil formation and various geological process that result in stable substrates have been going on uninterrupted for very long times in comparison to other North American areas, which have often been scoured to bare rock within the past 10,000 to 12,000 years. A second important factor is the location of the area at a place where many of the major mountain ranges of the world converge. The Brooks Range extends thousands of kilometers southward into North America, while similar connected mountain ranges extend deep into central Asia. Thus, the Beringian region has probably long served as a "staging area" for alpine plants that are slowly colonizing the Arctic (Young 1971). Finally, the complex local topography and history of local glacial advance and retreat have created great variety in local habitats in terms of substrate, soils, microclimates, and disturbance.

There is currently little agreement or understanding of the responses of vascular plant vegetation to changing conditions, although this field is developing rapidly (e.g., Bradley 1999). Treeline and its advances and possible retreats has been an area of major interest since the mid-20th century, but the processes that influence the spread or retraction of the ranges of conifers are complex enough, and long-term enough, that the documentation and interpretation of changing treeline is still in its early stages. Much recent research deals with changes in the nutrient regimes and the stability of various tundra plant communities, and this line of investigation is very promising in terms of developing a theoretical framework and set of protocols for monitoring tundra ecosystems and interpreting their response to changing environmental factors (Chapin et al. 2000, Mack et al. 2004).

In terms of local areas of rare or unusual species and communities of vascular plants, there are many examples known and undoubtedly many more to be discovered. An example would be the extensive serpentine barrens in the vicinity of Feniak Lake, in the middle Noatak Drainage. This area actually contains a great variety of sub-sites with their individual and unique array of plants. It is, of course, important to identify and protect these unusual situations, but their usefulness in determining the overall health of the environment is not entirely clear.

Nonvascular Plants

Lichens and bryophytes are a conspicuous and ecologically important element in Alaska's arctic parks. Nonvascular plants are likely to represent 75 to 80% of ARCN's flora (Neitlich and Hasselbach 1998, NPFlora 1989). In many cover types, these plants constitute a co-dominant portion of the biomass (Viereck et al. 1992, Swanson et al. 1985) and account for a significant amount of cover in NPS's satellite imagery-based landcover maps (Markon and Wesser 1997, Markon and Wesser 1998, Swanson et al. 1985) and vegetation classifications (TNC 1999, Viereck et al. 1992). Because of their fragility, ecological importance as forage, and high sensitivity to impacts from pollution (Pegau 1968, Nash 1988), the inventory and monitoring of lichens and bryophytes is a priority statewide.

Key among the ecological roles of Alaskan arctic lichens and bryophytes are forage, nesting materials or direct shelter, nitrogen fixation, and primary productivity. Lichens serve as a major food source for many small and large mammals, including muskoxen, Dall's sheep, and ground squirrels (Sharnoff and Rosentreter 1998). An adult caribou typically consumes 5–6 kg/day of lichens during winter (Boertje 1984). Lichen consumers represent a major prey base for several top predators (e.g., wolves, bears and owls). Lichens represent an exclusive food source for large numbers of arthropods (Gerson 1973), and contribute a small but significant quantity of fixed nitrogen to the region's nutrient-poor, low-productivity ecosystems (Gunther 1989).

Lichens are extremely fragile, slow-growing, and sensitive to air pollution (Richardson 1992). Different lichen species grow between 0.1 mm to about 5 mm per year. Because of slow growth and poor dispersal ability by lichens, attainment of late-successional terrestrial or epiphytic lichen communities can take up to 250 years in boreal and arctic environments (Black and Bliss 1978, Christiansen 1988). Lichens rely entirely on atmospheric inputs of water and nutrients for growth and have evolved to uptake atmospheric inputs readily without barriers of specialized tissue. Because of this, they are extremely susceptible to injury by S and N-based pollutants and acidification (Richardson 1992, McCune 1988). For this same reason, they are also reliable as passive monitors of contaminant accumulation via elemental analysis of tissue (Ford and Vlasova 1996).

Birds of the Arctic Network

Most birds found in the ARCN are summer nesters or migrants, with only about a dozen species overwintering within the network. There is evidence supporting the presence of a total of 177 bird species in the Arctic Network, with individual parks containing between 114 and 132 species (Appendix 2), and as many as 12 to 26 species that have yet to be documented in one or more of the parks (NPSpecies 2004). A certified species list with citations will be available in the spring of 2005, following the completion of final reports of the bird inventory efforts and the quality assurance/quality control process for the NPSpecies database.

Prior to current efforts, the ARCN was largely unsurveyed, leaving a gap in our knowledge of the breeding distribution and habitat requirements of many migrant and resident bird species. Fieldwork for a three-year montane-nesting bird inventory of the network was completed in 2003, with data analysis and final report compilation occurring in 2005. In addition, I&M and the Park Flight Program recently provided support for bird inventories within GAAR for a three-year landbird inventory scheduled for completion in 2005.

The northwest Alaska region provides important bird habitat because it is a major breeding area for migratory birds from as far away as Antarctica. This region encompasses a zone of interchange between the flyways of Asia and North America, and it includes important transitional habitat areas between boreal forest, coastal lands, and tundra.

More than 25 species of waterfowl inhabit the network's wetland areas. All four loon species are found in the Noatak drainage. The lagoons between Cape Krusenstern and Sheshalik are heavily used by migrating waterbirds. This area is also an important subsistence hunting area for waterfowl and as an egg gathering area. It is an important fall staging area for thousands of geese, ducks, shorebirds, and gulls. Prime waterfowl nesting areas also occur in the extensive wet lowlands in the Kobuk Valley. In BELA and CAKR, the marine/estuarine habitat, together with extensive freshwater ponds and lakes, provides resting, nesting, feeding, and molting grounds for large populations of migrating geese, ducks, and shorebirds. The salty grasslands and marshes at the mouths of the Nugnugaluktuk, Pish, and Goodhope rivers and Cape Espenberg are especially important for waterfowl adapted to estuarine conditions.

Raptors find important habitat within the Noatak drainage. Thirteen species of raptors are known in the preserve, and GAAR provides montane nesting habitat for numerous species with breeding ranges limited to Alaska, such as the surfbird and Smith's longspur (Tibbitts et al. 2003).

Of special interest among the remaining birdlife are several Asian species that have extended their ranges into North America along the Bering Land Bridge corridor. These include the wheatear, yellow wagtail, white wagtail, bluethroat, and arctic warbler (Young 1974).

Mammals of the Arctic Network

Approximately 42 species of terrestrial mammals are believed to occur within the boundaries of the Arctic Network park units (Appendix 1), ranging in size from the tiny shrew (*Sorex yukonicus*) to brown bears (*Ursus arctos*) and moose (*Alces alces*). A certified species list with citations will be available in spring 2005, following the completion of final reports of the mammal inventory efforts and the quality assurance/quality control process for the NPSpecies database.

Many arctic mammal populations, such as lynx (*Lynx canadensis*), snowshoe hare (*Lepus americanus*), caribou (*Rangifer tarandus*), and lemmings (*Dicrostonyx* spp. and *Lemmus* spp.), are characterized by local, seasonal, or cyclic abundance. Distribution and abundance data are almost nonexistent except for animals hunted for subsistence.

Distributions of arctic mammals are changing within historic times, such as the expansion of moose into the western Brooks Range within the last 70 years (Coady 1980), the extirpation of muskoxen in the mid 19th century and their subsequent reintroduction during the 1970s (Lent 1999). Other species that have recently expanded their ranges north and west into one or more of the arctic park units include beaver and coyotes. Other large changes in populations include the 50-70% decline in the GAAR sheep population in the late 1980s, the 70% decline in moose on the drainages on the north side of the Brooks Range in the early 1990s and the six-fold increase in the Western Arctic caribou herd during the last 25 years (75,000 animals in 1976 to 450,000 in 1999).

Ecological and distributional information about arctic mammals is scant compared to that of parks in the contiguous U.S., where small changes in species' ranges are being tracked at a fine scale as species move north and up in altitude, in a possible response to global climate change (Burns et al. 2003). Recent I&M field inventories have demonstrated the paucity of knowledge of even the presence of the few species in the Arctic by providing vouchers for 12 mammal species not previously documented in one or more of the ARCN parks. By park unit, the number of new mammal species documented during inventory fieldwork from 2001–2003 were GAAR, 5; NOAT, 2; KOVA, 8; BELA, 4; and CAKR, 6. Additional literature searches have located more obscure documentation of an additional 10 species that were not previously thought present in one or more of the ARCN parks. Overall, recent efforts have increased the number of mammal species known to be present in each of the ARCN parks by 19.

Some of the more notable species documented for the first time in one or more of the parks include: the tiny shrew (*Sorex yukonicus*) which was newly discovered in GAAR, KOVA, BELA, and CAKR; the pygmy shrew (*S. hoyi*) newly documented in KOVA and CAKR, resulting in a range extension of approximately 250 kilometers; the barren ground shrew (*S. ugyunak*) discovered in GAAR, BELA, CAKR, and NOAT (previously only documented on the North Slope, these new vouchers resulted in a range extension of 300 kilometers south); the taiga vole (*Microtus xanthognathus*), in KOVA and NOAT (new vouchers resulting in 150 kilometer range extension to the northwest); and the porcupine (*Erethizon dorsatum*) in GAAR of which few vouchers exist anywhere in the Brooks Range.

Among documented species, large data gaps and systematics issues remain. For example, very few vouchers exist for marmots in Alaska, especially in the Arctic, where it is thought there may be two separate species: the Alaskan marmot and hoary marmot (*Marmota broweri and M. caligata* respectively). Physical differences between these two species are so slight and understudied that no reliable published keys exist for identifying them. It is thought that the two species differ greatly in origin, with the Alaskan marmot being more closely related to Asian marmot species than to any North American marmot species (Olsen pers. comm.). A third species of marmot (*M. monax*), the woodchuck, has expanded its range from the Lower 48 as far north as Fairbanks during the previous decades. Additional Arctic and sub-Arctic species that are thought to occur in the park but for which no documentation exists include pika (*Ochotona collaris*), bats (*Myotis* spp.), and the tundra hare (*Lepus othus*). Species thought to be expanding their ranges to interior Alaska from Canada include mountain lions (*Felis concolor*) and mule deer (*Odocoileus hemionus*). Range information and monitoring is thought to be especially important for Alaskan species in light of the more dramatic climate changes predicted for the region and the "sky island" populations (as species ranges move up in altitude) that may result.

In addition to the terrestrial mammals, it is estimated that more than 13 species of marine mammals use the waters of the Chukchi Sea and Kotzebue Sound adjacent to Cape Krusenstern National Monument and Bering Land Bridge National Preserve. Both BELA and CAKR have mandates for the protection of marine mammal habitat (jurisdiction ends at the high-tide line). Polar bears and seals make dens or have haul-outs on the mainland, and many are frequently sighted in estuarine environments or small bays.

Records of Past Ecosystems and Events

The ARCN area contains exceptional opportunities for developing a picture of the events and processes that have resulted in the current array of ecosystems, both within the parks and preserves and in the circumpolar Arctic and boreal regions in general (c.f. Hopkins, et al. 1982, Elias and Brigham-Grette 2000). The evidence ranges from large physical features such as moraines and beach ridges, to long-term records of past environmental and climatic trends, such as sediments columns and animal fossils, to information derived from archaeological studies.

The importance of studies of this kind for our purposes is that they can establish a known trajectory for the direction and magnitude of ecosystem change and the processes that influence them over long periods of time. When information about the nature of the modern ecosystems and the processes occurring within them can be evaluated in relation to long-term environmental changes—or stability—this can greatly increase our ability to discern their significance.

The main reason for this unusual richness of potential paleoenvironmental data lies in the fact that much of the area was never glaciated during the Pleistocene and thus formed a part of unglaciated Beringia, as the eastern extension of the ancient Eurasian Arctic is often called. Other parts of ARCN were subject to only local glaciation, especially during the latter part of the Pleistocene. Additionally, some exceptional circumstances, such as the survival of ancient lake sediments at Immuruk Lake and the burial of ancient land surfaces under tephra, such as occurred on the northern Seward Peninsula, have created important opportunities for research.

The ARCN has been inhabited by humans for at least 12,000 to 13,000 years, and perhaps twice as long or even longer. There is abundant evidence for human activities for the past 4,000 to 5,000 years, and a major product of the study of these ancient cultures has been the accumulation of evidence for the nature of the environment in which these people lived. Archaeological studies are not only important in helping to document the role of prehistoric people in the local environment. They also often provide a rich source of data on aspects of the environment that are little affected by the presence of humans. For example, the spread of moose into northwestern Alaska in historic and late precontact times is largely known through the presence or absence of evidence for moose in well-documented archaeological sites throughout the area.

Literature Cited

Black, R. A., and R. C. Bliss. 1978. Recovery sequence of *Picea mariana-Vaccinium uliginosum* forests after burning near Inuvik, Northwest Territories, Canada. *Canadian Journal of Botany* 56: 2020–2030.

Boertje, R. D. 1984. Seasonal diets of the Denali caribou herd, Alaska. *Arctic* 37(2): 161–165.

Bradley, R. S. 1999: *Paleoclimatology—Reconstructing Climates of the Quaternary.* San Diego, Academic Press. 613 pp.

Burns, C.E., K. M. Johnston, and O. J. Schmitz. 2003. Global climate change and mammalian species diversity in U.S. national parks. *Proceedings of the National Academies of Science* 100: 11474–11477.

Chapin, F. S., E. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. Reynolds, D. U. Hooper, S. Lavorel, O. E. Sala, S. E. Hobbie, M. C. Mack, and S. Díaz. 2000. Consequences of changing biodiversity. *Nature* 405: 234–242.

Christiansen, J. S. 1988. A spruce-lichen woodland in northern Alaska: Post-fire regeneration and community dynamics. M.S. Thesis, University of Washington. Study Area: Walker Lake.

Coady, J. W. 1980. History of moose in northern Alaska and adjacent regions. *Canadian Field Naturalist* 94: 61–68.

Elias, S. A., and J. Brigham-Grette. 2000. Beringian paleoenvironments. *Quaternary Science Reviews.* Elsevier, London, 574 pp.

Ford, J., and T. Vlasova. 1996. Airborne contaminants in vegetation of arctic Alaska and Russia. Pp. 159–168 in R. Meehan, V. Sergienko, and G. Weller (eds.) *Bridges of Science Between North America and the Russian Far East.* Arctic Division, AAAS, Fairbanks, AK.

Gerson, U. 1973. Lichen-arthropod associations. *Lichenologist* 5: 434–443.

Gunther, A. J. 1989. Nitrogen fixation by lichens in a subarctic Alaskan watershed. *Bryologist* 92(2): 202–208.

Hopkins, D.A., J. V. Matthews, C. S. Schweger, and S. B. Young. 1982. *Paleoecology of Beringia.* New York, Academic Press. 489 pp.

Hulten, E. 1937. *Outline of the history of arctic and boreal biota during the Quaternary period.* Stockholm.

Hulten, E. 1968. *Flora of Alaska and Neighboring Territories.* Stanford. 1008 pp.

Lent, P. 1999. Alaska's indigenous muskoxen: A history. *Rangifer* 18: 3–4.

Mack, M. C., E. A. G. Schuur, M. S. Bret-Harte, G. R. Shaver, and F. S. Chapin III. 2004. Ecosystem carbon storage in arctic tundra reduced by long-term nutrient fertilization. *Nature* 431: 440–443.

Markon, C. J., and S. D. Wesser. 1997. The Bering Land Bridge National Preserve Land Cover Map and its comparability with 1995 field conditions. Open File Report 97-103. U.S. Geological Survey.

Markon, C. J., and S. D. Wesser. 1998. The Northwest Alaskan Parks Land Cover Map. Open File Report. U.S. Geological Survey.

McCune, B. 1988. Lichen communities along O_3 and SO_2 gradients in Indianapolis. *The Bryologist* 91: 223–228.

Nash, T. H., III, and V. Wirth (eds.) 1988. Lichens, bryophytes, and air quality. *Bibliotheca Lichenologica* No. 30. J. Cramer, Berlin-Stuttgart.

Neitlich, P.N., and L. M. Hasselbach. 1998. Lichen inventory and status assessment for Gates of the Arctic National Park, Alaska. NPS General Technical Report, Fairbanks, Alaska.

NPSFlora. 1989. Checklist of flora and fauna in collections of national park units in Alaska. U.S. Department of Interior, National Park Service, Alaska Regional Office, Anchorage, Alaska.

NPSpecies: The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/ (accessed September 2004).

Pegau, R. E. 1968. Growth rates of important reindeer forage lichens on the Seward Peninsula, Alaska. *Arctic* 21: 255–259.

Richardson, D. H. S. 1992. *Pollution Monitoring with Lichens.* Richmond Publishing, Slough.

Sharnoff, S., and R. Rosentreter. 1998. Wildlife uses of lichen in North America. On line: http://www.lichen.com/fauna.html.

Swanson, J. D., M. Schuman, and P. C. Scorup. 1985. Range survey of the Seward Peninsula Reindeer Ranges, Alaska. U.S. Department of Agriculture: Soil Conservation Service.

Tibbitts, T. L., D. Ruthrauff, R. E. Gill, and C. M. Handel. 2003. Inventory of montane-nesting birds in national parks of northwest Alaska: A summary of the 2001 and 2002 field efforts. U.S. Geol. Surv., Alaska Science Center, Anchorage, Alaska.

TNC (The Nature Conservancy). 1999. The National Vegetation Classification System. Online national vegetation classification at www.tnc.org (or) http://consci.tnc.org/library/pubs/class.

Viereck, L. A., Dyrness, C. T., Batten, A. R., and K. J. Wenzlick. 1992. The Alaska Vegetation Classification. U.S. Department of Agriculture: Forest Service. Pacific Northwest Research Station. General Technical Report PNW-GTR-286, July 1992.

Young, S. B. 1971. The vascular flora of St. Lawrence Island with special reference to floristic zonation in the arctic regions. *Contributions from the Gray Herbarium* 201: 11–115.

Young, Steven B. 1974. The environment of the Noatak River Basin, Alaska: Results of the Center for Northern Studies biological survey of the Noatak River Valley, 1973. Contributions from the Center for Northern Studies: Center for Northern Studies.

Young, S. B. 1989. *To the Arctic.* New York, John Wiley and Sons. 354 pp.

Overall Goals of the ARCN Monitoring Program

The overall goal of natural resource monitoring in the national parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems and to determine how well current management practices are sustaining those ecosystems.

NPS Vital Signs Monitoring Goals

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress towards performance goals.

In order to achieve the above goals, the Arctic Network is following the basic approach to designing a monitoring program laid out in the National Framework. The process involves five key steps:

1. Define the purpose and scope of the monitoring program.
2. Compile and summarize existing data and understanding of park ecosystems.
3. Develop conceptual models of relevant ecosystem components.
4. Select indicators and specific monitoring objectives for each.
5. Determine the appropriate sampling design and sampling protocols.

These five steps are incorporated into a three-phase planning process that has been established for the NPS monitoring program (Figure 5). Phase 1 involves defining goals and objectives; beginning the process of identifying, evaluating, and synthesizing existing data; developing draft conceptual models; and determining preliminary monitoring questions. Phase 2 involves refining the conceptual ecosystem models and selecting "vital signs" that will be used as indicators to detect change. Phase 3 of the planning process involves determining the overall sample design for monitoring, developing protocols for monitoring, and production of a data management plan for the network.

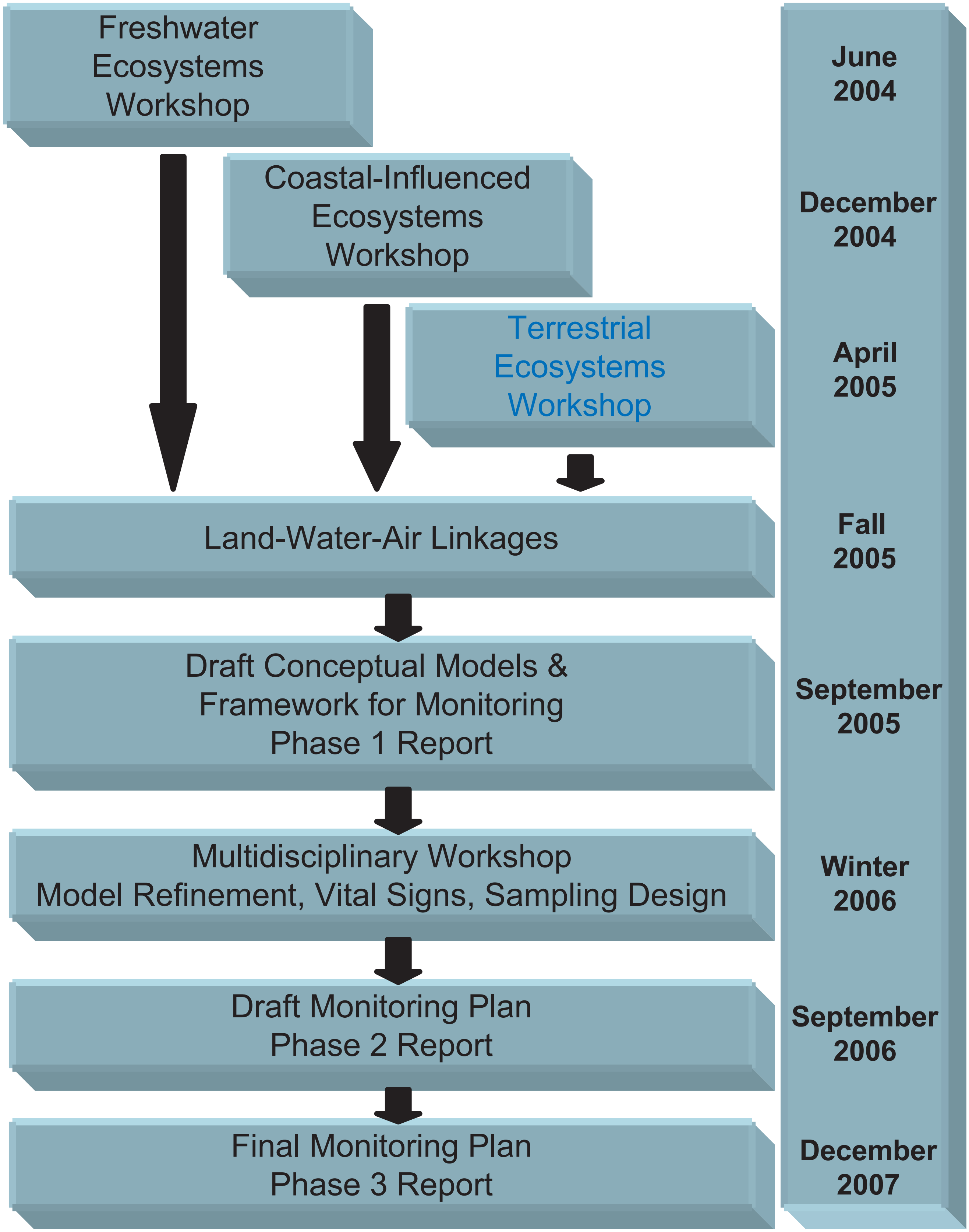

Figure 5. *Timeline for ARCN monitoring plan development.*

ARCN Draft Monitoring Objectives for Terrestrial Ecosystems

Objective 1: Collect baseline data on the physical, chemical, and biological parameters of tundra and boreal forests within the Arctic Network of Parklands.

Objective 2: Determine long-term trends in the physical, chemical, and biological characteristics of boreal and tundra ecosystems within the Arctic Network of Parklands.

Objective 3: Understand how landscape components interact at various spatial and temporal scales to affect terrestrial ecosystems.

Framework for Conceptual Model Development

The four scoping workshops planned for the Arctic Network (ARCN) are designed to gain expert advice from, and initiate longer term consultation with, a broad array of scientists who have performed or are familiar with ecological research in northern Alaska. The input from these meetings will be used to develop a set of conceptual models of the natural and anthropogenic features and processes of the enormous areas included in the parks. These, in turn, will lead to a detailed plan for monitoring critical aspects of the environment of the parks. It is expected that the data gathered in this program will contribute to responsible management of the parks so as to conserve their environmental integrity indefinitely. A valuable additional effect of this work should be to provide useful data and insights into the broader concerns of understanding and protection of the environment of the circumpolar north (Figure 6).

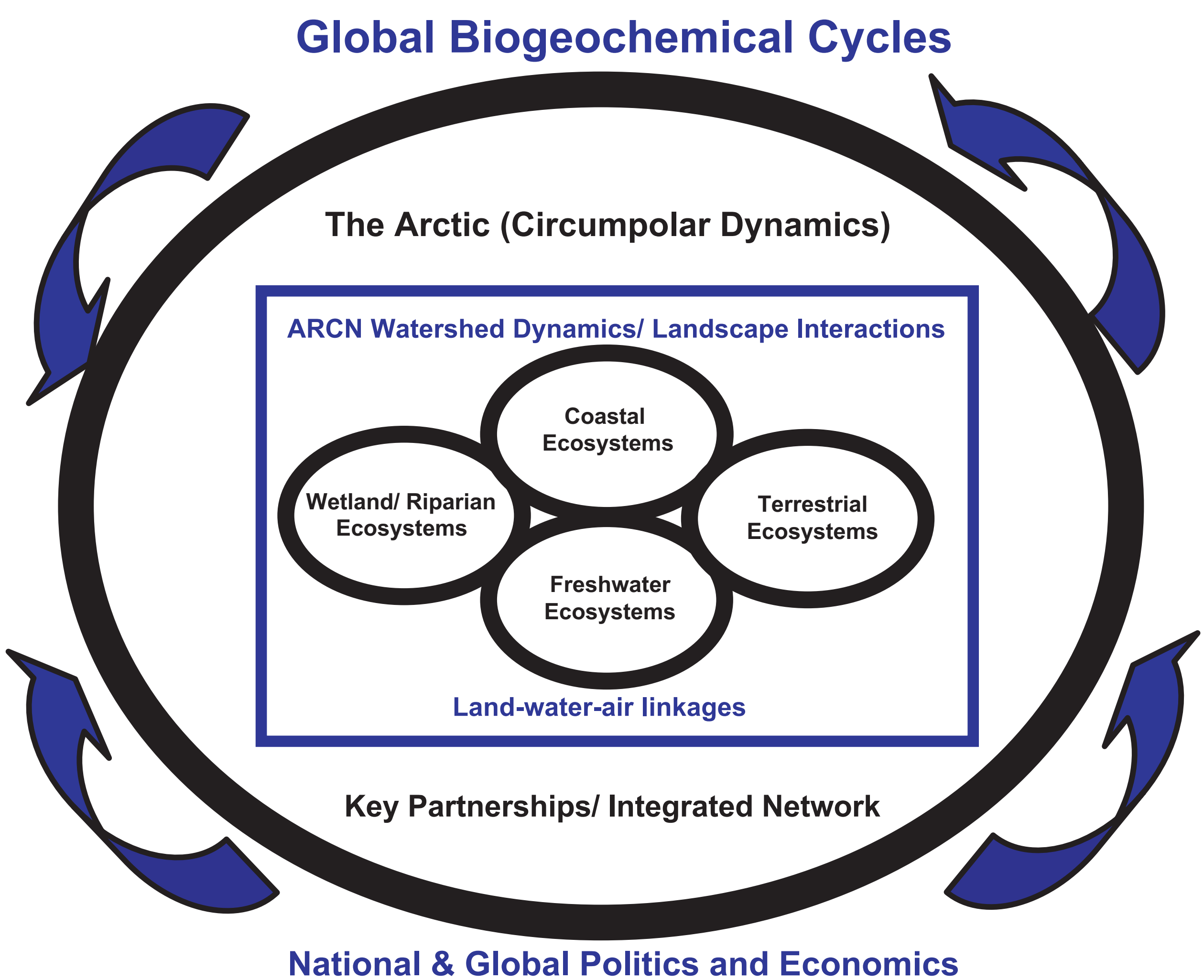

Figure 6. *Conceptual model showing how ARCN ecosystems fit within a national and global context.*

Long-term monitoring is increasingly recognized as an essential tool for understanding and managing environments at many levels of geographical scale and human use. Since monitoring is essentially a system of sampling, it requires knowledge and judgment on the part of the people who design and carry out the monitoring program. Thus, long-term monitoring is much more than the random gathering of data. Ideally, it is an evolving process that is guided by several concepts:

1. Efficiency: Monitoring must strive to get the maximum amount of useful information from a sampling system that is limited by factors such as cost, logistical concerns, and availability of trained personnel.
2. Relation to the broader world: Monitoring benefits from, and provides for, the exchange of useful information with comparable environments, even if they are being managed for different purposes, or have only minimal management programs/plans.
3. Flexibility: Monitoring plans must be able to incorporate new information and concepts and evolve with increased understanding of the ecosystems under study.
4. Scale: Monitoring deals with processes that take place over widely varying amounts of time and space. It must be designed to provide information on both local, often rapidly proceeding processes and those that occur over longer times and/or broader geographical areas.
5. Dynamism: Monitoring plans must recognize that ecosystems are never static, and that, even without anthropogenic impacts, complex changes will always be occurring.

The Biomes

The five western arctic parks, preserves, and monuments all straddle the circumpolar ecotone that has traditionally been considered to be the boundary between the Arctic (tundra) biome and the boreal forest (taiga) biome. The most obvious manifestation of this boundary is the treeline, or timberline. It has long been recognized that the presence or absence of trees in most northern environments is correlated with climate, most specifically temperatures during the growing season. Much recent work has underscored the complexity of the relationship between the distribution of forest and summer temperature. It is clear, for example, that white spruce, the dominant timberline tree species in much of North America, reacts differently to changing climate than does Siberian larch, the timberline tree of most of northeastern Russia, or the various birch species that define timberline in northern Europe, Iceland, and Greenland. While changes in the distribution of white spruce over time undoubtedly have relevance to the understanding of long-term climatic change and its effect on northern Alaska ecosystems, we need to be careful in making assumptions that the similar climatic factors will affect the distribution of tundra versus taiga ecosystems in other parts of the north.

The presence or absence of forest, although conspicuous, should not be overemphasized in discussions of what constitutes "arctic" versus "subarctic" ecosystems. Timberline is convoluted, often diffuse, and, on a local scale, clearly affected by nonclimatic factors such as drainage. Also, climatic factors may act indirectly, as in controlling the presence of permafrost with a shallow active layer, which in turn affects soil moisture and drainage. Also, while certain elements of the forested ecosystem are clearly associated with white spruce (e.g., red squirrels, certain bark beetles) many other organisms are not confined to one or the other ecosystem. For them, the traditional boundary between the Arctic and Subarctic is of little significance. We suggest that deemphasizing the traditional boundaries between arctic and boreal ecosystems in our region is appropriate when designing monitoring programs for our areas of interest. At the same time, we should recognize that changes in the distribution and abundance of many organisms, such as white spruce, in our study area may often be sensitive indicators of less visible changes in the environment.

A Conceptual Framework for Considering Climatic Change

It is generally accepted that global warming is occurring, and that it is especially evident in high latitude regions. While it is generally assumed that warming is a process that will continue into the foreseeable future, it is not inconceivable that cooling trends could develop. This is especially true over the very long (centuries or millennia) term, when orbital forcing or other factors could theoretically terminate the current interglacial. In the following model, we consider the potential effects of climatic cooling as well as warming. In the case of either warming or cooling trends in our study area, there are feedback mechanisms that suggest that some results of either process are counter-intuitive.

Scenarios based on regional warming or cooling trends that consider only annual means do not take into account changes in the seasonality that may occur. Increased seasonality, often associated with increased continentality, means, under a warming trend, warmer summers; decreased seasonality means warmer winters. Thus, a warming trend that involves increased winter temperature may increase precipitation, resulting in greater snowfall, delayed onset of the growing season, and quite possibly increased cloud cover during summer. A consequence of this could actually be lowered air and soil temperatures at ground level. The result of a warming trend might then appear at the vegetation level as stress on "warm climate" plants: those that require certain levels or duration of warmth during the growing season. Over the long term, this could, theoretically, result in the retraction or fragmentation of the ranges of "low Arctic" species in areas such as the North Slope of the Brooks Range. This concept leads directly to concerns of range extension and retraction, such as the location of the treeline. This and related issues are treated in the next conceptual model, discussed below.

The example developed above is obviously simplified and isolated from many related factors. It also says little about the scale of time and space over which effects might be visible. For example, a long-term warming trend would probably result in a thinning of the sea ice cover, so that open water near the north and west coast of Alaska would extend farther from the shore and remain open for more months of the year. This might set up a feedback loop in which additional warming was encouraged by the lowered albedo of the open sea as opposed to pack ice. On the other hand, increased open water could increase precipitation and cloudiness over the land, tending to reverse the warming trend. But this, in turn, would depend at least partially on wind and other weather patterns; these are notoriously difficult to predict, and there is usually wide variation between results when only slight modifications are made in the parameters that are fed into climatic models.

The diagram presented here attempts to show graphically how a general warming or cooling trend might be expected to affect the nature of the physical environment at high latitudes (Figure 7). It includes examples of some of the feedback loops that could tend to drive the system toward, or away from, stability.

A Conceptual Framework for Considering Changing Distribution Patterns

Long-term changes in climate are associated with changes in the distributions of various organisms (Figure 8). In the North, the most conspicuous and well-studied expression of this is the location of

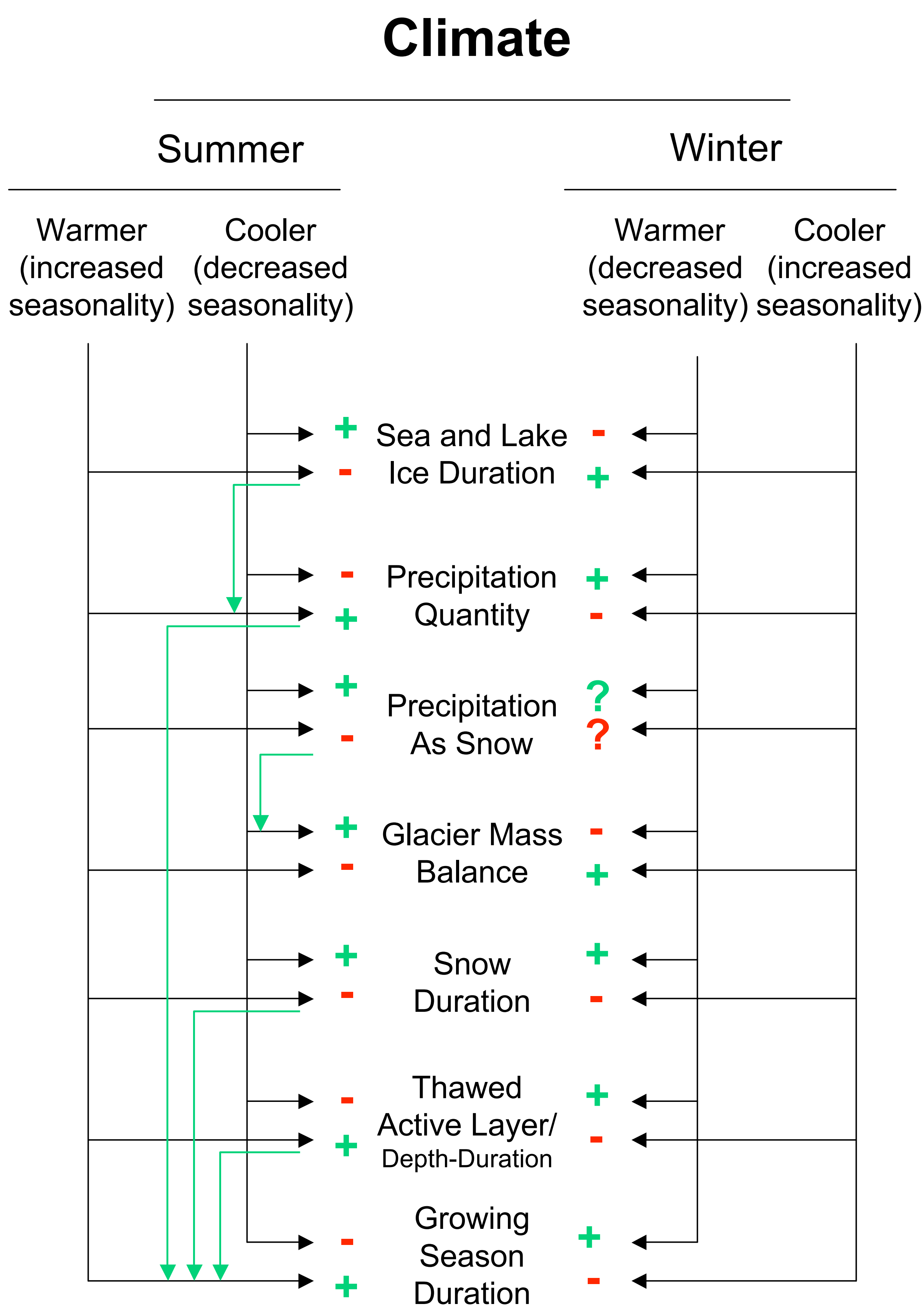

***Figure 7:** Simplified model of climate change in arctic ecosystems*

the treeline, often defined as the poleward or seaward limit of coniferous forest. The correlation of the location of treeline with summer temperature is well known (Young 1989); and it is generally accepted that the location of the northernmost forests closely approximates the location of the 10° C isotherm for the warmest month of the year, July in most parts of the North. However, this is only a rough correlation. The array of physiological processes that facilitate or limit the northward spread of certain tree species must take place at a microclimatic level, there may be more than a single set of limiting factors, and different sets of factors may be operating under different climatic conditions and in different geographic areas.

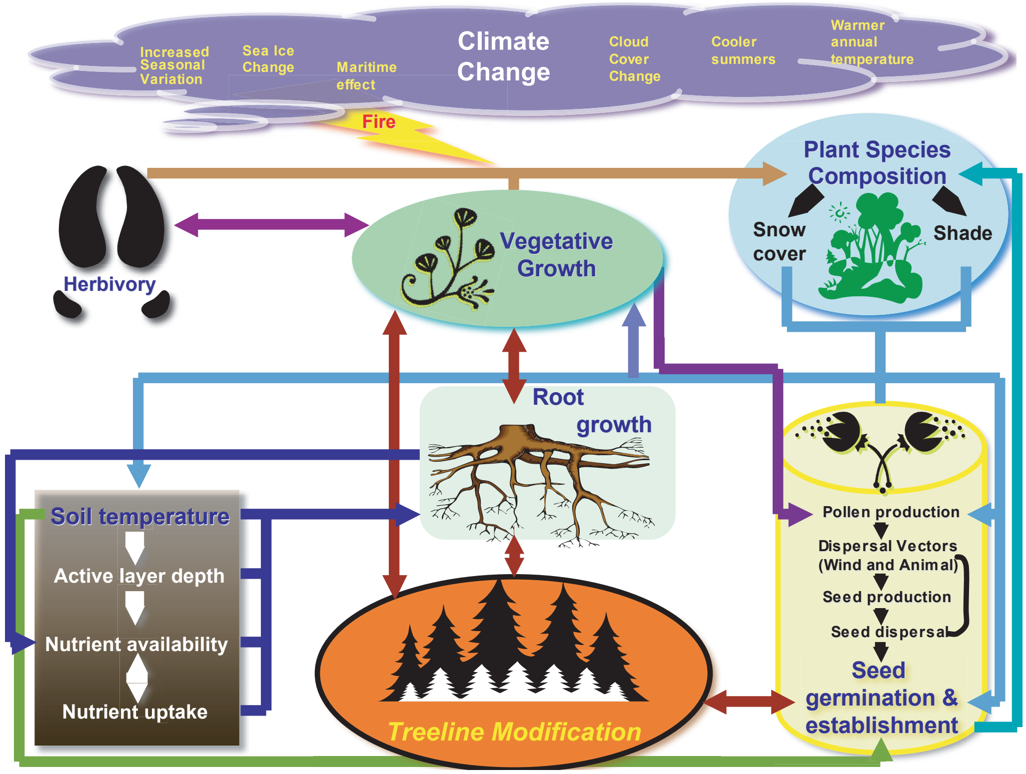

Figure 8: *Biomechanics and feedback loops of treeline modification in relation to climate change*

For example, the limiting factor in some situations might be the production of viable seed, which would require certain conditions of intensity and duration of warmth in the upper portions of mature trees during the growing season. On the other hand, germination and establishment of seeds might be the weak link in the chain, in which case temperatures at the soil surface would probably be critical. In this case, factors such as depth and duration of snow cover and/or shade from nearby mature trees might become dominant in determining success of reproduction and, over time, the advance or retreat of the forest. An additional complexity, of course, is the consideration that necessary conditions need to be met only often enough to allow successful reproduction occasionally during the long life span of plants such as conifer trees. Thus, a cooling but unstable climatic regime with an occasional unusually warm summer could conceivably facilitate the spread of trees more effectively than a slightly warmer but more stable climate.

Even this brief consideration of one type of distribution pattern points up the complexity of factors that are implicated in controlling the advance or retraction of the ranges of plants and animals. It will be noted that we have not mentioned the role of dispersal mechanisms and their effectiveness. These would presumably have little relevance with respect to current treeline trees, but the spread of some other organisms could be quite dependent on effective dispersal mechanisms.

Finally, we might note that the presence or absence of conspicuous organisms such as forest trees is easily established, and the changes in their distributions can be monitored by such means as aerial photography. Even ancient ranges can be provisionally plotted on the basis of fossil evidence. This becomes only somewhat less true in the case of species such as shrub birch (*Betula glandulosa* and related forms) or the various willows that comprise the overstory of the riparian shrub communities. In the case of less conspicuous species, such as tussock-forming cottongrass (*Eriophorum vaginatum*), only careful, on-the-ground studies may be able to show its presence or absence or its advance or retreat.

Equally important, changes in the distribution of a species such as the above could occur either by migration along a broad front or by the expansion of small, isolated, perhaps relict colonies outside the "normal" range of the species. Under the latter situation, range extensions could be expected to occur much more rapidly in response to changing climate or other environmental changes.

In spite of the complexity noted above, alterations in the distribution of various species and communities can be expected to lead to some of the most powerful concepts and tools with which to monitor the trajectory of overall environmental changes and of the "health" of the environment in general. We have concentrated here, and on the accompanying diagram, on plant species and some of the factors and interactions that can be involved in changes in distribution. In some cases, the migration and range extension of certain vertebrates and invertebrates would be dependent on the spread or retreat of vegetation types. This is probably at least partially the case, for example, in the spread of moose into arctic Alaska over the past couple of centuries. In other cases, especially in highly mobile species such as some migratory birds, the correlation between range changes and climatic or other environmental change is difficult to address successfully. Studies addressing these issues will probably be important in any long-term monitoring program in our study area.

Time Scale

Northern and western Alaska, perhaps even more than most regions of the world, has undergone enormous changes in the relatively recent geological past. In order to understand both the current array of organisms and the processes that maintain their interactions with the environment, it is necessary to approach them with a historical perspective in mind (Figure 9). In particular, we must recognize that the current environmental situation results from the interaction of processes that take place over greatly varying time scales. For purposes of discussion, we suggest the following time scales:

Long-term geological: dealing with events that have occurred over millions of years, such as mountain building, the distribution of certain substrates, etc.

Late Quaternary: changes that have been important in the late Pleistocene and Holocene, especially the roughly 20,000 years since the last glacial maximum. These would include the termination of continental glaciation over much of the Northern Hemisphere, the submergence of huge areas of continental shelf (especially the Bering Land Bridge), the extinction of many important megafaunal species, and the earliest activities of humans within our area.

Early-mid Holocene: changes primarily in vegetation and fauna associated with the emergence of modern ecosystems. Beginning of establishment of modern coastal features, such as the beach ridges of Cape Krusenstern and Cape Espenberg. Stabilization of many terrestrial features such as dunes and loess deposits.

Prehistoric: the emergence of the ancestors of the indigenous cultures of the area and the increasing importance of archaeological sites and materials as sources of data on the nature of the environment.

Historic-current: the time including the influence of Western industrial society on the environments and peoples of our area, beginning soon after 1,800 C. E.

Short term: many of the phenomena with which we are concerned may be evident in the course of a very few years. They may be individual, recurrent, or cyclical.

Spatial Scale

Monitoring can usefully occur in situations as geographically limited as a single thaw pond, mountain slope, or heavily used fishing location. It is likely to be most useful if observations on this scale are incorporated into a broader perspective. In a sense, all larger scale monitoring plans are composed of local sampling schemes, with information obtained, collected, and interpreted to provide a broader picture. Not only does monitoring within the parks in our study area provide information on the condition of the park itself, but it may also be highly significant on a scale as large as the whole circumpolar North. Thus, while the primary function of long-term monitoring may be seen at one level as being useful in providing information to be used in managing parks, or areas within parks, we should not lose sight of the potential for NPS-sponsored monitoring to affect our overall understanding of the northern environment. At the same time, it needs to be recognized that many of the changes that appear as local phenomena within the parks are, in fact, manifestations of much larger scale events that are expressed in a wide variety of ways over broad areas of the earth.

During park scoping workshops, natural resource staff compiled a list of potential anthropogenic stressors to arctic park ecosystems. For the purpose of this workshop we have developed a series of nested conceptual models to depict these potential stressors and the spatial scales at which they are operating (Figures 10–15). During this workshop we will review these models for further development and refinement. Understanding potential impacts to the ARCN ecosystems and the cumulative effect of these changes will be key to managing ARCN natural resources.

Human impacts to ARCN come at varying spatial scales. At the largest spatial scale, national and international politics, laws, and treaties could have an impact on arctic ecosystems (Figure 10). Although NPS may not have the resources or staff to directly effect legislation or treaty status, these global stressors must be considered when thinking about how arctic ecosystems might be changing. For example, it should be acknowledged that persistent organic pollutants (POPS), which are accumulating in the arctic, their final repository, are coming from other parts of the world (Figures 10 and 14). The presence of these pollutants could be having an effect on the fecundity, reproduction, and survivorship of large mammal species living in arctic ecosystems (Arctic Monitoring and Assessment Program 1997, Wiig et al. 1998, Jepson et al. 1999).

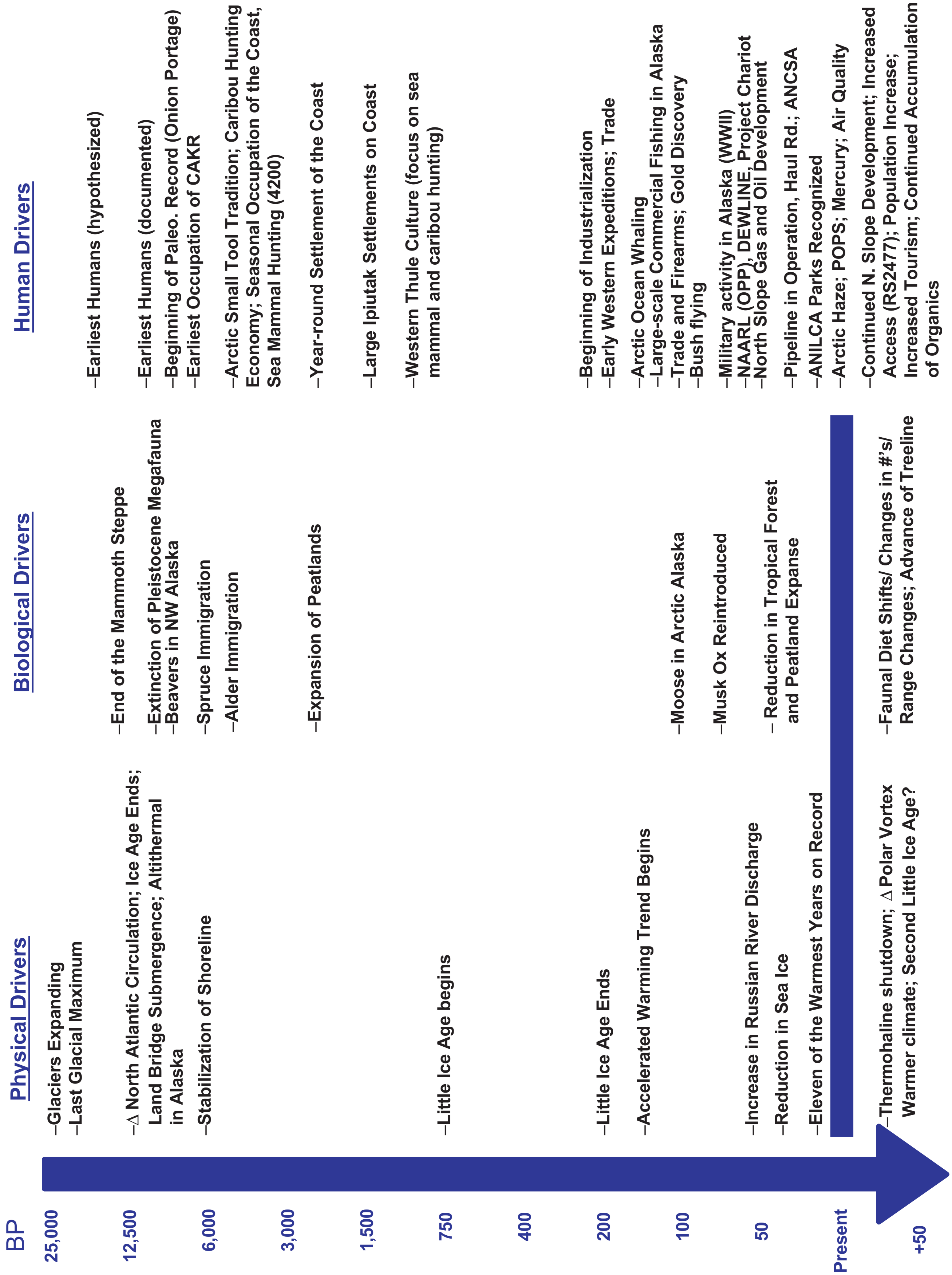

Figure 9: *Significant physical, biological, and human drivers in the Arctic the last 25,000 years before present.*

A large suite of human activities in the circumpolar arctic may also have a direct impact on ARCN ecosystems (Figure 11). For example, human-induced climate change and its effect on arctic sea ice thickness and extent could have an impact on weather and climate in arctic ecosystems. This in turn could have an impact on the coastal ecosystems of ARCN and local subsistence practices (Figure 12). Local anthropogenic stressors within or adjacent to ARCN park boundaries could also have a direct impact on ARCN ecosystems (Figure 13). For example, the cumulative effects of oil and gas development on the North Slope could directly impact ARCN ecosystems in a variety of ways (National Research Council 2003). Possible ecosystem responses of anthropogenic impacts include things like: changes in disturbance regime, physical shifts in the landscape (e.g., thermokarst formation), decreases in ecosystem stability and resilience, population shifts of certain species, etc. Of special concern are the exotic species and invasive diseases that may relocate in the parklands due to the cummulative impacts of stressors at various levels (Figure 15).

Data Gathering and Experimental Design

Efficient and useful monitoring depends on maintaining a balance between the random collection of massive quantities of data and focused sampling strategies designed to provide answers to highly specific questions. Random data collection creates problems of cost, storage and management, but it also may uncover unsuspected patterns of phenomena that would be missed in a more narrowly oriented program. It also may create a cache of information that may be useful in the future in totally unexpected ways. Narrowly focused research may rapidly provide understanding of critical processes and problems, and conclusions are easily formulated and transmitted. But it may allow important phenomena to slip through the cracks, and it may lead workers to conclusions that turn out to have only limited applicability when an effort is made to apply them on a broad scale.

It is particularly important that monitoring plans be flexible enough to incorporate data that comes in from unusual or unexpected sources. This is especially true in wilderness parks, since baseline data may be scanty and even anecdotal evidence for environmental change may be hard to come by. Under these circumstances, the use of proxy data derived from a variety of sources is critical. The best examples of this approach involve archaeological investigations and geological/paleoecological research. Excavations conducted by archaeologists often provide well-stratified and well-dated samples of biological elements of past environments. Careful analysis of the data from this source can provide detailed and reliable evidence for environmental change extending back for centuries or even millennia.

It is also important that monitoring plans be able to encompass and evaluate the significance of unusual and unique events such as insect outbreaks, fires, rapid changes in vertebrate populations or distributions, or exceptional floods.

In our scoping meetings we will be concerned with identifying the array of biological features and processes that might be usefully and appropriately monitored in ongoing efforts to protect and manage the five national parks and preserves in northwestern Alaska.

Literature Cited

Arctic Monitoring and Assessment Programme. 1997. *Arctic Pollution Issues: A State of the Arctic Environmental Report.* Arctic Monitoring and Assessment Programme, Oslo.

Jepson et al. 1999. Investigating potential associations between chronic exposures to polychlorinated biphenyls and infectious disease mortality in harbour porpoises from England and Wales. *Science of the Total Environment,* 243–244.

National Research Council. 2003. *Cumulative Environmental Environmental Effects of Oil and Gas on the North Slope.* National Academies Press, Fifth Street, NW, Washington, DC 20001.

Wiig, O. et al. 1998. Female pseudohermaphrodite polar bears in Svalbard. *Journal of Wildlife Diseases* 34: 792–796.

Young, S. B. 1989. *To the Arctic.* New York, John Wiley and Sons. 354 pp.

Figure 10: *Global anthropogenic stressors/drivers to ARCN ecosystems.*

Circumpolar Anthropogenic Stressors/Drivers

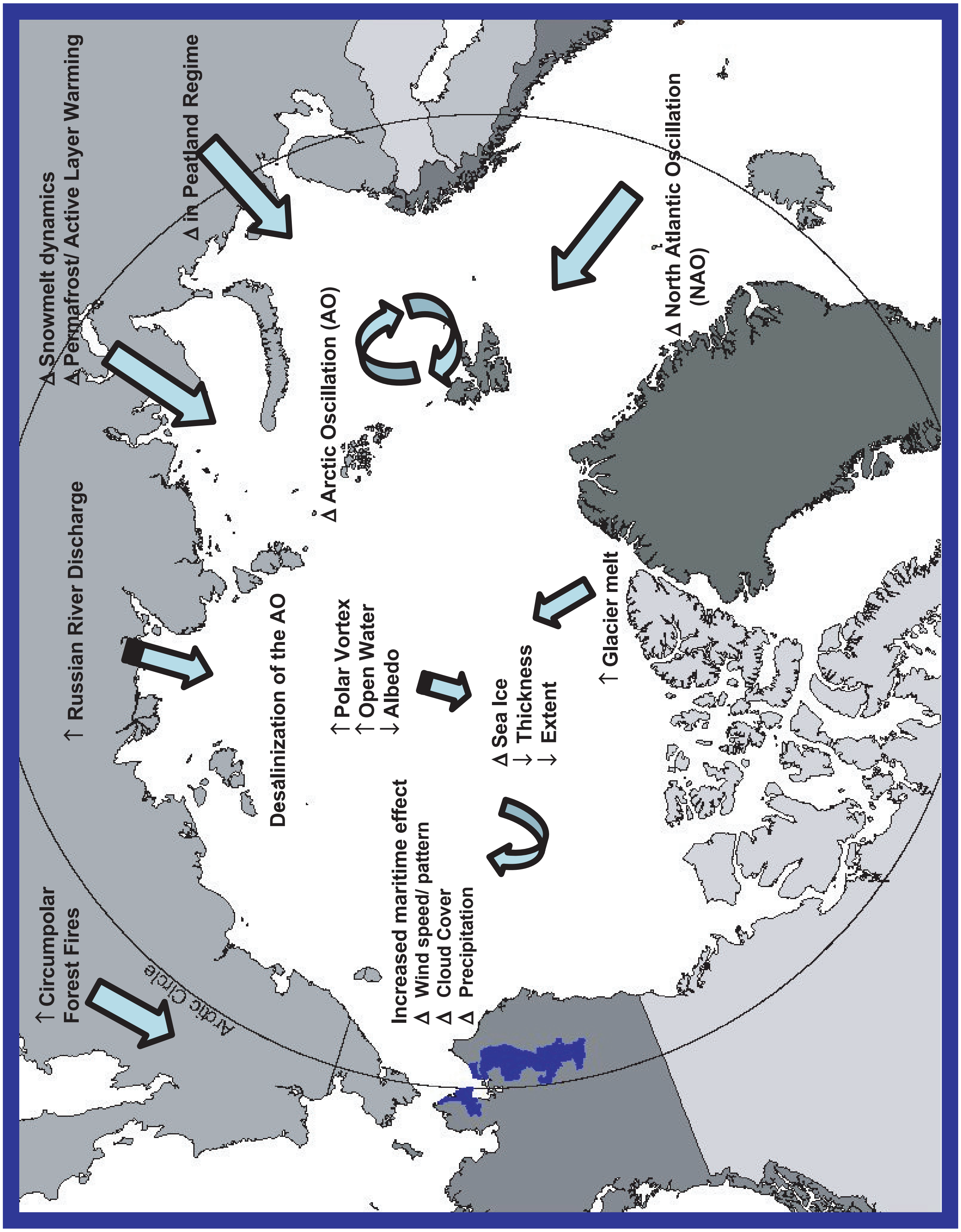

Figure 11: *Human-induced global warming and potential ecosystem responses and feedbacks in the circumpolar north.*

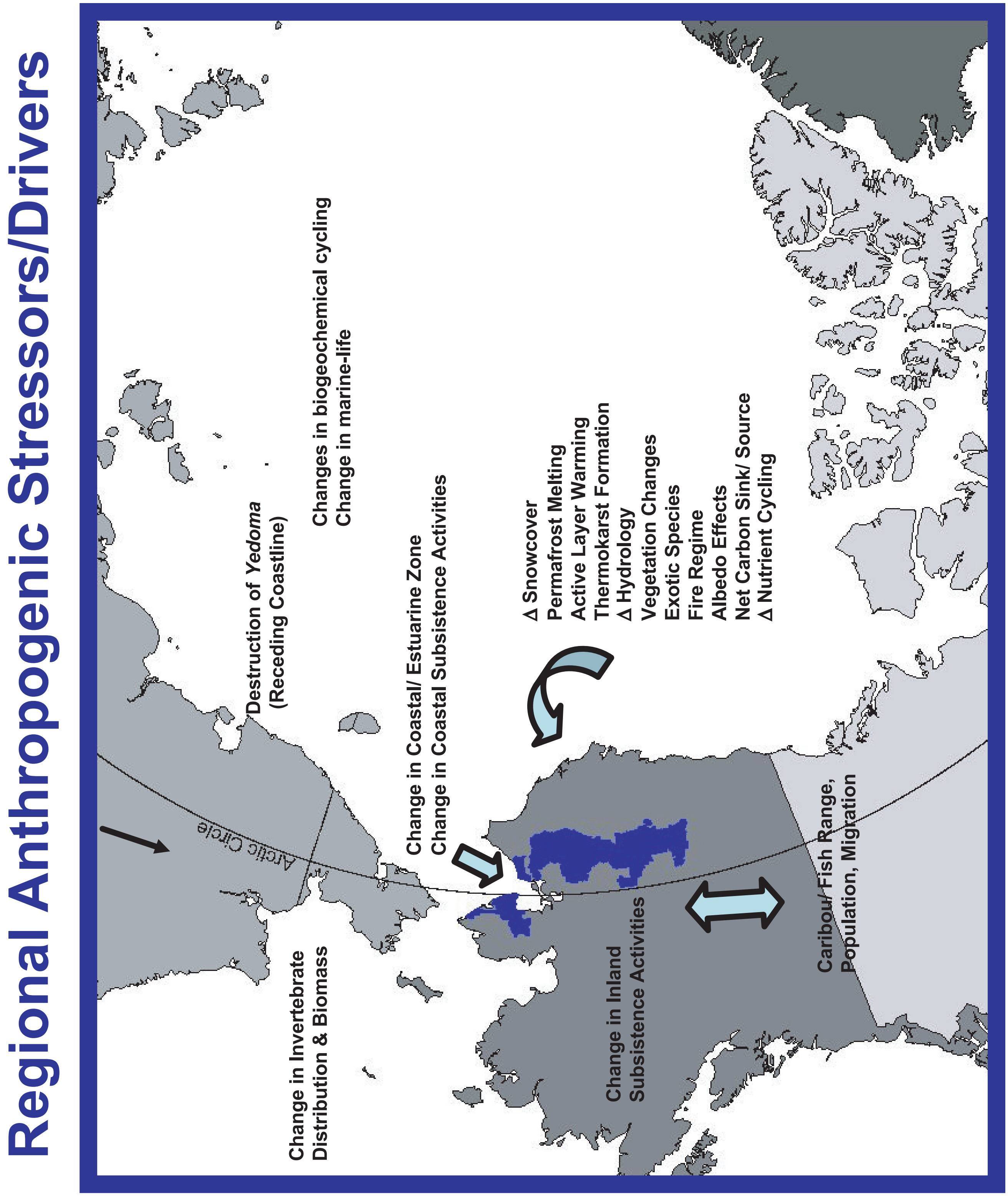

Figure 12: *Human-induced global climate change and potential impacts at a regional scale.*

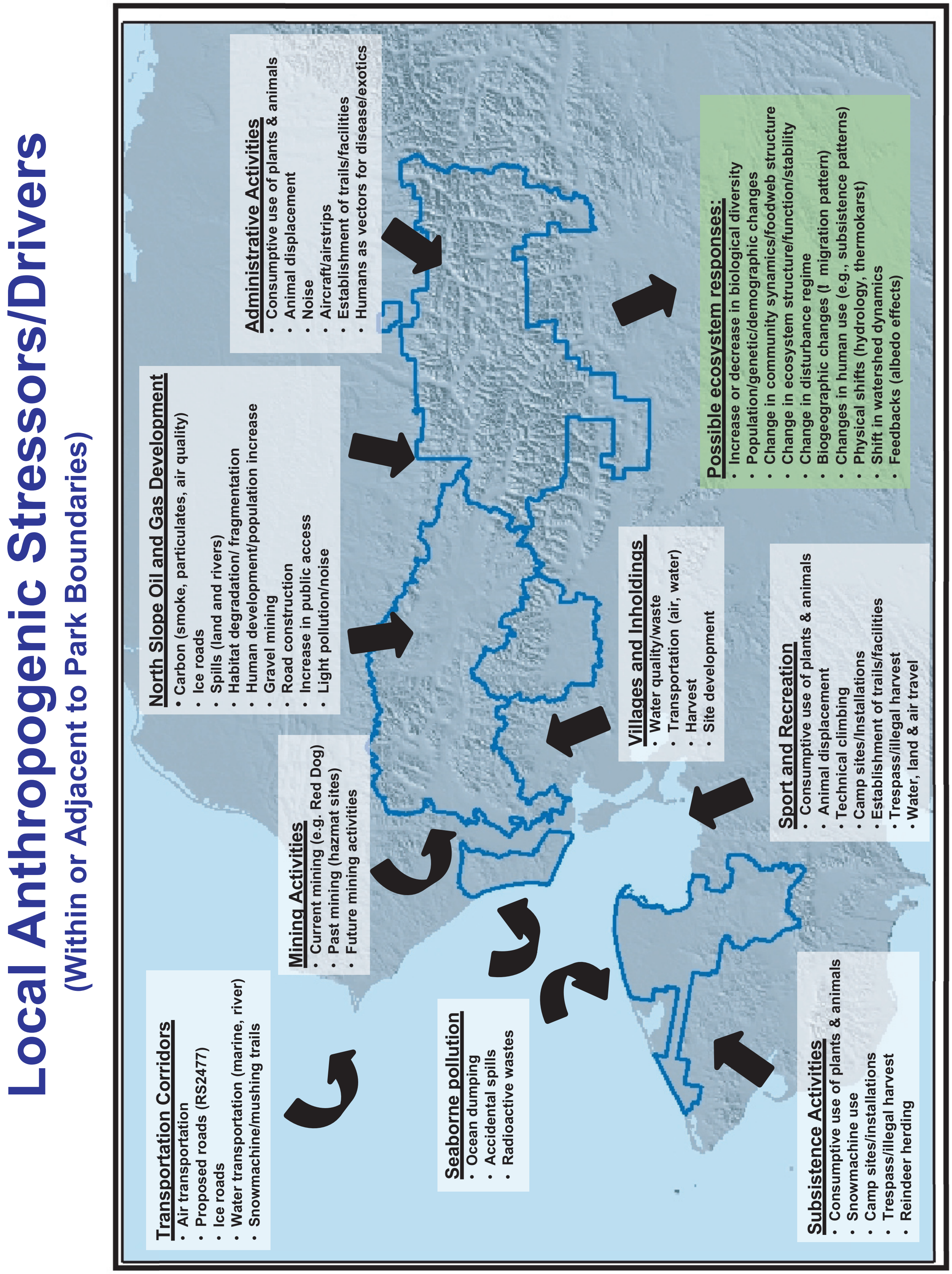

Figure 13: Local anthropogenic stressors/drivers to ARCN and possible ecosystem responses.

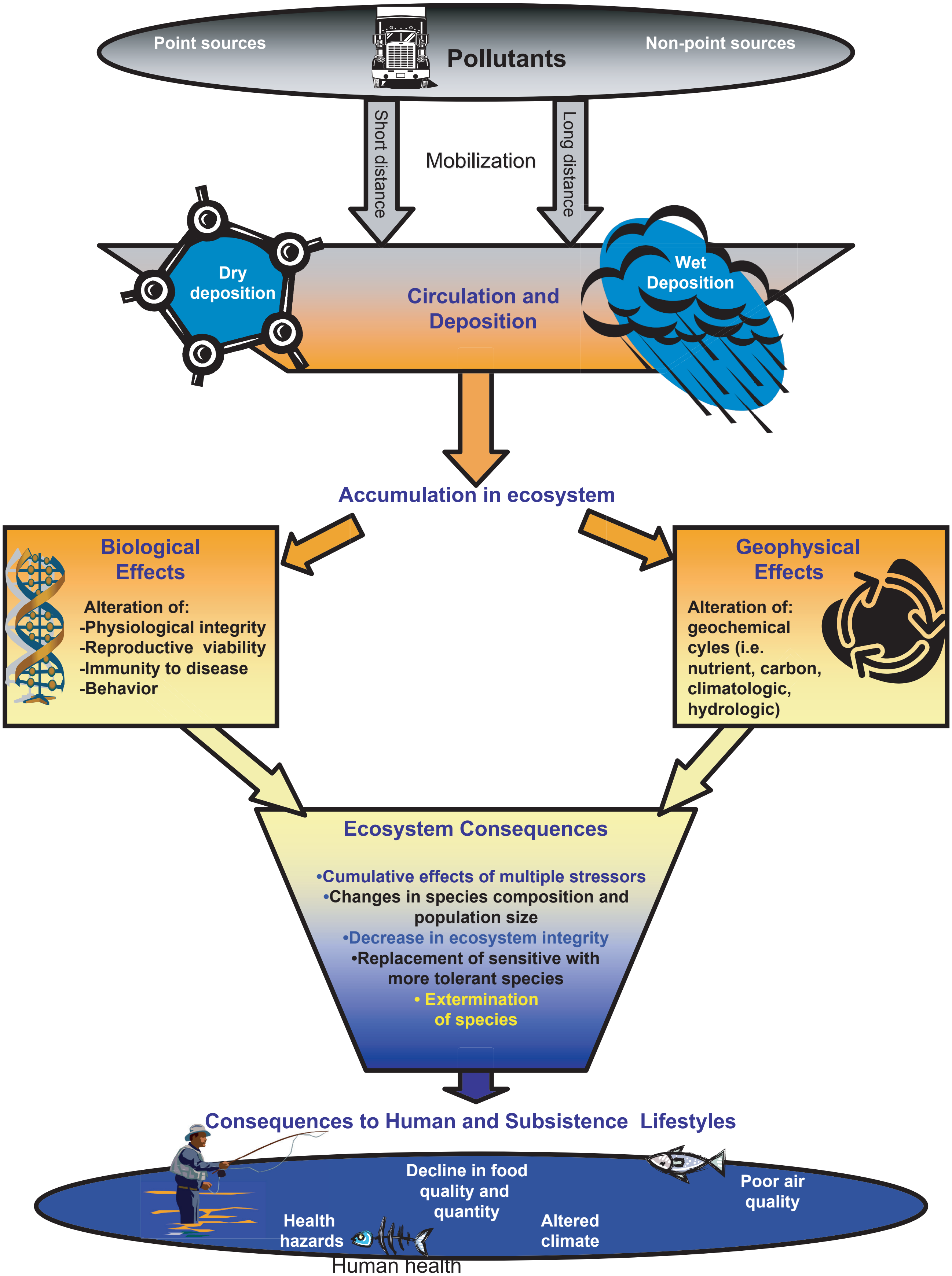

Figure 14: *The path of airborne toxic pollutants and their effects on ecosystem and human health.*

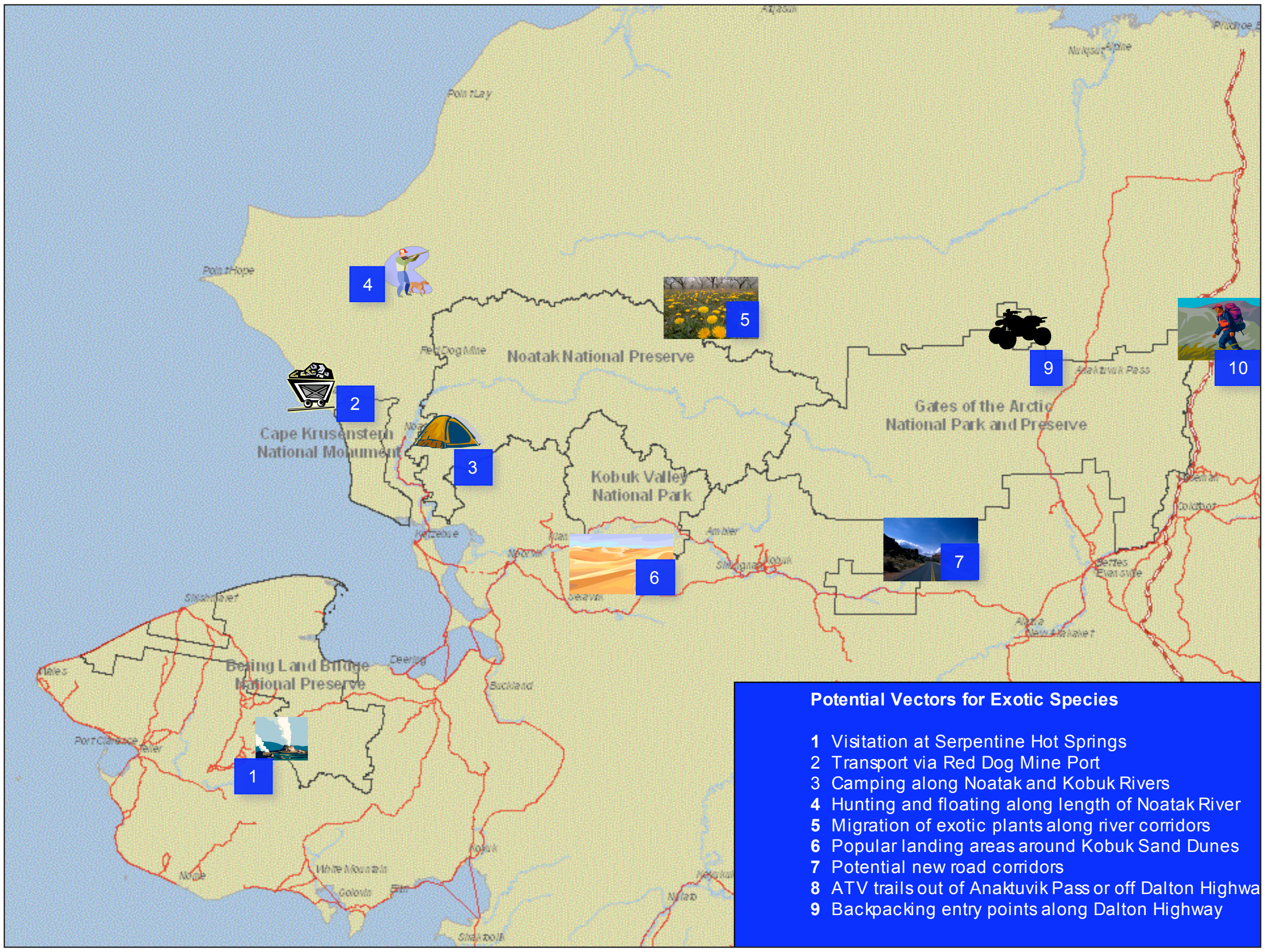

Figure 15. Potential vectors for exotic species into ARCN.

* Note on the use of terms "drivers" and "stressors"

The concept of *drivers* and *stressors* is a useful tool in visualizing the interactions of ecosystems. As we use the terms here, *drivers* are those factors on which the continued functioning of the ecosystem depends, while stressors are factors that tend to force change in the ecosystem. A simple example of a driver would be solar energy, which, directly or indirectly, supplies the energy that drives an ecosystem. Stressors tend to act more locally. At a broad scale, climatic warming might be considered to be a stressor. At a more local scale, increased predation, the presence of pollutants, or the melting of permafrost would be stressors. It is important to note that changes in the biological environment, although usually the result of stress, are not intrinsically detrimental. Climatic warming, for example, may encourage the success of certain species and communities in a local area at the expense of others. The net result is likely to be a new equilibrium or a regime of ongoing change. In a simple example, a rapid spread of willow thickets into the tundra might reduce appropriate habitat and fodder for caribou, causing a decline in numbers, but might encourage the spread and increase in number of moose in the same area.

It is important to keep in mind that changes in the environment, and the stressors that are associated with these changes, are not always anthropogenic. There has probably been no time in the recent geological past in which the environment changed more rapidly and profoundly than in the late stages of the last Ice Age and the early Holocene, perhaps 14,000 to 8,000 years ago. At this time, human activities would hardly have constituted an important stressor, with the possible exception of increased human predation on large animals.

Finally, we need to recognize that there are random events in the history of an ecosystem. These are not always easily distinguished from the results of stress. For example, a major ash fall from a volcanic explosion is, in a sense, a random event. However, if it results in massive dieoff of a particular animal species, this dieoff is clearly the result of stress. If a migratory bird species dramatically extends its range, as species such as the white wagtail, bluethroat, or black-bellied plover have recently done in western Alaska, this may be a random event, or it may be the result of subtle changes in the environment.

An important feature of this random aspect of environmental change over long time periods has come to be called the "no analogue" concept as applied to paleoecology. The suggestion here is that it is not always possible to predict the future nature of a disturbed or stressed ecosystem, even if the disturbance should cease and the physical parameters of the ecosystem should return to "normal." Invasions or extinctions of some of the biological elements may create permanent changes in the environment. A classic example is the extinction of the wooly mammoth in northwestern Alaska, presumably at about the beginning of the Holocene. No reconstituted environment could ever entirely recreate the Mammoth Steppe of the past without the presence of one of its major constituents.

ARCN Program Criteria for Monitoring Projects

The Arctic Network Technical Committee and invited scientific experts from outside NPS attending the Freshwater Scoping Workshop in June of 2004 came up with the following draft criteria for monitoring projects. This list will serve as a checklist for whether the proposed projects meet the goals of the network monitoring program. We include it in this notebook for further review by outside experts attending the terrestrial ecosystems workshop.

- Foundational: Either for the collection of baseline data (status) or protocol development for monitoring (trends)
- Repeatable
- Relevant to arctic ecosystems and arctic ecosystem monitoring
- Of interest to local, circumpolar, and global communities
- Take an integrative and efficient approach (how much data-gathering can we do for the same logistic effort)
- Collaborative with as many federal and state agencies, nonprofit organizations, academia, Native corporations, and local communities as possible
- Cost-effective
- Comprehensive (network-wide inference)
- Achievable (realistic regarding access, logistics, etc.)
- Valuable to park managers and scientists
- Complement the "infrastructure capital"

The Arctic Network Parklands

Bering Land Bridge National Preserve

Established: 1980, under ANILCA

Size: 1,026,930 hectares (2,537,592 acres)

Enabling Legislation

Bering Land Bridge National Preserve was established by the Alaska National Interest Lands Conservation Act (ANILCA) on December 2, 1980. As stated in ANILCA, Section 202 (2), the purpose of Bering Land Bridge is to:

> *Bering Land Bridge National Preserve shall be managed for the following purposes, among others: To protect and interpret examples of arctic plant communities, volcanic lava flows, ash explosions, coastal formations, and other geologic processes; to protect habitat for internationally significant populations of migratory birds; to provide for archeological and paleontological study, in cooperation with Native Alaskans, of the process of plant and animal migration, including man, between North America and the Asian Continent; to protect habitat for, and populations of, fish and wildlife including, but not limited to, marine mammals, brown/grizzly bears, moose, and wolves; subject to such reasonable regulations as the Secretary may prescribe, to continue reindeer grazing use, including necessary facilities and equipment, within the areas which on January 1, 1976, were subject to reindeer grazing permits, in accordance with sound range management practices; to protect the viability of subsistence resources; and in a manner consistent with the foregoing, to provide for outdoor recreation and environmental education activities including public access for recreational purposes to the Serpentine Hot Springs area. The Secretary shall permit the continuation of customary patterns and modes of travel during periods of adequate snow cover within a one-hundred-foot right-of-way along either side of an existing route from Deering to the Taylor Highway, subject to such reasonable regulations as the Secretary may promulgate to assure that such travel is consistent with the foregoing purposes.*

Purposes

- Protect and interpret examples of arctic plant communities, volcanic lava flows, ash explosions, coastal formations, and other geologic processes
- Protect habitat for internationally significant populations of migratory birds
- Provide for archeological and paleontological study, in cooperation with Native Alaskans, of the process of plant and animal migration between North America and the Asian Continent
- Protect habitat for, and populations of fish and wildlife including, marine mammals, brown/grizzly bears, moose, and wolves
- Continue reindeer grazing use
- Provide for outdoor recreation and environmental education activities at Serpentine Hot Springs

Ecological Overview

Bering Land Bridge National Preserve occupies about one-third of the Seward Peninsula. The peninsula is approximately 320 km from east to west, and the greatest north to south distance is 240 km. The peninsula is the divide between the Pacific and Arctic oceans, with Norton Sound and Bering Sea to the south and Kotzebue Sound and Chukchi Sea to the north. The northernmost point of the peninsula, Cape Espenberg, extends just north of the Arctic Circle, and the westernmost point, Cape Prince of Wales, is only 88 km from Siberia.

The Seward Peninsula consists of a mixture of coastal plain, plateau, and mountain range. The coastal plain may be as wide as 40 km, with a variety of features along the sea: rocky headlands predominate in the south and west, while broad beaches, lagoons, offshore bars, inland wetlands, bays, and lakes are common along the north shore. Plateaus occupy a large portion of the interior of the peninsula, with elevations ranging from 180 to 900 m. These areas tend to have broadly rounded hills and irregular topography, but they lack a well-defined system of ridges. An exception is the Kigluaiks, whose rugged terrain reflects their recent history of intense glaciation. The principal mountain ranges are the Kigluaiks, known locally as the Sawtooths (elevation 1,500 m) northwest of Nome, the York Mountains (elevation 1,100 m) in the west, and the Bendeleben Mountains (elevation 1,100 m) in the center of the peninsula. The latter range forms the southern boundary of the preserve.

Climate

The climate of the Seward Peninsula and Bering Land Bridge National Preserve shows both maritime and continental influences. When surrounding marine waters are ice-free (mid June to early November), temperatures are moderate, humidity is high, and skies are typically cloudy, especially near the coast. Interior sections, even during this summer period, are somewhat drier and less cloudy, and therefore have greater heat buildup during daytime hours and a greater daily temperature change.

When offshore waters are frozen, both inland and coastal climates are more continental (i.e., drier, clearer, less windy). However, winter temperatures do not reach the extreme lows that are encountered in interior Alaska at this same latitude. Information from a few coastal stations (Nome, Wales/Tin City, Shishmaref, Teller, and Kotzebue) has traditionally been used to characterize the preserve area. Climatological records for the preserve suggest somewhat colder winters (minimum January temperatures on the coast –23 to –29° C, inland –51° C), and warmer summers (maximum July temperatures on the coast lower 10s, inland mid-teens) than in coastal areas.

Winds are moderate to strong year-round but are strongest during winter. Winter winds are predominately from the east, whereas summer winds and storm approach from the south and southwest. Typical monthly average wind speeds are 8 to 12 mph year-round, but during stormy periods winds of 50 to 70 mph are possible.

Summer is the wettest period, with perhaps 7 to 10 cm of the 25 cm of annual precipitation being recorded. Snow, with a relatively low water content, averages about 127 to 152 cm per year.

Sea ice usually breaks up in early to mid June along the Chukchi Sea coast, although breakup can vary by several weeks. Even after breakup, ice lingers near the coast for a month or more and may be blown back to shore. Inland lakes and ponds thaw at varying times according to their depth, location, and exposure to winds.

Freshwater Resources

Extensive surface water is present in the northern half of the preserve, but the actual annual hydrologic budget is relatively small owing to the modest precipitation (25-38 cm). Five major rivers have substantial drainage basins within the boundary of the preserve, including the Serpentine, Cowpack, Nugnugaluktuk, Goodhope, and Noxapaga rivers. Others have only a small portion within or along the boundaries of the preserve. These include the Inmachuk, Kugruk, Koyuk, and Kuzitrin rivers.

Serpentine Hot Springs is the main geothermal resource in the park. There are four areas along a 0.8 km reach of Hot Springs Creek where hot water discharge is evident. Discharge at the upper hot spring area (the location of the wooden bath area) is approximately 106 L/s, with average temperatures ranging from 61–72° C (Roeder and Graham 1979). Discharge at the lower portion of the spring area is 146 L/s. The surface water temperature has been measured at 15–21° C. There are also several small springs at Pilgrim Springs.

There is a lack of basic information about fish diversity and distribution within BELA. The Alaska Natural Heritage Program (AKNHP) identified 25 freshwater species with 9 documented. Information on fish presence in BELA appears to come mainly from reconnaissance type trips to specific locations or from incidental observations by biologists working on other taxa. While there has been considerable work on freshwater and marine/coastal fish in the region by the Alaska Department of Fish and Game, and others, very little of that work has occurred within the bounds of the preserve.

Geology

The surface geology of the preserve is dominated by recent volcanic lava and ash flows and by unconsolidated wind- or water-borne sediments. The five distinct lava flows around Imuruk Lake range in age from 65 million years (the Tertiary Kugruk volcanics) to as recently as 1,000 years (the Lost Jim flow). The older flows occurred on many separate occasions from a variety of vents and are now largely buried by the more recent flows as well as by wind-blown deposits of silt. The exposed volcanic rocks, all dark basaltic material, were originally rather smooth "pahoehoe" flows, but older flows have been severely shattered by frost action into large angular fragments. More recent flows are progressively less affected by frost fracturing and are little weathered, although virtually all exposed rock is covered by a nearly continuous mat of lichens.

A distinctly different series of volcanic events that consisted of small but violent explosions of steam and ash and small quantities of lava occurred on the preserve's northern lowlands around Devil Mountain. These explosions created several large craters known as maars that are now filled with water. These features are rare at this latitude and differ from craters within volcanoes or calderas by having relatively low surrounding rims. The single or short-term explosions that created them simply blew out the original surface material, and there was no subsequent ash or lava to build up a cone or rim. The maars now known as the Devil Mountain Lakes and the Killeak Lakes are paired; the largest maar is White Fish Lake.

Other than the exposed volcanic features and some bare ridges of exposed bedrock, most of the preserve is covered by an unconsolidated layer of sediment, including gravels, sand, and silt. Nearest the coast are layers of terrestrial sand and gravel and some marine sediments that represent a mix of river-borne materials and wind- and wave-transported beach materials left from earlier higher sea levels.

Farther inland in the western part of the preserve are alluvial (river-borne) sediments derived from erosion of the higher mountainous regions south of the preserve. To the east, mantling the Imuruk volcanics and other bedrock, are extensive areas of fine wind-borne silts derived from Pleistocene glacial outwash plains now covered by the sea.

One specific geologic feature of significance is the small area of intrusive rock of Cretaceous age around Serpentine Hot Springs. Dozens of granitic spires and outcrops called tors are exposed, providing one of the relatively few dramatic geologic landscapes in the otherwise rolling and gentle topography of the preserve. The hot springs area is underlain by diverse, metamorphosed granite.

The most significant geological history theme of the preserve is the land bridge itself, which has intermittently been a dry land connection between the continents of Asia and North America. The land bridge was the result of lowered sea levels during the great ice ages, when vast amounts of water were tied up in continental glaciers. The land bridge chronology is not entirely understood, and opinions differ as to the actual times and duration of the connections. There was probably a connection in very ancient times, long before recorded glacial periods and before modern flora and fauna evolved. At that time some ancient plants may have been exchanged between the two continents. However, it was only during later connections, especially in the past 50,000 to 100,000 years that human and recent Asian mammals migrated to North America, and some species migrated from North America to Asia. The land bridge in some form probably existed through most of the later Quaternary. At times the land bridge may have lasted 5,000 years or more and covered a very broad area over which plant and animal life slowly expanded.

Glaciers at the time of the land bridge did not completely cover the Seward Peninsula. The peninsula's mountains were covered by glaciers on several occasions, resulting in typical glacial sculpturing and glacially derived sediments washed down to the lowlands. However, many lowlands remained free of ice, and there is no evidence in the preserve of glacial sculpturing or moraines and isolated rock piles. This implies that substantial ice-free areas during the time that the land bridge existed were continuously occupied by modern plants and animals. Thus the lowlands now in the preserve were an important element in the land bridge story. Further study of these particular areas may be expected to locate additional specific evidence of earlier human and animal occupancy. Although some permanent ice fields still occur in the Bendeleben Mountains, there are no major glaciers anywhere on the Seward Peninsula.

Soils

Soils throughout the preserve are the typical peaty and loamy surface layers of arctic tundra lands over permafrost, with some areas (windswept ridges or recent volcanics) having very shallow or no soil development. Virtually all tundra soil types are rated as having medium to high erosion potential if they are distributed by roads, structures, or other activities like gardening or concentrated grazing of hoofed animals. No arable soils are known to occur within the preserve.

Surface features of the preserve are much influenced by the existence of a nearly continuous permafrost layer. The depth of the seasonally thawed active layer may vary from 0.3 to 3 m, depending on the type of surface (e.g., under a lake, gravel bar, or vegetated soil), while the perennially frozen layer below may be 4.5 m to over 60 m thick.

Permafrost is the cause of several topographic features. Thaw lakes form in depressions where water pools, or where vegetation is disturbed, causing local melting of the permafrost and continued expansion until adjacent lakes join to form large, irregularly shaped, shallow lakes. Pingos are ice-cored hills where the overlying soil is pushed up by the expansion of ice when permafrost reinvades a drained pond, or when ice or pressurized water is injected from below. Ice wedge polygons are extremely common on flat or gently sloping ground where soil in the upper active zone contracts during freezing, leaving symmetrical polygonal cracks which then fill with snow and eventually ice. Solifluction sheets form where the upper active layer, unable to drain down through the permafrost, becomes saturated and slips downslope.

Vegetation

All of Bering Land Bridge National Preserve lies beyond timber line. There are, however, scattered groves of balsam poplar (*Populus balsamifera*) in many areas of the preserve, and dense spruce forest occurs within a few kilometers of its eastern boundary. Several recent studies suggest that the warming climate of much of the Seward Peninsula will allow the spread of spruce northward and westward within the next few decades, and a few scattered white spruce (*Picea glauca*) seedlings may well be found within the preserve at present.

Other than the scattered balsam poplar groves, the closest approach to forest within the preserve are the well-developed riparian willow thickets that occur along the larger rivers. In these areas willow brush may be four to five meters tall. They consist mainly of *Salix alaxensis,* often with an admixture of other tall species such as *S. arbusculoides, S. lanata,* and along smaller streams, *S. pulchra.* Isolated patches of tall willow brush are also found around springs, snowbeds, and seepage areas on hillsides. There are also both extensive alder thickets and isolated stands of alder (*Alnus crispa*) in many areas, especially on wetter north or east facing slopes and near seepage areas.

The northern and much of the eastern boundary of the preserve is formed by the Chukchi Sea and Kotzebue Sound. Most of this shoreline consists of lagoon and barrier beach systems, often with relatively extensive dunes and beach ridges. The more exposed and less stable portions of these areas are dominated by extensive stands of beach rye grass (*Elymus arenarius*), often mixed with an array of common plants such as *Mertensia maritima* and *Senecio pseudo-arnica.* Backshores and other more protected areas have a much richer array of species, and many of the smaller brackish pools and wetlands support dense stands of various salt-tolerant species such as *Hippurus vulgaris.*

Tundra vegetation within the preserve is varied, largely because of the variety of substrates. Much of the lowland area is covered by tussock tundra, dominated by the clump-forming cottongrass *Eriophorum vaginatum* which is accompanied by a substantial lichen cover. Lichen cover in tussock tundra includes mixed *Cladina* and *Cladonia* spp. as well as *Cetraria laevigata*. Broad areas of tussock tundra have also been invaded by other vegetation communities. One invasive community type is low shrub vegetation, dominated by dwarf birch (*Betula nana*) and willow (mainly *Salix pulchra*). Low shrub vegetation is associated with a lichen community of mixed *Cetraria*s and *Cladonia*s, including *C. amaurocraea* and *C. maxim.* Two other invasive community types may be dominated by either various Ericaceae such as cranberries and blueberries (*Vaccinium vitis-idaea* and *V. uliginosum*) and Labrador tea (*Ledum* spp.) or by sedges such as *Carex bigelowii* and a variety of grasses. Lichen species composition in both ericaceous and sedge tundra is similar to that of tussock tundra vegetation; however, lichen cover in these communities is much less substantial. Recent studies have shown that tussock tundra that has burned may be replaced by shrub thickets.

Lava fields of the Quaternary age are quite extensive within the preserve. There is little cover of vascular plants in these situations, but there is extensive growth of lichens due to the presence of myriad natural grazing exclosures which have permitted development of late successional lichen mats up to 50 cm thick atop of rocks. Lichen species include *Cladina stellaris, Umbilicaria probiscidea, Melanelia stygia,* and *Cetraria hepatizon*.

The upland tundra of the area is complex. Outcrops of calcareous rock, although more common south of the preserve, generally support an array of specialized plants such as some Draba species, although the overall vegetation cover is generally thin and broken.

A unique lichen species composition is also associated with calcareous rock, including *Asahinea chrysantha, Thamnolia subuliformis, Cetraria nivalis, Cetraria tilesii,* and *C. cucullata*.

Low vegetation areas associated with the granitic slopes of the Bendeleben Mountains and Serpentine uplands exhibit lichen communities of up to 75% cover (Holt and McCune 2004). Where more neutral or acid rocks outcrop, or where there has been a deep buildup of peat, the normal array of typically low-Arctic tundra species. Prevalent in these communities are members of the Ericaceae which are accompanied by the lichens *Bryocaulon divergens* and mixed *Alectoria*s. Since the area lies in the heart of the Beringian region, famous for its endemic plant species, and since the climate is comparatively mild for the Arctic, the number of species known from the area is impressive, with at least 500 species.

Fauna

Wolverines (*Gulo gulo*), red fox (*Vulpes vulpes*), arctic fox (*Alopex lagopus*), muskrats (*Ondatra zibethicus*), arctic ground squirrels (*Spermophilus parryii*), and short-tailed and least weasels (*Mustela erminea* and *M. nivalis*) are common in the preserve.

Before the 1950s moose (*Alces alces*) were generally absent throughout northwestern Alaska, but in the past 30 years moose range has expanded dramatically (Coady 1980). Moose concentrate in winter along watercourses where they browse on willows in the riverine shrub thickets. During summer and fall moose may be more broadly distributed, but they still feed on willows in both lowlands and uplands. Within the preserve moose have been seen or their presence noted in all the major drainages (Melchior 1979) but generally not along the coast. An increase in moose harvest for both subsistence and recreational use has paralleled the expansion of moose populations on the peninsula.

Until the 1870s, the western arctic caribou herd (*Rangifer tarandus*) occupied most of the peninsula during the winter. Current estimates by ADF&G (2001) are 430,000 individuals. Winter ranges now extend from Kobuk and Nulato as far west as Serpentine Hot Springs (Western Arctic Caribou Herd Working Group 2003). Overlap between caribou wintering grounds and commercial reindeer on the Seward Peninsula has resulted in loss of commercial reindeer to the caribou herd (G. Finstad, unpublished data). Currently it is estimated that the total number of commercially herded reindeer on the peninsula has been reduced from over 20,000 in the early 1990s to 500 (G. Finstad, unpublished data).

Muskoxen (*Ovibos moschatus*) naturally occurred on the Seward Peninsula until they were extirpated in the early 1900s (Lent 1999). The State of Alaska reintroduced muskoxen to the peninsula with a release of 36 animals in 1970 and 35 animals in 1981 (Lent 1999). These introduced animals have grown in number to 2,050 individuals, distributed throughout the peninsula (2002 ADF&G survey data unpublished). Subsistence and sport hunting is currently allowed on muskoxen.

Wolves (*Canis lupus*) were known to range over the Seward Peninsula in historic times. However, the introduction of reindeer herds and a long history of predator control and bounties (lasting through the 1960s) have probably resulted in low wolf numbers in the preserve. ADF&G staff in Nome estimated that the wolf population on the peninsula in 1983 was 100 to 200. No surveys quantifying the wolf population have been conducted in recent years. Most wolves that are reported are found in the eastern part of the peninsula within spruce forest areas.

Brown bears (*Ursus arctos*) occur throughout the Seward Peninsula and in the preserve. Black bears (*Ursus americanus*), a more forest-oriented species, are not found in the preserve. Grizzlies typically tend to use river valleys or coastal areas after emerging from their upland winter hibernation dens. At this time they feed on carrion left from winter kills, on moose and reindeer calves, and on berries that stayed on the plants over the winter. In the summer, bears may move to coastal lowlands to graze on grasses and sedges or to concentrate along salmon streams. Current density estimates for grizzlies of all ages north of Nome are 29.1 bears/1,000 km^2 (Miller and Nelson 1993). Polar bears (*Ursus maritimus*) have not been officially documented in the park; however, it is extremely likely that they occur along the coastal areas of BELA.

Approximately 18 species of marine mammals use the waters of the Chukchi Sea and Kotzebue Sound, adjacent to BELA. Several species of marine mammals are found along the coast: ringed seals (*Phoca hispida*), bearded seals (*Erignathus barbatus*), spotted seals (*Phoca largha*), ribbon seals (*Phoca fasciata*). Beluga whales (*Delphinapterus leucas*), which are small whales (about 5 m long), occur throughout the Chukchi and Bering seas. Bowhead, gray, and finback whales have also been observed within the waters of the Chukchi Sea.

The Seward peninsula is an extremely rich and diverse area for birds. Approximately 129 bird species have been recorded as present within the preserve (Appendix 2), and another 23 species are thought to occur. Of the more than 350 species known in Alaska, at least 170 are known from the Seward Peninsula (Melchior 1979) and some 108 species have been recorded in and around the preserve. This diversity is related in part to the preserve's nearness to Asia and also to the occurrence of three distinctive habitats: marine/estuarine, tundra, and boreal forest. The Asian birds include some species that regularly migrate across the Bering Strait to breed on the peninsula. Some North American species go the opposite direction to Siberia or further to breed. Because of the harsh winter conditions, only five or six species are present throughout the winter season.

The marine/estuarine habitat, together with extensive freshwater ponds and lakes, provides resting, nesting, feeding, and molting grounds for large populations of migrating geese, ducks, and shorebirds. Many of the waterfowl species are important in local subsistence use. The salty grasslands and marshes at the mouths of the Nugnugaluktuk, Pish, and Goodhope rivers and Cape Espenberg are especially important for waterfowl adapted to estuarine conditions.

Colonies of seabirds are also found within the preserve, with the most important being on the Sullivan bluffs and Cape Deceit west of Deering. A large number of pelagic seabirds, including various species of gulls, can be found in the waters immediately off the Chukchi Sea coast.

The estuarine habitat along the preserve's Chukchi Sea coast and in the river deltas is very important for migrating and nesting waterfowl. These lagoons and estuaries are used as resting areas during northward and southward migrations.

The tundra habitat supports the majority of the preserve's passerine birds, as well as hawks, owls, and other predatory birds. Relatively few boreal forest birds are found within the preserve, but such species as the varied thrush, American robin, and an assortment of warblers are sometimes seen along the eastern boundary where "stringers" of white spruce forest extend near the preserve.

Literature Cited

Alaska Department of Fish and Game. 2001. Caribou management report of survey-inventory activities, 1 July 1998–30 June 2000. Project 3.0. Juneau, Alaska.

Coady, J.W. 1980. History of moose in northern Alaska and adjacent regions. *Can. Field Nat.* 94: 61–68.

Holt, E., and B. McCune. 2004. Macrolichen community structure and successional trends in Bering Land Bridge National Preserve, AK. PhD Thesis, Chapter 1. Oregon State University, Corvallis, OR.

Lent, P. 1999. Alaska's indigenous muskoxen: A history. *Rangifer* 18: 3-4.

Melchior, Herbert R. (ed.). 1979. *Biological survey of the Bering Land Bridge National Monument Final Report* CX-900-3-0316: Biology and Resource Management Program, Alaska Cooperative Park Studies Unit, University of Alaska Fairbanks.

Miller, S., and R. R. Nelson. 1993. A brown bear density and population estimate for a portion of the Seward Peninsula, Alaska. Alaska Department of Fish & Game Report. Anchorage, AK.

NPSpecies: The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/(certified organisms; accessed September 2004).

Roeder, Theodore, and Graham, E. A. Limnological Investigations. In Melchior, H. R., *Biological Survey of Bering Land Bridge National Moument: Revised Final Report.* Fairbanks, Alaska: Biology and Resource Management Program, Alaska Cooperative Park Studies Unit, University of Alaska Fairbanks, 1979; pp. 193–217.

Western Arctic Caribou Herd Working Group. 2003. Western arctic caribou herd cooperative management plan. Nome, AK. 33 pp.

Cape Krusenstern National Monument

Established: 1980, under ANILCA

Size: 236,448 hectares (584,276 acres)

Enabling Legislation

Cape Krusenstern National Monument was established in 1978 by presidential proclamation and then designated in the 1980 Alaska National Interest Lands Conservation Act (ANILCA, 16 USC 3101). Section 201(3) of ANILCA specifies that:

> *The monument shall be managed for the following purposes, among others: To protect and interpret a series of archeological sites depicting every known cultural period in arctic Alaska; to provide for scientific study of the process of human population of the area from the Asian Continent; in cooperation with Native Alaskans, to preserve and interpret evidence of prehistoric and historic Native cultures; to protect habitat for seals and other marine mammals; to protect habitat for and populations of birds and other wildlife and fish resources; and to protect the viability of subsistence resources. Subsistence uses by local residents shall be permitted in the monument in accordance with the provisions of Title VIII [of ANILCA].*

Purposes

- Protect and interpret a series of archeological sites depicting every known cultural period in arctic Alaska
- Provide for scientific study of the process of human population of the area from the Asian Continent
- Preserve and interpret evidence of prehistoric and historic Native cultures, in cooperation with Native Alaskans
- Protect habitat for seals and other marine mammals
- Protect habitat for, and populations of, birds other wildlife, and fish
- Protect the viability of subsistence resources

Ecological Overview

Cape Krusenstern National Monument is in northwest Alaska; its southeastern boundary lies approximately 15 km northwest of Kotzebue. The monument is bordered by the Chukchi Sea to the west and Kotzebue Sound to the south. To the north and east are the river drainages of the Wulik and Noatak rivers.

The monument is characterized by a coastal plain dotted with sizable lagoons and backed by gently rolling limestone hills. On the east, the coastal plain meets an ancient sea cliff now mantled with tundra and blue-gray limestone rubble. Mount Noak (elevation 613 m) in the southeast portion of the monument is the highest point.

Cape Krusenstern's bluffs and its series of 114 beach ridges show the changing shorelines of the Chukchi Sea and contain a chronological record of an estimated 6,000 years of prehistoric and historic uses of northwest Alaska's coastline, primarily by Native groups. The beach ridges along the monument's coast are known to contain exceptional resources for analyzing and interpreting the life cycles and technologies that ensured human survival in the Arctic for the last 60 centuries.

Along the shoreline of the monument, shifting sea ice, ocean currents, and waves have formed, and continue to form, spits and barrier islands that are considered important for their scientific, cultural, and scenic values. These same oceanic forces are integral to the dynamic nature of the beach ridges and the annual openings and closings of lagoon outlets.

The broad plain between the hills of the cape and the hills in the northern sector of the monument is the tundra-covered bed of a glacier, probably of Illinoisan age, and formed roughly 250,000 years ago. It is also the former (now dry) course of the Noatak River. Pingos, eskers, frost polygons, thermokarst lakes, and ice lenses are permafrost or glacial forms found in the monument. There are five rivers of moderate size located in the monument.

Climate

The climate of Cape Krusenstern is essentially maritime, influenced by the adjacent Kotzebue Sound and Chukchi Sea. Average daily temperatures in Kotzebue for the summer months (June, July, August) range from 7 to 12° C, with temperatures occasionally as high as 29° C. The coldest months are from January until early March, when average daily temperatures range between –40 and –18° C, with occasional lows in the –46° C range.

Precipitation in Kotzebue is light, with only about 23 cm falling annually. More than half of this moisture falls between July and September, when a warm, moist movement of air from the southwest predominates. August is the wettest month, with a mean monthly precipitation of 5.74 cm. In total, precipitation occurs on an average of 110 days per year. Snowfall can occur during 10 months of the year, July and August usually being the exceptions. Annual snowfall averages less than 127 cm.

Strong winds are common in the monument, particularly along the coastline, with mean annual speeds of approximately 13 mph. Mean monthly winds at Kotzebue are above 12 mph from September until April and blow from the east. Cyclonic storms are frequent during this time and are often accompanied by blizzard conditions. Wind speeds can reach 100 mph. Mean monthly wind speeds are comparable for the summer months but are from the west.

Freshwater Resources

The lands within the monument are drained by a number of streams that flow from the uplands and empty into the Chukchi Sea or coastal lagoons. During the ice-free season, some of these streams and associated coastal lagoons provide important habitat for anadromous and freshwater fish populations, birds, and terrestrial mammals. During the winter, streamflow at the surface ceases as waters freeze. In areas where substantial springs exist, water may continue to flow out at the surface and then freeze into successive thin sheets of ice forming aufeis areas. Both Jade and Rabbit creeks are subject to aufeis formation and have numerous channels and low intervening gravel bars.

Most of the streams in the monument are clear water streams, exhibiting low levels of suspended solids, turbidity, and nutrients. Water is highly oxygenated, moderately hard to hard, and of the calcium bicarbonate type. At the Red Dog Mine site outside the monument, waters are naturally contaminated with cadmium, lead, and zinc. This contamination occurs because the ore in the ground is of sufficient quantity and concentration to alter the water as it passes over the ore deposit. There are several large lagoons and a few small lakes located within the monument.

Ground water information for the monument is currently very scarce. Development of wells for public water supplies could be very costly.

The Alaska Natural Heritage Program (AKNHP) expected species list for freshwater/anadromous fish in the monument included 24 species; 18 of those have been documented. Their list of marine fish included 38 species, with only 8 species documented. Of primary importance to subsistence users are whitefish, including humpback whitefish (*Coregonus pidschian*), least cisco (*Coregonus sardinella*), Bering cisco (*Coregonus laurettae*), and broad whitefish (*Coregonus nasus*). They are taken seasonally at many locations, but Sheshalik Spit and Tukruk River are particularly important areas.

Arctic char (*Salvelinus alpinus*) are also important fish for local use, with quantities usually being taken at Sheshalik Spit. They are also found and spawn in Rabbit, Jade, and Kilikmak creeks and in the Situkuyok River. Arctic grayling (*Thymallus arcticus*) are known to overwinter in the Rabbit Creek drainage and in the streams draining the Igichuk Hills. All five salmon species are found within Kotzebue Sound. Spawning pink (humpy) salmon (*Oncorhynchus gorbuscha*) and chum (dog) salmon (*Oncorhynchus keta*) are found in the Wulik and Noatak Rivers, as are king (chinook) salmon (*Oncorhynchus tshawytscha*), and red (sockeye) salmon (*Oncorhynchus nerka*). Both chum and pink salmon most likely also occur in Rabbit Creek.

Northern pike (*Esox lucius*) are present in many streams in the monument south of Krusenstern Lagoon and east to Sheshalik Spit. Occasionally burbot (*Lota lota*) are found in the same areas (ADF&G 1978). Dolly Varden (*Salvelinus malma*) are known to spawn in Rabbit Creek. Herring (*Clupea* spp.) spawn in Krusenstern Lagoon and in the shallow coastal waters north of Sheshalik Spit, where sheefish (*Stendous leucichthys*) also overwinter. Other species that are occasionally used for human and dog food include saffron cod (*Eleginus gracilis*), arctic cod (*Boreogadus saida*), rainbow smelt (*Osmerus mordax*), starry flounder (*Platichthys stellatus*), four-horned sculpin (*Myoxocephalus quadricornis*), nine-spined stickleback (*Pungitius pungitius*), and herring. Some crabbing has been done in ice-free periods, but only with very limited success.

Geology

The geological framework of the northwest Alaska region was set in the late Paleozoic era, 520 million years before present. During the Triassic period, 225 million years ago, the site of the present Brooks Range was stabilized and limestone and chert were formed. The process of mountain-building began during the mid-Jurassic period. The land was intensely folded and faulted 135 million years ago, and the existing east-west fault trends within the area were established. In the late Miocene time, 25 million years ago, seas flooded much of the formerly dry area of the Chukchi zone but retreated somewhat to form a land bridge between Siberia and Alaska. This land area was again overlain by seas about four million years ago and remained so until approximately one million years ago. The ice advances that occurred repeatedly during later Pleistocene time, the last approximately one million years ago, caused a substantial drop in sea level and a consequent exposure of the lowlands of the land mass known as Beringia. The last retreat of the glaciers established the near present sea level by approximately 4,500 years ago.

Bedrock geology of the inland area north and east of the Krusenstern Lagoon includes rocks from Precambrian to Devonian times. Limestone, dolomite, chert, and phyllite are greatest in abundance. The southern extension of the Mulgrave Hills within the monument, known as the Tahinichok Mountains, contains dolomite, sandstone, shale, and limestone from the Devonian to Mississippian periods.

Glaciofluvial deposits are found over an area between the Noatak River to Kotlik Lagoon and between the Kilikmak and Jade Creek drainages. Within the monument this area was twice affected by glacial advances during the Pleistocene epoch. The first glacial advance occurred during the middle Pleistocene. This event occurred between 250,000 and 1,250,000 years ago. The second, and more recent, glaciation correlates with the Illinoisan glaciation of the central United States and occurred between 125,000 and 250,000 years ago. During both periods of glaciation large glaciers extended down the Noatak River drainage, across the lowland area east of the Kotlik Lagoon, and left the present glaciofluvial deposits. The monument has not been glaciated for approximately 125,000 years. An unusual feature within the monument is a recognizable Illinoian glacial esker or gravel ridge marking the bed of a subglacial stream. An esker of this age (over 100,000 years old) is rare.

The coastal area of the monument north of Kotzebue Sound is a beach ridge plain, which has received sediments deposited by longshore currents over the last several thousand years. The primary purpose of the Cape Krusenstern National Monument is to protect and interpret this beach ridge complex, which contains archeological sites depicting every known cultural period in arctic Alaska over a 6,000-year period.

Soils

The major soil types associated with the monument include upland or mountain slope soils and those associated with the lowland areas nearer the coast. The lower slopes of the western Igichuk Hills and the Mulgrave Hills where soil has developed are covered with poorly drained, gravelly or loamy soils with a surface layer of peat. Depth to permafrost is variable. The upper slopes of these hilly areas have well-drained gravelly or loamy soils with a deep permafrost table. There are also extensive areas of exposed limestone bedrock, or bedrock mantled with fine to coarse rubble, where zonal soils have not developed.

Along the coastline of the monument and flanking Krusenstern, Kotlik, and other major lagoons are marine and alluvial deposits that form beaches, spits, and deltas. Soils of lowland areas along the coast are poorly drained, with a surface layer of fibrous peat and a shallow permafrost table. The peat layer ranges from 20 to 61 cm in depth.

Permafrost plays an important role in the topographic development and appearance of lands within the monument. The lowland areas of the monument are underlain by thick continuous permafrost. Permafrost can reach depths of 610 m, but generally reaches a maximum depth of 427 m within the inland portions of the monument. At nearby Kotzebue, permafrost depths are generally less than 73 m because of saltwater intrusion at that depth (City of Kotzebue 1971).

A variety of permafrost features are evident within the monument, particularly in the lowland areas. These include thaw lakes, ice polygons, pingos, frost mounds, and solifluction lobes. Many of these features are caused by localized melting of ground ice, resulting in thermokarst formation.

Vegetation

Cape Krusenstern National Monument lies almost entirely within the tundra zone, with only a few of the northwesternmost outliers of the boreal forest reaching its eastern boundary. The only forest trees are scattered white spruce (*Picea glauca*) at the absolute northern and western limit of arborescent conifers in North America.

Although typical boreal forest is mostly absent from the area, extensive stands of tall willow occur along the many small watercourses that drain into the Noatak River from the eastern side of the monument and into the lagoon systems and the Chukchi Sea of the western side. These riparian willow thickets may reach a height of 3 to 6 m; they are important winter habitat for moose. The main willow species include *Salix alaxensis, S. arbusculoides,* and especially along the smaller streams, *S. pulchra.* Along shaded, north-facing slopes and around the edges of snow beds, alder (*Alnus crispa*) may form fairly extensive thickets.

Tussock tundra occurs extensively on the lower slopes of many of the hills, especially where the substrate is noncalcareous. Tussock tundra is usually dominated by a single species of cottongrass, *Eriophorum vaginatum,* which forms tussocks 10 to 50 cm high, separated from each other by a network of wet ditches that often hold water and provide a breeding ground for mosquitos. The tussocks are unstable and make walking difficult, especially in summer. Tussock tundra is often invaded by shrubs, especially *Ledum* spp. and dwarf birch (*Betula glandulosa*) and by some sedges such as *Carex bigelowii.* This suggests that "pure" tussock tundra needs to be rejuvenated occasionally by frost soil disturbances or fire. However, there is also evidence that fire may encourage the replacement of tussock tundra by shrubs under some circumstances.

The majority of the alpine area of Cape Krusenstern National Monument is calcareous uplands, often beginning on the slopes of low hills within 100 meters or less of sea level. Vegetation cover of vascular plants in these situations is often less than 1%, and even lichens are poorly developed and consist mainly of crustose forms. Common plants in these desert-like situations include a variety of calciphiles such as *Draba* species, *Smelowskia* species, and certain *Saxifraga* species, as well as a few sedges (*Carex* spp.) and other graminoids. Based on NPS's most recent landcover product (Jorgenson et al. 2004), it appears that a typical range of calcareous substrate Brooks Range lichens should be present at upper elevations in the southern part of the monument. However, to date almost no lichenological or bryological work has occurred in CAKR. Alpine areas along the eastern boundary of the monument tend to be underlain by less calcareous rocks and support a more typical array of alpine species, including many *Ericaceae* such as bell heather (*Cassiope tetragona*), *Arctostaphylos* species, and mountain cranberry (*Vaccinium vitis-idaea*).

The inland portion of the area has many small lakes, and some of these are unusual in that they support populations of the tiny, floating, unrooted angiosperms known as duckweeds (*Lemna* spp.) These do not normally occur under tundra conditions, and it may be that their populations are regularly reestablished by migratory waterfowl.

The Cape Krusenstern area has a broad array of coastal vegetation types, many of which cover extensive areas. The more active beach ridges are dominated by stands of Lyme grass (*Elymus arenarius*), which is an important dune stabilizer on beaches around much of the circumpolar north. Elymus is also common on the more stable inland beach ridges, but it shares this habitat with a much broader array of species than occur on the dunes and foreshores. Especially important on the ridges are cinquefoil (*Potentilla* spp.) fireweed (*Epilobium angustifolium*), and several species of wormwood (*Artemisia* spp.). The swales between ridges often support low willow thickets (mainly *Salix pulchra*) and a wide variety of species typical of mesic or wetland habitats.

The array of marsh, shoreline, and shallow-water aquatic vegetation within the monument is extensive and is complicated by the widely variable salinity of various portions of the lagoon systems and coastal marshes. Small amounts of eelgrass (*Zostera marina*) have been observed along some lagoon shores, and this plant may be of some importance to migrating waterfowl. Important wetland and emergent plants, including several sedges (*Carex* spp.), marestail (*Hippurus vulgaris*), and groundsel (*Senecio congestis*) occur in these areas of the park.

Lichens are generally sparse in the abundant wet communities in the monument. The nonvascular plant communities of CAKR are dominated by bryophytes, as the majority of this unit consists of wet tussock tundra or mixed tundras. Mosses have been used to document heavy metal deposition from the Red Dog Mine haul road and port site (Hasselbach et al. 2004). Elevated values of Pb and Cd raise concerns about bioconcentration, especially among high consumers of nonvascular plants such as muskox. Lacking a root system, nonvascular plants get all of their mineral nutrition from the atmosphere and water via direct absorption, and are adept at high levels of mineral uptake. This puts them at far greater risk of heavy metal uptake than vascular plants.

Cape Krusenstern lies near the heart of the Bering Strait region, whose flora has long been recognized as being exceptionally rich and containing many endemic species. A number of these are known from or can be expected to be found within the monument. Examples include *Primula borealis* and *Douglasia ochotensis.*

Fauna

Red fox (*Vulpes vulpes*), arctic fox (*Alopex lagopus*), snowshoe hare (*Lepus americanus*), and arctic hare (*Lepus othus*) are present within the monument. The arctic fox generally prefers coastal and delta areas, but can be found in other areas of the park. Although dens are found within the monument, the arctic fox spends much of its time searching on the ocean ice for carrion. Snowshoe hares are found in the western Igichuk Hills in timbered areas and within large patches of willow near the coast. The arctic hare inhabits the monument east of Krusenstern Lagoon and in other areas where willow, alder, and spruce are located. Wolverine (*Gulo gulo*) are harvested within the monument despite limited populations. Porcupines (*Erethizon dorsatum*) are numerous in the monument and feed on the bark of willow and spruce. Usually restricted to the timber zones, porcupines are sometimes seen along the beach areas in mid-summer. Weasels, minks (*Mustela vison*), lynx (*Lynx canadensis*), river otters (*Lontra canadensis*), and muskrats (*Ondatra zibethicus*) are also found within the boundaries of the monument.

Wolves (*Canis lupus*) inhabit the major drainages within the monument. Food sources for wolves include caribou (*Rangifer tarandus*), moose (*Alces alces*), hare, microtines, and salmon, depending on availability. The number of wolves in the monument is unknown since no surveys have been conducted to quantify the current population.

Grizzly bears (*Ursus arctos*) occur in the monument and are often seen along stream courses and along the shoreline adjacent to mountainous terrain. It is estimated that the density of age three and older bears on the northern border of the park is one per 66.5km^2 (Ballard et al. 1993). Grizzly bears have an omnivorous diet. During the summer months they forage for grasses, shrubs, and riparian vegetation. Salmon, ground squirrels (*Spermophilus parryii*), carrion (including marine mammals washed ashore), and berries are often eaten in the fall. There are no recorded sightings of black bears (*Ursus americanus*) within the monument. Polar bears (*Ursus maritimus*) have been seen off the coast of Cape Krusenstern but have not been officially documented within the park boundaries.

Moose within the region are most abundant in areas of transitional vegetation, which include mixed willow and spruce forests. Although these areas are limited within the monument, moose numbers have increased in recent years. Uhl and Uhl (1980) report that moose were generally not known to occur within the area now encompassed by the monument until 1947. Although moose have been used as a source of meat by subsistence hunters near the monument during years when caribou were scarce, caribou are preferred by local residents.

Caribou found within the monument are part of the western arctic herd that ranges over the entire northwest Alaska region. The herd declined from a population of at least 242,000 in 1970 to an estimated 75,000 in 1976. Since that time the herd has increased in size and was estimated to be 430,000 in 1999 (Western Arctic Caribou Herd Working Group 2003). In modern times, caribou were first reported moving in the area encompassed by the monument in 1949 (Uhl and Uhl 1980). In general, the movement of the western arctic herd in the area of the monument varies greatly from year to year.

Dall's sheep (*Ovis dalli*) are present throughout the Baird and DeLong mountains west to the Wulik Peaks; the area is the northwestern limit of their range. Dall's sheep feed on grasses, forbs, lichens, and willow. The sheep remain near rugged and rocky areas, which provide escape routes from wolves, bears, and other predators.

The last naturally occurring musk-ox in Alaska died in 1865, but muskox were reintroduced to the state from Greenland starting in 1936. The release of 36 muskox (*Ovibos moschatus*) near Cape Thompson in 1970, and a second release of 30 animals in the same area in 1977, have resulted in a significant muskoxen herd within the monument. The 2000 summer survey of the Cape Krusenstern and Cape Thompson areas estimates the population to be 424 individuals (B. Shults, unpublished data).

Approximately 18 species of marine mammals use the waters of the Chukchi Sea and Kotzebue Sound, adjacent to CAKR. Several species of marine mammals are found along the coast in Cape Krusenstern: ringed seals (*Phoca hispida*), bearded seals (*Erignathus barbatus*), spotted seals (*Phoca largha*), and ribbon seals (*Phoca fasciata*). Walrus are uncommon off Cape Krusenstern, although stray animals and carcasses washed ashore are taken for their ivory, blubber, and meat.

Beluga whales (*Delphinapterus leucas*), which are small whales (about 5 m long), occur throughout the Chukchi and Bering seas. A few beluga are taken from year to year along the monument's coastline when the shoreline becomes ice free or when they appear in open leads in the ice during sealing season (Uhl and Uhl 1980). Bowhead, gray, and finback whales have been observed within the waters of the Chukchi Sea off Cape Krusenstern.

Most birds found in the monument are summer nesters or migrants. Moist tundra lowlands and wet sedge meadows near the coast are especially important habitat areas. Currently it is estimated that approximately 132 bird species have been recorded as present within the preserve (Appendix 2), and another 18 species are thought to occur.

Although the importance of the monument to migrating birds in the spring probably varies with snow and ice conditions, the lagoons between Cape Krusenstern and Sheshalik are heavily used by migrating waterbirds when conditions permit. This area is also an important subsistence hunting area for waterfowl and as an egg-gathering area. It is an important fall staging area for thousands of geese, ducks, shorebirds, and gulls.

Literature Cited

Alaska Department of Fish and Game. 1978. *Alaska's fishery atlas, vols. I and II.* Anchorage, Alaska.

Ballard, W.B., L.A. Ayres, D.J. Reed, S.G. Fancy, and K.E. Roney. 1993. *Demography of grizzly bears in relation to hunting and mining development in northwestern Alaska.* Scientific Monograph NPS/NRARO/NRSM-93/23. U.S. Department of the Interior, National Park Service.

City of Kotzebue. 1971. *Comprehensive development plan.* Prepared by the Alaska State Housing Authority. Anchorage, Alaska.

Hasselbach, L., Ver Hoef, J., Ford, J., Neitlich, P., Crecelius, E., Berryman, S., Wolk, B., and Bohle, T. 2004. Spatial patterns of cadmium and lead deposition on and adjacent to National Park Service lands near Red Dog Mine, Alaska: NPS Final Report. Resource Report, NPS /AR /NRTR-2004-45. July 2004. U.S. Department of the Interior/National Park Service/Alaska Region.

Jorgenson, M. T., Roth, J. E., Emers, M., Davis, W., Schlentner, S. F., and Macander, M. J. 2004. Landcover mapping for Bering Land Bridge National Preserve and Cape Krusenstern national monument, Northwestern Alaska. Final Report. Prepared for National Park Service 240 West 5th Avenue, Anchorage, Alaska 99501. ABR, Inc.—Environmental Research & Services, P.O. Box 80410, Fairbanks, AK, 99708, November 2004.

NPSpecies: The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/ (certified organisms; accessed September 2004).

Uhl, William R. 1979. *The Noatak National Preserve: Nuatakmiit: A study of subsistence use of renewable Resources in the Noatak River Valley.* Occasional Paper No. 19, University of Alaska Cooperative Park Studies Unit, Anthropology and Historic Preservation.

Uhl, W.R., and C.K. Uhl. 1980. *Tagiumsinaagmiit, ocean beach dwellers of the Cape Krusenstern Area: Subsistence patterns.* University of Alaska, Cooperative Studies Unit. Fairbanks, AK.

Western Arctic Caribou Herd Working Group. 2003. Western arctic caribou herd cooperative management plan. Nome, AK. 33 pp.

Gates of the Arctic Park and Preserve

Established: 1980, under ANILCA

Size: 3,323,270 hectares (8,211,974 acres)

Enabling Legislation

Gates of the Arctic Park and Preserve was established by the Alaska National Interest Lands Conservation Act (ANILCA), Public Law 96-487. Section 201(4)(a) of this act directs the following:

> *The park and preserve shall be managed for the following purposes, among others: To maintain the wild and undeveloped character of the area, including opportunities for visitors to experience solitude, and natural environmental integrity and scenic beauty of the mountains, forelands, rivers, lakes, and other natural features; to provide continued opportunities, including reasonable access, for mountain climbing, mountaineering, and other wilderness recreational activities; and to protect habitat for and the populations of, fish and wildlife, including, but not limited to, caribou, grizzly bears, Dall's sheep, moose, wolves, and raptorial birds. Subsistence uses by local residents shall be permitted in the park, where such uses are traditional, in accordance with the provisions of title VIII.*

Purposes

- Maintain the wild and undeveloped character of the area, including opportunities for visitors to experience solitude, and the natural environmental integrity and scenic beauty of the mountains, forelands, rivers, lakes, and other natural features
- Provide continued opportunities, including reasonable access, for mountain climbing, mountaineering, and other wilderness recreational activities
- Protect habitat for and populations of fish and wildlife, including, but not limited to, caribou, grizzly bears, Dall's sheep, moose, wolves, and raptorial birds

Ecological Overview

Gates of the Arctic Park and Preserve is located just north of the Arctic Circle in the northernmost stretch of the Rocky Mountains, the Brooks Range. The entire Noatak River drainage, whose headwaters lie within the park, is internationally recognized as a biosphere reserve in the United Nation's Man in the Biosphere program.

Two sites within the park and preserve were designated national natural landmarks in April 1968—Arrigetch Peaks (15135 ha) and Walker Lake (73297 ha). In addition, several other sites have been identified as potential natural landmarks: Anaktuvuk River; Castle Mountain; Fortress Mountain; Monotis Creek; Noatak, Sagavanirktok-Itkillik, Alatna, Nigu and Killik River headwaters; Anaktuvuk, Cocked Hat and Limestone mountains; Kipmuik, Kurupa, Wild and Cascade lakes; Hickel Highway; Mount Igikpak; North Fork Koyukuk Pingos; Redstar Mountain; and Reed River Hot Springs.

Climate

The central Brooks Range has long winters and relatively short cool summers. The entire region receives continuous sunlight during the summer for at least 30 days. Precipitation on the south side of the Brooks Range averages 30 to 46 cm in the west and 20 to 30 cm in the east. Snow falls at least eight or nine months of the year, averaging 152 to 203 cm. The average maximum and minimum July temperatures are approximately 18 to 21° C and 6 to 8° C, respectively. Average maximum and minimum January temperatures are approximately –18 to –23° C and –29 to –34° C. Thunderstorm activity is common during June and July, and generally June through September is the wettest time of year. Prevailing winds are out of the north.

The north side of the Brooks Range has an arctic climate. The influences of the Arctic Ocean and North Slope weather patterns predominate, especially during the summer months. Mean annual temperatures are colder than on the south side. Average maximum and minimum February temperatures are –21 to –23° C. The warmest month, July, has average maximum temperatures of 13 to 18° C and average minimum temperatures of 0 to 8°C. Precipitation is extremely light, about 13–26 cm a year. Average annual snowfall ranges from 89 to 127 cm. Prevailing winds come from the east in summer and west in the winter months.

Freshwater Resources

Tributaries of four major river systems originate in the park and preserve. To the north the Nigu, Killik, Chandler, Anaktuvuk, and Itkillik rivers drain to the Colville River. The Noatak River flows west and the Kobuk River southwest, both from the headwaters in the western part of the park. The Reed and the Noatak rivers both start as glacial run-off from the flanks of Mount Igikpak. Here you see the start of the Reed as it flows south. The approach to Igikpak is to the left. The John, Alatna, and North Fork of the Koyukuk rivers drain south to the Yukon River. Six rivers within the park boundary are designated as Wild and Scenic: Alatna, John, Kobuk, Noatak, North Fork of the Koyukuk, and Tinayguk rivers. The John River may have some water quality issues arising from the village of Anaktuvuk Pass. The Middle Fork and North Fork of the Koyukuk may show some effects from placer mining.

Three warm springs are located within the park and preserve. The Reed River spring is located near the headwaters of the Reed and had a measured water temperature of 50° C at the warmest pool (NPS 1982). A warm spring is also located on the lower Kugrak River and another near the Alatna River.

The expected species list for the fishes of GAAR developed by the Alaska Natural Heritage Program included 16 species, of which 14 were documented (88%). More common fish species include: arctic grayling (*Thymallus arcticus*), lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), arctic char (*Salvelinus alpinus*), whitefish (*Coregonus* spp.), sheefish (*Stenodus leucichthys*), salmon (*Oncorhynchus* spp.), long-nosed sucker (*Catostomus catostomus*), burbot (*Lota lota*), nine-spined stickleback (*Pungitius pungitius*), and slimy sculpin (*Cottus cognatus*).

The Kobuk and Koyukuk rivers are major chum salmon spawning streams. Sheefish also spawn in the Kobuk. These fish, along with the whitefish, are the most important subsistence fishes. Some lake trout and arctic char are also taken from lakes for subsistence use. Recreational fishing is primarily for arctic grayling, arctic char, sheefish, and lake trout.

Geology

The central Brooks Range is a remote area of rugged, glaciated east-trending ridges that rise to elevations of 1,220 to 2,438 m or more. This range is part of the Rocky Mountain system that stretches completely across the northern part of Alaska. Gates of the Arctic National Park and Preserve spreads across three physiographic provinces: Arctic Foothills, Arctic Mountain, and Western Alaska (NPS, USDI 1974). Two primary mountain ranges make up the central Brooks Range-the Endicott and Schwatka mountains. Several episodes of uplift, deformation, and intrusion have produced complex patterns of folding, fracturing, and overlapping thrust fault blocks. Uplift, erosion, and heavy glaciation account for the rugged mountain profiles and U-shaped valleys evident today. Metamorphic rocks, primarily quartz mica schist and chloritic schists, belt the south flank of the range. There are also a few small bodies of marble and dolomites. Granitic intrusion created the rugged Arrigetch Peaks and Mt. Igikpak areas.

Four major glaciations have been recognized within this region of the Brooks Range. The first glaciation (Anaktuvuk River) took place more than one-half million years ago. The second (Sagavanirktok River) is thought to be broadly equivalent to the Illinoisian glaciation of central North America. The last two glacial periods (Itkillik and Walker Lake) are thought to correlate with the Wisconsin advance in central North America (Geological Survey, USDI 1979). Glaciers were generated at relatively high altitudes near the crest of the range during the more extensive glaciations. Ice flowed from these sources southward through the major valley systems to terminate at and beyond the south flank of the range. Terminal glacial moraines created dams that formed large lakes along the southern foothills.

The primary metallic minerals found within the region include copper, gold, lead, and zinc. The major known deposits of minerals occur in a schist belt that generally lies south and west of the park in the Ambler mining district and may extend into the unit.

Soils

Soils within the park are highly variable, depending on topography, drainage, aspect, fire history, permafrost, and parent material. The classification used by the U.S. Department of Agriculture, Soil Conservation Service (1979) indicates that most of the park lies within a zone characterized by rough mountainous land with thin, sandy soils on hilly to steep topography. The soils are often composed of poorly drained, very gravelly loam on hilly moraines and south-facing colluvial slopes. A thin peaty mat is underlain by sandy loams and occasional lenses of permafrost.

Lower elevation benches and rolling uplands are covered by a gray to brown silty loam overlaid by a peaty organic layer that varies in depth depending on the local environment. The soil surface is irregular, with many low mounds, solifluction lobes, and tussocks.

Soils in the park overlie thick continuous permafrost zones that sometimes lie less than 10 cm below the surface. These soils have been subjected to long periods of soliflucition, the gradual downslope creep by frost-shattered rock and debris, and to a constant seasonal process of freezing and thawing. Lower elevation sediments have combined over time with windblown silts, river and glacial deposits, and peat accumulations. The processes of frost heaving and sorting, ice lens or wedge formations, and stream erosion have worked these soils into a complex mosaic of roughly textured tundra polygons, pingos, oxbows, and terraces. Almost totally underlain by permafrost, the soils adjacent to the valley floodplains are highly susceptible to thermokarst formation, due to warming of the ground and subsequent soil collapse.

The northern area of the park, primarily the upper Noatak River drainage, contains poorly drained soils formed from very gravelly glaciofluvial material derived from limestone rock in the surrounding mountains. A few well-drained soils are found in very gravelly, nonacid and calcareous drift on hilly moraines. Fibrous peat soils are located in shallow depressions on terraces.

Vegetation

Gates of the Arctic National Park and Preserve lies far from the influence of the Arctic Ocean and the Chukchi Sea, and its climate is more continental than that of other parks in northern and western Alaska. Most of the area lies within the Brooks Range, and the cool, short summers at higher elevations do not encourage tree growth. Instead, various forms of alpine tundra dominate.

At elevations of less than approximately 500 to 800 meters along the south slopes of the Brooks Range, and especially along the Koyukuk River and its tributaries, the boreal forest of interior Alaska is an important vegetation type. In drier, well-drained sites, this is dominated by white spruce (*Picea glauca*). In some locations, especially those that have been subject to fire at some time, stands of white birch (*Betula papyrifera*) and aspen (*Populus tremuloides*) may occur, with aspen predominating on the driest slopes and river bluffs. Black spruce (*Picea mariana*) forms nearly pure stands in poorly drained river bottoms and on some cool slopes. Occasional stands of balsam poplar (*Populus balsamifera*) occur along the banks of the larger rivers and as isolated stands on sunny slopes near timberline in some of the upper reaches of stream valleys. These forest communities feature a broad spectrum of epiphytes from genera including *Bryoria, Hypogymnia, Leptogium, Parmelia, Parmeliopsis, Cladonia,* as well as some cyanolichens.

The same general lichen species composition is found in the various types of scrub and brushland, which are very extensive along watercourses and on many slopes near and immediately above timberline. This type of vegetation is often classified as a form of tundra, but it is so extensive and well-developed in the central Brooks Range that it is best treated as a distinct vegetation type, containing several subcategories.

Riparian willow thickets are extensively developed along many of the watercourses in the area. In larger streams that have built-up gravel bars, the dominant species is usually *Salix alaxensis,* although several other species may be found, especially on the less stable bars and shores. These thickets serve as small forests, with a distinct understory comparable to that of spruce forests. In the western portion of the area, especially in the upper reaches of the Noatak drainage, there are broad areas of silt and other alluvium derived from calcareous rocks of nearby mountains. These lowlands often support willow stands dominated largely by *Salix glauca* but again with several other species also represented. In the upper reaches of small streams, the lower-growing *Salix pulchra* dominates, and this type of vegetation shades into shrub tundra. Riparian willow thickets are found throughout Gates of the Arctic Park and Preserve and extend northward beyond its boundaries, especially along the Colville River and its tributaries. Less stable river bars support a typical array of disturbance-tolerant species, especially dwarf fireweed (*Epilobium latifolium*), several legumes of the genera *Oxytropis, Astragalis,* and *Hedysarum,* and *Compositae,* such as *Aster sibiricus.*

On moister slopes, especially those in narrow stream valleys and those that face to the north, alder thickets are extensive. The important shrub species here is *Alnus crispa,* which may reach a height of two to three meters; it is often very dense and difficult to travel through. Alder slopes occur mainly south of the Continental Divide and are especially well-developed in the upper Noatak Drainage.

Low stature, treeless vegetation occurs in several distinct forms within the area. At low elevations in the southern portion of the park, the boreal forest is often interrupted by extensive areas of muskeg and wet marsh, especially on river flats and old stream channels. Muskeg is a dense peatland vegetation, sometimes including a few trees (mostly black spruce). It tends to be dominated by ericaceous shrubs such as *Ledum* species, tundra blueberry (*Vaccinium uliginosum*), mountain cranberry (*Vaccinium vitis-idea*), and tussock-forming cottongrass (mainly *Eriophorum vaginatum*) and sedges. Mosses, especially *Sphagnum* spp., are an important component of the vegetation. In contrast to the tussock and wet sedge/ericaeous tundra of BELA, these vegetation types in GAAR are virtually depauperate of lichens.

Gates of the Arctic contains an enormous array of treeless vegetation types that can be generally lumped under the term alpine tundra. The area is farther from the heartland of the richly endemic Beringian flora than the other parks and preserves in northwestern Alaska, but the size of the preserve and the rich array of alpine and arctic habitats ensures that a wide variety of alpine tundra vegetation types and species is found within the area. The classification of alpine tundra vegetation and lichen communities is complex and usually concerns the rock type of the substrate (carbonate versus noncarbonate, plus special types such as serpentine), exposure and drainage (e.g., snowbed and seepage areas versus dry ridges and scree), and climatic factors based on elevation and latitude.

Lichen community structure is correlated with substrate in alpine tundra environments. Rocky environments with sparse vascular vegetation and a sod substrate are associated with *Bryocaulon divergens, Alectoria ochroleuca* and *A. nigricans.* Similar rocky environments, but with a saxicolous (siliceous) substrate, support *Umbilicaria probiscidea, Melanelia stygia,* and *Cetraria hepatizon*.

In the Gates of the Arctic, open slopes immediately above the tree and brush line support a rich complex of graminoids and forbs, which include all or most of the characteristic circumpolar low-arctic species, as well as some of the more narrowly endemic Beringian plants. Examples of the former are grasses such as *Arctagrostis latifolia, Deschampsia caespitosa,* and many *Calamagrostis, Poa,* and *Festuca* species, sedges such as the cottongrasses (*Eriophorum* spp.), and many true sedges (*Carex* spp.). Dwarf shrubs such as Labrador tea (*Ledum* spp.), tundra blueberry (*Vaccinium uliginosum*), mountain cranberry (*V. vitis-idaea*), bearberry (*Arctostaphylos* spp.), and arctic heather (*Cassiope tetragona*) are common in lower and less exposed sites. Open low shrub dominated mesic communities are associated with mixed *Cetraria*s and *Cladonia*s. Forbs include many species of buttercup (*Ranunculus* spp.), saxifrage (*Saxifraga* spp.), cinquefoil (*Potentilla*), lousewort (*Pedicularis* spp.), and groundsel (*Senecio* spp.). At the higher elevations and in more exposed areas, the narrower array of circumpolar high-arctic species is well represented, as are the characteristic lichens. At high elevations (up to 8500 ft.) the arctic-alpine zone is dominated by crustose lichen zone.

Fauna

The medium-sized mammal species common in Alaska are present in GAAR, although many, such as the marten (*Martes americana*) and lynx (*Lynx canadensis*), are mostly limited to the forested areas in the southern half of the park. Beaver (*Castor canadensis*), mink (*Mustela vison*), and otter (*Lontra canadensis*) are present but are limited by a scarcity of low-gradient aquatic habitats. Red foxes (*Vulpes*

vulpes), occur throughout the area, and arctic foxes (*Alopex lagopus*) occur occasionally in the northernmost parts of the park and preserve. Wolverines (*Gulo gulo*) are present throughout. The species most important for subsistence users within the park are marten, lynx, wolverine, fox, and wolf (*Canis lupus*).

Wolves occur throughout the park and preserve. Their main prey in the central Brooks Range and North Slope is caribou (*Rangifer tarandus*) or moose (*Alces alces*), depending on family group. However, other prey species may be used extensively if these prey are not available; principally Dall's sheep (*Ovis dalli*) and small mammals in the north and moose, snowshoe hare (*Lepus americanus*), and beaver in the southern forested areas. Wolves are a source of income for rural residents who trap and hunt them.

Brown bears (*Ursus arctos*) occur throughout the park and preserve but are most commonly found in open alpine or tundra habitats. Black bears (*Ursus americanus*), which are more common in the southern forested regions, have similar food habitats and behavior to brown bears. In the Brooks Range brown bears feed mostly on berries, sedges, and small mammals. Bears will kill moose calves and caribou fawns and occasionally adults. Some scavenging also occurs. Populations of both bear species are extremely difficult to count; however, hunting of bears is permitted within the park under federal subsistence and state regulations.

Moose, Dall'ssheep, and caribou are the three ungulates occurring in the area. Moose are most common in the forested regions south of the Brooks Range, but their range extends up mountain valleys and into the larger northern drainages. In summer, moose frequently move into alpine habitat, although they are uncommon at the crest of the range. The most important moose concentrations are found along the Alatna, John, North Fork of the Koyukuk, Killik, and Itkillik rivers. Moose are an important subsistence resource for villages south and west of the park, as well as the residents of Anaktuvuk Pass.

Dall'ssheep are widespread throughout the mountainous alpine areas of the park and preserve. Rugged terrain with cliffs, steep slopes, and rocky outcrops is essential escape habitat. There are no current sheep population estimates for the park, but in 1983 there were an estimated 14,000 animals living in the park and preserve. Sheep can be harvested by qualified subsistence users, and by sport hunters in the preserve portion of GAAR.

Caribou of the western arctic herd range over the majority of the park. In 1999 the herd was estimated at 430,000 animals (ADF&G 2001). The herd migrates through GAAR as it moves from wintering grounds south and west of the park to calving areas northwest of the park and to the summer range north of the park. Some of the animals use the northern reaches of the park as part of their summer range, and some winter in the southern part of the park, especially in the Kobuk River valley. Caribou of the central arctic herd use the northeastern and southeastern part of the park during winter. This herd numbered about 14,000 in 1983 and had increased to 27,000 animals by 2000 (ADF&G 2001). Caribou from the Teshekpuk herd (27,000 animals; ADF&G 2001) can also be found using portions of the park. The principal habitat of this herd is north of the park. Caribou have historically played an important role in human survival in arctic regions, and modern subsistence users still rely heavily on them.

Birds

Approximately 130 bird species are documented as having been observed within the park. Nearly half of those recorded are normally associated with aquatic habitats. It is thought that as many as 150 bird species could be found within GAAR (Tibbitts et al. 2003). GAAR provides montane nesting habitat for numerous species with breeding ranges limited to Alaska, such as the surfbird and Smith's longspur (Tibbitts et al. 2003).

Prior to current efforts, Gates of the Arctic National Park and Preserve was largely unsurveyed, leaving a gap in our knowledge of the breeding distribution and habitat requirements of many migrant and resident bird species. I&M and the Park Flight Program recently provided support for bird inventories within GAAR. Fieldwork for a three-year montane-nesting bird inventory was completed in 2003, with data analysis and final report compilation occurring in 2004. The pilot year for a land bird inventory occurred in 2003, with larger efforts scheduled for 2004 and project completion scheduled for 2005.

Literature Cited

ADF&G. 2001. Caribou management report of survey-inventory activities 1 July 1998–30 June 2000. C. Healy, editor. Project 3.0. Juneau, Alaska.

Lent, P. 1999. Alaska's indigenous muskoxen: A history. *Rangifer* 18: 3-4.

Geological Survey, U.S. Department of the Interior. 1979. Surficial geologic map of the Wiseman quadrangle, Alaska. Miscellaneous field studies, MF-1122.

National Park Service, U.S. Department of the Interior. 1982. Special report on Reed River Hot Springs, Gates of the Arctic National Park and Preserve. Denver Service Center, Branch of Special Programs. Denver, Colorado.

NPSpecies: The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/ (certified organisms; accessed September 2004).

Rieger, S. D. C., D. B. Schoephorster, and C. E. Furbush. 1979. Exploratory soil survey of Alaska. Soil Conservation Service, U.S. Department of Agriculture.

Tibbitts, T. L., D. Ruthrauff, R. E. Gill, and C. M. Handel. 2003. Inventory of montane-nesting birds in National Parks of Northwest Alaska: A summary of the 2001 and 2002 field efforts. U.S. Geol. Surv., Alaska Science Center, Anchorage, AK.

Kobuk Valley National Park

Established: 1980

Size: 675,747 hectares (1, 669,808 acres)

Enabling Legislation

Kobuk Valley National Park was established by the Alaska National Interest Land Conservation Act (ANILCA), Public Law 96-487. Section 201(6) of this act directs the following:

> *Kobuk Valley National Park shall be managed for the following purposes, among others: To maintain the environmental integrity of the natural features of the Kobuk River Valley, including the Kobuk, Salmon, and other rivers, the boreal forest, and the Great Kobuk Sand Dunes, in an undeveloped state; to protect and interpret, in cooperation with Native Alaskans, archeological sites associated with Native cultures; to protect migration routes for the Arctic caribou herd; to protect habitat for, and populations of, fish and wildlife including but not limited to caribou, moose, black and grizzly bears, wolves, and waterfowl; and to protect the viability of subsistence resources. Subsistence uses by local residents shall be permitted in the park in accordance with the provisions of title VIII. Except at such times when, and locations where, to do so would be inconsistent with the purposes of the park, the Secretary shall permit aircraft to continue to land at sites in the upper Salmon River watershed.*

Purposes

- Maintain the environmental integrity of the natural features of the Kobuk River Valley, including the Kobuk, Salmon, and other rivers, the boreal forest, and Great Kobuk Sand Dunes, in an undeveloped state
- Protect and interpret, in cooperation with Native Alaskans, archeological sites associated with Native cultures
- Protect migration routes for the arctic caribou herd
- Protect habitat for, and populations of, fish and wildlife including but not limited to caribou, moose, black and grizzly bears, wolves, and waterfowl
- Protect the viability of subsistence resources

Ecological Overview

The boundaries of Kobuk Valley National Park run along the ridges of a set of mountains that form a circle. These mountains define and enclose the Kobuk Valley. The Kobuk River cuts across the southern third of this circle. The encircling mountains are the Baird Mountains to the north, which are the westernmost extension of the Brooks Range, and the Waring Mountains to the south.

The Kobuk River begins in the central Brooks Range. In the river's midsection, as it passes through the Kobuk Valley, it is wide, slow moving, and usually clear. Its banks and bottom are sandy. Lively clearwater tributaries to the Kobuk have their headwaters in the Baird Mountains. These are the Akillik, the Hunt, the Kaliguricheark, the Tutuksuk, the Salmon, and the Kallarichuk. After tumbling over rocky bottoms in the mountains, they slow as they cross the nearly level floor of the Kobuk Valley.

Their waters take on a slight brownish color from the peat and other organic matter that overlay the valley floor. They enter the Kobuk through low breaches in the sandy banks. Only slow-moving creeks enter the Kobuk from the south.

Trees approach their northern limit in the Kobuk Valley, where forest and tundra meet. Vast expanses of tundra cover the valley in some locations, while forests cover other better-drained portions of the valley. In some locations sparse stands of spruce (*Picea* spp.), tree birch (*Betula papyrifera*), and poplar (*Populus* spp.) grow above a thick and brittle ground cover of light-colored lichens, creating a bright and easily traversed forest.

Sand created by the grinding of glaciers has been carried to the Kobuk Valley by winds and water. Large sand dunes lie on the south side of the Kobuk River. These are the Great Kobuk Sand Dunes, the Little Kobuk Sand Dunes, and the Hunt River Dunes. Older, vegetated dunes cover much of the southern portion of the valley.

Caribou pass through the valley on their spring and fall migrations. In the spring, caribou come over the Waring Mountains heading north, cross the Kobuk River, and move into north-south passes in the Baird Mountains. They continue on to the North Slope for calving. In the fall the migration is reversed. Caribou cross the valley in such great numbers and on such regular routes that they form trails that are obvious from the air and ground. Many caribou cross the Kobuk River at Onion Portage on the eastern side of the valley.

Native people have probably lived in the Kobuk Valley for at least 12,500 years. This human use is best recorded at the extensive archeological sites at Onion Portage. Each fall for thousands of years, people have waited at Onion Portage for the caribou to arrive. Caribou trails pass through the middle of this cluster of housepits and other remains of the activities of these Native peoples. Numerous other prehistoric villages and campsites have been discovered in the Kobuk Valley.

Climate

Average temperature and precipitation for the park are estimated from the closest weather stations in Kotzebue, Noorvik, and Kobuk. In July, mean temperatures range from 11 to 14° C. Mean temperatures in January range from –19 to –22° C.

The Bering and Chukchi seas provide the primary source of precipitation to northwest Alaska during the summer months, when the waters are ice free. But prevailing winds blow from the east across the landmass, causing comparatively low precipitation levels. Coastal and lower elevation areas in the southwest portion of the region receive approximately 20 to 25 cm of precipitation annually. Higher inland areas to the east receive 40 to 76 cm of precipitation. Snowfall ranges between 114 cm annually in the southwest to more than 254 cm at higher elevations in the east.

Freezing of rivers generally occurs from early to mid-October, and breakup occurs in mid to late May. At Kotzebue freeze-up occurs about October 23 and breakup about May 31. At Kiana, on the Kobuk River, these events occur on about October 18 and May 18, respectively.

Freshwater Resources

The Kobuk and Noatak rivers are the largest rivers in northwest Alaska and together drain an area of 63,654 km^2. The Kobuk River drains 31,028 km^2 and has an estimated annual average flow of 438 m^3 per second. The river is 558 km long and 0.30 to 0.45 km wide in its lower and middle reaches. It is clear, except at the highest water stage, and has a generally sandy or gravelly bottom. The river is 50 m above sea level at the eastern boundary of Kobuk Valley National Park. Meander scrolls, oxbow bends, and sloughs are abundant along the river's course. The floodplain of the Kobuk River varies from 1.6 to 12.8 km wide.

The major tributaries of the Kobuk River within the park are the Kallarichuk, Salmon, Tutuksuk, Kaliguricheark, Hunt, and Akillik rivers. All have their headwaters in the Baird Mountains, and all are entirely undeveloped. The Salmon River has been designated as a wild river in the Wild and Scenic Rivers System; it drains 1,709 km^2. The Tutuksuk, east of the Salmon River, is 48 km long and drains 906 km^2. The Hunt River, in the eastern portion of the park, is 64 km long and drains 1,592 km^2.

Numerous small lakes and ponds lie in the Kobuk River watershed, particularly in the lowlands along the river. Some ponds and lakes formed as detached oxbows of the meandering river, while others are thaw ponds, formed where permafrost has melted and caused depressions. Some small lakes of indeterminate origin lie on the north slopes of the Waring Mountains, and some true cirque lakes are found in the Baird Mountains.

Total dissolved solids in most streams in the region are generally less than 200 milligrams per liter. The Kobuk River at Kiana contains less than 250 mg/L of dissolved solids—magnesium and bicarbonate are most prevalent, while calcium and chloride are found in smaller quantities. The concentrations of dissolved solids increase from the headwaters of the Kobuk to its mouth at the Hotham Inlet. Sediment loads are comparatively low; the free-flowing waters of northwest Alaska generally have the lowest yield of sediment in the state, due largely to low topographic relief, lack of glaciers, low levels of runoff, and the stabilizing effect of permafrost on soils.

The expected fish species list developed by the AHNP included 22 expected species, with 16 species documented (72%). A review of the available literature suggests that fish in KOVA are less well-known than in NOAT. Most of the prior work has been conducted by the Alaska Department of Fish and Game relative to commercial and subsistence fisheries. The pre-ANILCA expedition of Melchior et al. (1976) included some fish inventory work in KOVA and reviewed the literature existing at that time.

Although all five species of Pacific salmon occur in the waters of the region, only chum (*Oncorhynchus keta*), king (*Oncorhynchus tshawytscha*), and pink (*Oncorhynchus gorbuscha*) salmon occur in the drainages of Kobuk Valley National Park. Chum salmon is the most abundant species of salmon in the region and is the most significant species for commercial and subsistence fisheries. The Salmon and Tutuksuk rivers are major spawning and production tributaries of the Kobuk River for chum salmon. Arctic grayling (*Thymallus arcticus*) and arctic char (*Salvelinus alpinus*) are distributed throughout the waters of the park. *Inconnu*, or sheefish (*Stenodus leucichthys*), inhabit the Kobuk and Selawik rivers. Sheefish overwinter in Hotham Inlet and Selawik Lake. After ice breakup, sheefish move upriver to spawning areas. Known spawning areas are located upriver from the village of Kobuk. Within the park whitefish (*Coregonus* spp.), inhabit the Kobuk River. Northern pike (*Esox lucius*), whitefish, burbot (*Lota lota*), long-nosed sucker (*Catostomus catostomus*), slimy sculpin (*Cottus cognatus*), and least ciscos (*Coregonus sardinella*) inhabit most rivers and lakes in the region, including those of the park.

Geology

Three general landscape types exist within Kobuk Valley National Park: the Baird Mountains, the Waring Mountains, and the Kobuk Valley lowlands (floodplain and terraces). The Baird Mountains are a western extension of the Brooks Range; they separate the Noatak and Kobuk river drainages. They rise abruptly from the lowland on the south to heights of 762 to 1,450 m. The Baird Mountains consist primarily of Paleozoic sedimentary and older metamorphosed rocks that have been thrust-faulted and folded. Rock types are shale, conglomerate, sandstone, and metamorphosed limestone. On the southern flanks of the Baird Mountains, within the park, sediments metamorphosed into phyllite and schist are found. Jurassic to Permian volcanic and intrusive rocks are also present.

The Waring Mountains, to the south of the Kobuk River, are broadly folded, northeast-trending mountains primarily of Cretaceous sedimentary rock. Rock types include graywacke, sandstone, siltstone, shale, and conglomerate. The peaks of this range are generally less than 609 m high.

The Kobuk River runs through the lowland between the Baird Mountains and Waring Mountains. This area is largely covered by glacial drift and alluvial deposits, including clayey till, outwash gravel, sand, and silt. The underlying bedrock of the lowlands is composed of Cretaceous sedimentary rocks such as shale, sandstone, siltstone, conglomerate, and graywacke.

Although there are currently no glaciers within the park, at least five major Pleistocene glaciations have been identified in northwest Alaska. The greatest of these glacial events occurred during Illinoisian time when glaciers extended west to the Baldwin Peninsula. The two earlier glaciations, the Kobuk and Ambler glaciations, covered large areas of the Kobuk and Selawik valleys and the drainages of the Baird Mountains. The later glaciations were restricted to portions of the Schwatka Mountains east of the park.

During the interglacial period between the Kobuk and Ambler glaciations, glacio-fluvial deposits on river bars and outwash plains were worked by strong easterly winds. The down-valley movement of large volumes of silt and sand created dune fields, which cover an area of approximately 90,000 ha. Most of this dune area is currently vegetated by tundra and forest, except for the three active dunes—the Great Kobuk Sand Dunes, the Little Kobuk Sand Dunes, and the Hunt River Dunes. These active dunes cover approximately 8,300 ha. The Great Kobuk Sand Dunes lie less than 3 km south of the Kobuk River, immediately east of Kavet Creek. The Little Kobuk Sand Dunes lie about 8 km south of the Kobuk River in the southeastern portion of the park. The Hunt River Dunes are located on the south bank of the Kobuk River, across from the mouth of the Hunt River.

The Great Kobuk Sand Dunes display a complete and readily observable sequence of dune development, from the U-shaped, concave dunes with vegetative cover in the eastern portion of the field to the crescent-shaped, unvegetated barchan dunes, which stand over 30 m high, in the western portion. It is the largest active dune field in arctic North America.

Lowland areas in the Kobuk River drainage are underlain by discontinuous permafrost with a maximum depth to its base of 118 m. The Baird Mountains to the north are underlain by continuous permafrost, while the Waring Mountains to the south have thin to moderately thick permafrost.

A variety of permafrost features are evident within the park. These features include thaw lakes, ice wedges, polygons, pingos, frost mounds, and solifluction lobes.

Numerous large mineral deposits occur about 48 km to the east of the park in the vicinity of Cosmos Mountain and the Schwatka Mountains. Mineral terranes occur in the park through most of the Baird Mountains. The Salmon River and Tutuksuk River watersheds are reported to have unusual (anomalous) concentrations of copper, lead, and zinc. A mineral terrane thought to be favorable for the occurrence of nickel, platinum, and chromium deposits runs along the base of the Baird Mountains from about the center of the park, east along the base of the Schwatka Mountains. Despite the known or suspected mineral terranes that occur within the park, no significant mineral deposits have been identified in the park (AEIDC 1975, 1982).

Jade is mined on the southern slopes of the Jade Mountains to the east of the park. Jade boulders are removed from the surface of talus slopes and are transported during the winter to the Kobuk River, where they are stockpiled to be taken by barge to Kotzebue after breakup. The boulders are cut and the jade is fashioned into jewelry and other items in Kotzebue.

Thin seams of subbituminous and bituminous coal (generally less than 0.6 m thick) occur along the Kobuk River, between the village of Kiana and the Pah River, 96 km east of the park. Small outcrops of coal can be seen along the Kobuk River between Trinity Creek (6.4 km downstream from the park's western boundary) and the Kallarichuk River within the park. Coal deposits have also been reported along a tributary at the Kallarichuk River.

Soils

Soils on the higher slopes of the Baird Mountains consist of thin layers of highly gravelly and stony loam. Where soils accumulate in protected pockets on steeper mountain slopes, they support mosses, lichens, and some dwarf shrubs. Soils on the broad lowlands within the park are generally poorly drained, with a peaty surface layer of variable depth and a shallow depth to permafrost. Texture within these soils varies from very gravelly to sandy or clayey loam.

An area of approximately 90,000 ha south of the Kobuk River is composed of well-drained, thin, strongly acidic soils. These are vegetated and unvegetated sand dune fields. The unvegetated Great Kobuk and Little Kobuk sand dune fields are comparable in soil type and texture to the vegetated portions of the dune fields, but they are rated as having high erosion potential due to scarcity of vegetation.

The floodplains of the Kobuk River and its tributaries, including the Hunt, Akillik, and Salmon rivers, are characterized by silty and sandy sediments and gravel. Soil erosion along the banks of the Kobuk River can be significant. Most bank erosion occurs during spring breakup, when high volumes of water and ice scour the riverbanks and carry sediment downstream. In places where river water comes into contact with permafrost in river banks, thermal erosion can occur. Additional erosion can occur during high precipitation in the summer months. Along the Kobuk River, evidence of the erosion and slumping of sandy riverbanks is readily observable at numerous locations.

Vegetation

Kobuk Valley National Park differs from the other arctic parks and preserves in that it lies mostly within the limits of the boreal forest region of Alaska. Its vegetation and flora, although containing a number of unique elements, is, in many ways, characteristic of the extensive forested areas of interior Alaska. However, the park lies near the northwestern limit of this forest; timberline occurs at low elevations (200 to 500 meters), there are extensive unforested areas even within the lowlands, and black spruce muskeg, so typical of the lowlands of interior Alaska, is rare or absent. The dominant forest tree is white spruce (*Picea glauca*). Much of the spruce forest is developed on ancient, stabilized dunes and glacial deposits, where drainage is excellent and the active layer deep. The trees are widely scattered, and there is a well-developed ground cover consisting largely of dwarf birch (*Betula glandulosa* and *B. nana*), various *Ericaceae* such as *Ledum* species, and a dense mat of lichens. Some areas of this type have only scattered trees and are best considered to be a form of brushland.

Denser, closed-canopy spruce forest is mostly confined to river shore areas and a few moist hillsides. Cottonwood (*Populus balsamifera*) groves are found throughout the lowlands of the park and extend as isolated copses along feeder streams and on favorable locations on hillsides. Cottonwood stands are especially well developed on river bars and shores. In old, closed canopy forests dominated by both conifers and hardwoods cyanolichens such as *Lobaria scrobiculata* may be found in abundance along with numerous foliose (e.g., Parmelioid, Cetrarioid) and fruticose (e.g., Bryoria) genera.

There are also extensive areas of brushland throughout the park. Riparian willow thickets characterize the river and stream valleys up to elevations of 500 meters or more. The dominant species here is generally *Salix alaxensis,* although other species such as *S. lanata, S. arbusculoides,* and *S. glauca* are locally abundant. *Salix pulchra* becomes dominant along smaller streams and at higher elevation and also is important in some forms of tussock tundra. Alder thickets (*Alnus crispa*) are also widespread; they occur mainly on moist, shaded, or north-facing slopes and in incised stream valleys.

Even in the lowlands within the borders of the forest region, the Kobuk Valley contains broad stretches of treeless vegetation that can be classified as tundra. The most prevalent form is tussock tundra, dominated by clumps of the tussock-forming cottongrass, *Eriophorum vaginatum.* This vegetation type is essentially identical to that which dominates much of the Noatak Valley and Arctic Slope to the north of the Kobuk. Much of the tussock tundra has been colonized by a variety of shrubs. The most abundant of these are *Salix pulchra,* dwarf birch, mountain cranberry (*Vaccinium vitis-idaea*), tundra blueberry (*Vaccinium uliginosum*), Labrador tea (*Ledum palustre*), and salmonberry (*Rubus Chamaemorus*).

Probably largely because of the comparatively warm, dry summers, much of the forest and lowland tundra of the Kobuk valley is subject to periodic fires. Some types of lowland vegetation may be at least partially a fire climax. Fire favors the spread of species such as fireweed (*Epilobiuim angustifolium*) and a variety of shrubs.

Exposed sandy river shores support a wide variety of low shrubs, grasses, and herbs, including rare species such as *Oxytropis kobukensis.* The open dunes support little vegetation, but their margins are populated with many of the same species as rivers shores and bars. The unique but sparse flora of the dunes includes terricolous morphs of normally saxicolous lichen taxa (e.g., *Ramalina almquistii, Evernia perfragilis*).

Alpine tundra is less prevalent in the Kobuk Valley National Park than in other northwestern parks and preserves but is well developed at the higher elevation in the Baird Mountains, and to a lesser extent in the lower and less rugged Waring Mountains. Like other alpine tundras in western Alaska, these areas are influenced by the richness of the Beringian flora and contain many species absent in alpine tundra in other parts of the circumpolar north. The polar desert vegetation typical of high arctic and high elevation tundra is not widely represented within the Kobuk, since there is little land above 1,000 meters.

Fauna

Lynx (*Lynx canadensis*) are found in the forested areas of the park where they prey on hare (*Lepus othus* and *americanus*) and ptarmigan (*Lagopus* spp.). Wolverine (*Gulo gulo*), ermine (*Mustela erminea*), river otter (*Lontra canadensis*), marten (*Martes americana*), least weasel (*Mustela nivalis*), and mink (*Mustela vison*) inhabit the park. The wolverine is the largest land-dwelling member of the weasel family and inhabits most of the state. Other mammals known to exist within Kobuk Valley National Park include arctic ground squirrels (*Spermophilus parryii*), porcupines (*Erethizon dorsatum*), beavers (*Castor canadensis*), and muskrats (*Ondatra zibethicus*).

Wolves (*Canis lupus*), coyotes (*Canis latrans*), and red fox (*Vulpes vulpes*) inhabit the park. Wolves are predators of caribou (*Rangifer tarandus*) and moose (*Alces alces*) within the region and travel near migrating caribou in the spring and fall (Resource Analysts 1983). Some wolves appear to be permanent residents of the Kobuk Valley, while others appear to be transient, residing in the valley only during the winter months. Wolf dens have been observed within the park (Melchoir et al. 1976).

Grizzly bears (*Ursus arctos*) frequent moist tundra and shrub associations and are found along rivers throughout northwest Alaska. Population estimates for grizzly bears are between 26 and 63 bears within Kobuk Valley National Park (Melchior et al. 1976). Black bears (*Ursus americanus*) are known to inhabit the forested portions of the Kobuk River drainage, and sightings are common in the park. The number of black bears inhabiting the park is unknown.

Moose are found within major drainages of northwest Alaska. Moose were scarce within the region until about 50 years ago. The population has steadily increased in recent years, and current estimates for the Kobuk River drainage are 1,500 animals (ADF&G 1983a). The primary fall moose range is the willow habitat above treeline, and the primary winter moose range in the park is along the Kobuk River.

Caribou of the western arctic caribou herd today range over the entire region. The herd declined from a population of at least 242,000 in 1970 to an estimated 75,000 in 1976. Since that time the herd has increased in size and was estimated to be 430,000 in 1999 (Western Arctic Caribou Herd Working Group 2003). The greatest numbers of caribou generally move across the Kobuk Valley from mid-September until early October. The Hunt River valley within the park and the Mileut Creek and Redstone River drainages (to the east of the park) are usually primary corridors for migration through the Baird Mountains (ADF&G 1983b). In most years a large percentage of the herd crosses the Kobuk River at and around Onion Portage on the eastern side of the park. Onion Portage is a traditional fall caribou hunting area for residents of the region. Caribou continue toward winter range to the south.

Although Dall's sheep (*Ovis dalli*) have been reported to have inhabited the Baird Mountains in the park as late as 1974 (Melchior et al. 1976), recent surveys indicate that significant numbers of Dall's sheep do not inhabit the park (NPS 1984) nor does the park appear to contain prime Dall's sheep habitat. However, small numbers of sheep sometimes inhabit the portion of the Baird Mountains that lies within the park.

Incidental sightings of muskoxen in the park are becoming more frequent (Jim Lawler, pers comm.).

Birds

Currently it is estimated that approximately 114 bird species have been recorded as present within the preserve (Appendix 2), and another 12 species are thought to occur. Prime waterfowl nesting areas occur in the extensive wet lowlands in the Kobuk Valley. Northwest Alaska provides major breeding areas for migratory birds and encompasses a zone of interchange between the flyways of Asia and North America (Melchior et al. 1976). In general, very little bird work has been conducted within KOVA.

Literature Cited

Alaska Department of Fish and Game. 1983a. Moose survey-inventory report. Game Management Unit 23. Kotzebue, AK.

Alaska Department of Fish and Game. 1983b. Caribou survey-inventory report. Game Management Unit 22A, 22B, 23, 24 and 26A. Kotzebue, AK.

Arctic Environmental Information and Data Center. 1975. *Alaska regional profiles, Northwest region.* University of Alaska Anchorage, Anchorage, AK.

Arctic Environmental Information and Data Center. 1982. *Mineral terrains of Alaska.* University of Alaska Anchorage, Anchorage, AK.

Markon, C. J. and S.D. Wesser. 1998. The northwest Alaskan parks land cover map. Open File Report. U.S. Geological Survey.

Melchior, H.R., Whitten, K.R., Schideler, R.T, and Melchior, H.R. 1976. *Vertebrates of the proposed Kobuk Valley National Monument, biological survey of the proposed Kobuk Valley National Monument: Final report.* University of Alaska, pp. 154-197.

National Park Service, U.S. Department of the Interior. 1984. *Dall's sheep numbers and distribution in the Noatak National Preserve.* National Park Service, Natural Resources Survey and Inventory Report.

NPSpecies: The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/ (certified organisms; accessed September 2004).

Resource Analysts, Fall Creek Environmental, LZH Associates. 1983. Biological resource and habitats of the NANA coastal resource service area. Eagle River, AK.

Western Arctic Caribou Herd Working Group. 2003. Western arctic caribou herd cooperative management plan. Nome, AK. 33 pp.

Noatak National Preserve

Established: 1980, under ANILCA

Size: 2,539,910 hectares (6,276,255 acres)

Enabling Legislation

Noatak National Monument was created by presidential proclamation in December 1978. On December 2, 1980, through the enactment of the Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96-487) the monument became Noatak National Preserve. Section 201(8) of this act specifies that:

> *The preserve shall be managed for the following purposes, among others: To maintain the environmental integrity of the Noatak River and adjacent uplands within the preserve in such a manner as to assure the continuation of geological and biological processes unimpaired by adverse human activity; to protect habitat for, and populations of, fish and wildlife, including but not limited to caribou, grizzly bears, Dall's sheep, moose, wolves, and for waterfowl, raptors, and other species of birds; to protect archeological resources; and in a manner consistent with the foregoing, to provide opportunities for scientific research. The Secretary may establish a board consisting of scientists and other experts in the field of arctic research in order to assist him in the encouragement and administration of research efforts within the preserve.*

Purposes

- Maintain the environmental integrity of the Noatak River and adjacent uplands to assure the continuation of geological and biological processes, unimpaired by adverse human activity
- Protect habitat for, and populations of, fish and wildlife, including but not limited to caribou, grizzly bears, Dall's sheep, moose, wolves, and for waterfowl, raptors, and other species of birds
- Protect archeological resources
- Provide opportunities for scientific research

Ecological Overview

Noatak National Preserve lies in northwestern Alaska, in the western Brooks Range, and encompasses over 402 km of the Noatak River watershed. The preserve is north of the Arctic Circle and is approximately 560 km northwest of Fairbanks and 25 km northeast of Kotzebue at its closest point.

The Noatak basin is bounded on the north and the northwest by the DeLong Mountains and is considered part of the Arctic Mountains Physiographic Province. The DeLong mountain range contains rugged, narrow, glaciated ridges between 1,200 and 1,500 m in elevation with a local relief of 457 to 915 m. Rivers on the north and west of the mountains drain into the Beaufort and Chukchi seas. The lower, western end of the mountain range trends southward to become the Mulgrave Hills, which divide the central Noatak basin from the Chukchi Sea coast on the west. From the Mulgrave Hills the Noatak River flows south into Kotzebue Sound.

To the south of the Noatak drainage are the Baird Mountains, ranging from 760 to 915 m in elevation. The Baird Mountains slope gently northward toward the Noatak basin and divide it from the Kobuk drainage to the south.

The lowland area formed by the Noatak River drainage can be divided into two distinct zones. The Mission Lowlands, on the downstream end of the Noatak River, encompass a broad, flat area of forests and treeless marshlands. This has numerous permafrost features including thaw lakes and spectacular pingos. Permafrost is discontinuous along the actual river drainage. The Aniuk Lowlands are an irregular rolling plain to the north of the drainage that slope gently toward the Baird Mountains on the south and are underlain by continuous permafrost.

From a point just west of Lake Matcharak, at Douglas Creek, the Noatak River enters the preserve. A major moraine belt begins along the valley below Douglas Creek. There the river channel becomes filled with boulders. Below the Aniuk River confluence, the Noatak valley floor widens into a broad plateau, flanked by bedrock ridges 32 to 64 km apart. The valley floor is, in fact, a vast till plain into which the river and its modern floodplain are incised to a depth of 60 m or more. Nearly continuous lines of 30-m-high bluffs border the floodplain or intersect the river's course in places where the river flows against them.

In the middle of Noatak National Preserve, the landscape is characterized by immense sweeps of tundra country, which is dotted with ponds and marshes. This landscape extends beyond the lower morainal ridges to the distant mountain edges of the basin. The Noatak's broad central basin extends some 80 km west to the Aglungak Hills near the Nimiuktuk River confluence. There the valley narrows again, sometimes to less than three miles wide. The surrounding mountains reach heights of 609 to 915 m. This 105-km-long valley is known as the Grand Canyon of the Noatak. At the lower end of the valley the river cuts for 11 km through the spectacular Noatak Canyon, a gorge with vertical walls of metamorphic rock some 60 to 90 m high. The Noatak River bends to the south just downstream of the Kelly River, leaves the preserve, and enters a lowland forested plain before passing through the Noatak lower canyon. The river enters a broad, coastal delta zone before emptying into Kotzebue Sound just north of Kotzebue.

The Noatak River Basin was recognized in 1976 for its international importance as a "biosphere reserve" under the Man and the Biosphere program by the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

Climate

The climate of the northwest region is characterized by long, cold winters and cool, sometimes wet summers. While the coastal area experiences a predominantly maritime climate, the interior area, which includes the Noatak and Kobuk river drainages, experiences a more continental climate, with greater seasonal variations in temperatures and precipitation. Mean summer temperatures for the northwest region range from ~ 0° C in the higher mountains to as high as 12° C in the Mission Lowlands. Mean winter temperatures for the region range between –17 and –28° C.

The coastal areas typically receive regular high winds. Mean monthly winds at Kotzebue are above 10 knots from September through April and blow from the east. Mean wind speeds are comparable during the summer months (average 10.5 knots) but are from the west. August and September are the windiest months, while the most extreme winds are associated with winter storms. Wind speeds are somewhat less in the interior than at the coast.

Coastal and lower elevation areas in the southwest portion of the region receive approximately 25 cm of precipitation annually. Higher inland areas to the east receive 63 to 76 cm of moisture. Rainfall usually increases as the summer months progress, usually peaking in August. Annual snowfall ranges from 114 cm in the southwest to more than 250 cm at higher elevations in the east.

Freeze-up of surface waters generally occurs from early to mid October, and breakup occurs in mid to late May. At Kotzebue freeze-up usually occurs about October 23 and breakup about May 31.

Freshwater Resources

The Noatak and Kobuk rivers are the principal surface water resources within northwest Alaska. The Noatak is the eleventh largest river in Alaska in terms of the area it drains. Before flowing into Hotham Inlet of Kotzebue Sound, the river drains 32,600 square kilometers and has an average annual flow of 309 m^3 per second. The main artery of the Noatak is 700 km long. Eleven relatively large streams, from 50 to 160 km long, are tributaries to the Noatak, as are 37 smaller streams.

Many lakes are within the Noatak watershed. Feniak Lake is the largest within the preserve boundary. Countless thaw ponds and potholes occur throughout the area, most as a result of permafrost that impedes the downward percolation of water that collects in depressions. Other ponds and lakes were formed as detached oxbows of the meandering river or developed as part of the extensive flat delta at the mouth of the Noatak River. Lake waters are generally lower in dissolved solids than river waters. Tundra lakes, however, are often characterized by unpleasant odor and brownish color or by the presence of iron. Lowland surface waters are generally high in organic material.

Approximately 22 species of fish are found within the Noatak drainage. Arctic grayling (*Thymallus arcticus*) and arctic char (*Salvelinus alpinus*) are the most common sport fish. Both spawn on sandy gravel substrate shortly after breakup in the Noatak and its tributaries. Most char are anadromous and are found in the Noatak River and its tributaries upriver as far as the Kugrak River. Chum salmon (*Oncorhynchus keta*) are found throughout the Noatak drainage; sockeye (*Oncorhynchus nerka*), coho (*Oncorhynchus kisutch*), king (*Oncorhynchus tshawytscha*), and pink (*Oncorhynchus gorbuscha*) salmon are also present, but in fewer numbers and confined to the lower reaches of the Noatak River.

Inconnu, or sheefish (*Stenodus leucichthys*), inhabit the lower Noatak River. Lake trout (*Salvelinus namaycush*) are found in some larger and deeper lakes (Feniak, Desperation, Kikitutiorak, and Narvakrak). Burbot (*Lota lota*), or freshwater cod, also inhabit deep lakes and large streams. Northern pike (*Esox lucius*), whitefish (*Coregonus* spp.), and least ciscos (*Coregonus sardinella*) inhabit rivers and lakes in the region. The long-nosed sucker (*Catostomus catostomus*) is found in rivers, streams, and lakes in the Noatak drainage and is occasionally dried or smoked for eating. The slimy sculpin (*Cottus cognatus*) and the nine-spined stickleback (*Pungitius pungitius*) are common prey fish. Blackfish (*Dallia pectoralis*) inhabit lowland ponds in the lower Noatak.

Geology

The basic geological framework of the northwest region was set by the late Paleozoic era and included the Brooks Range geosyncline (a broad sedimentary trough), the Arctic Foothills, and the Arctic Coastal Plain. During the Triassic period (Mesozoic era), the site of the present Brooks Range was stabilized, and limestone and chert were formed. The process of mountain-building began during the mid-Jurassic period. By the Cretaceous period the Brooks Range dominated the landscape, and volcanic activity from the Jurassic period continued in an area south of the range.

The sedimentary rocks of the Brooks Range and the DeLong Mountains were intensely folded and faulted during the late Cretaceous period. It was during this time that the existing east-west fault trends within the area were established. A resurgent strong uplift during the early Tertiary period (Cenozoic era) was responsible for the present configuration of the Brooks Range. Volcanic activity produced intrusions and debris throughout the region during the Tertiary and Quaternary periods.

Bedrock geology of the DeLong Mountains includes faulted and folded sheets of sedimentary clastic rocks with intrusions of igneous rock. Shale, chert, and limestone of Paleozoic and Mesozoic eras are dominant. Graywacke and mafic rock of the Jurassic and Cretaceous periods are also found.

The lowland area of the Noatak drainage is underlain primarily by siltstone, sandstone, and limestone of the mid-to-late Paleozoic era. Also in evidence are graywacke, chert, and igneous rock of Mesozoic origin.

The Baird Mountains south of the lowland are composed of strongly folded sedimentary rocks with granitic intrusions. Known bedrock consists primarily of Paleozoic or older, highly metamorphosed rocks.

Permafrost plays an important role in the geologic processes and topographic development of the preserve. The Noatak drainage and adjacent lowland areas are underlain by discontinuous permafrost, and areas in the Baird and DeLong mountains are underlain by continuous permafrost. Permafrost can reach depths of 610 m, but is generally between 4 and 79 m in the Noatak area.

Continental ice sheets did not cover all of northwest Alaska during the Pleistocene period, although glaciers did cover most upland areas. The last retreat of the glaciers established the present sea level and the extensively glacially carved landscape that is in evidence today. This landscape is characterized by deep, U-shaped valleys, rocky peaks, and braided streams. A portion of the Noatak valley lowland was glaciated during Wisconsin time and today is typified by such glacial features as kame, kettles, moraines, and alluvial till.

Soils

The three major soil types within the preserve include the upland or mountain slope soils of the lithosol type, tundra soils, and soils associated with the Noatak drainage and lowlands. Lithosol soils on the higher slopes of the DeLong and Baird mountains are limited and are mostly imperfectly weathered rock fragments and barren rock. The soil is without zonation and consists of a thin layer of highly gravelly and stony loam. Where this soil accumulates in protected pockets on mountain slopes, it supports mosses, lichens, and some dwarf shrubs. Below the upland soils on more gently rolling terrain, the tundra soils predominate. These are dark, humus-rich, often nonacid soils. Texture in the tundra soils varies from highly gravelly to sandy. The floodplains of the Noatak and its tributaries are characterized by silty and sandy sediments and gravel. These soils occur in association with the greatest proportions of organic material along the lower reaches of the Noatak. A fibrous peat extends to the permafrost layer in many areas.

Soil erosion along the Noatak riverbanks is often severe. Erosion occurs especially during spring breakup when high volumes and velocities of water scour the riverbanks and carry sediment downstream. In places where waters contact ground ice in adjacent riverbanks, thermal erosion can occur. As the ice melts, banks are undercut and sediments are swept downstream. Additional erosion can occur during high precipitation and storm periods in summer.

Vegetation

While the majority of the Noatak Preserve is vegetated with tundra, the boreal forest reaches its northwestern-most limit along the middle and lower reaches of the valley. The forest here is dominated by white spruce (*Picea glauca*); other species typical of the interior forest (e.g., black spruce) reach their limit south and east of the Noatak. Otherwise, the spruce forest is similar to that of interior lowland Alaska; it occurs mainly on well-drained river banks and on gentle slopes at low elevations from near the mouth of the Noatak to the vicinity of the Noatak Grand Canyon. Typical understory shrubs include several species of willow (*Salix*), *Betula glandulosa, Alnus crispa,* and often less abundant species such as *Rosa acicularis.* At its outermost limits, porcupines appear to be a major factor in confining the spread of spruce forest. Beyond the spruce limit, especially on the middle and upper Noatak, occasional stands of cottonwood (*Populus balsamifera*) occur.

Along smaller streams and at higher elevations, an important component of the vegetation is shrub thicket. The banks of many streams and lakes support riparian willow thickets, composed mainly of *Salix alaxensis, S. arbusculoides, S. pulchra,* and several other willow species. These thickets provide important moose habitat, especially in winter. They are found extensively at elevations as high as 800 meters. Moist and shaded slopes at lower elevations, especially north-facing slopes, often support extensive stands of alder (*Alnus crispa*).

The lower reaches of larger streams and the Noatak River itself have extensive river bars. These are generally relatively unstable, often inundated, and vary considerably in terms of their vegetation depending on their history. In addition to willows and other tall shrubs on the more stable bars and shores, an array of characteristic herbaceous can usually be found. These include dwarf fireweed (*Epilobium latifolium*), legumes such as *Oxytropis, Astragalus,* and *Hedysarum* species, and, often, plants more typical of the better-drained alpine sites such as *Castilleja* (Indian paintbrush) species.

Wet, treeless vegetation, usually considered to be a form of tundra, covers large areas in the lowlands bordering the lower reaches of the Noatak, especially in the Mission Lowlands. These areas are underlain by deep permafrost; drainage is impeded and much of the terrain is marsh, thaw pond, and slow, meandering streams. Vegetation is widely varied, but it usually is dominated by extensive stands of *Carex aquatilis, Eriophorum angustifolium* (narrow-leaved cottongrass), and grasses such as *Arctophila fulva* and *Calamagrostis* species. Small streambanks often support dense stands of willow, mainly *Salix pulchra.* Occasional patches of spruce are found in better drained situations; the south-facing slope of at least one large pingo supports a dense grove of white spruce.

In the middle and upper reaches of the Noatak valley, much of the lowland terrain is gently rolling surfaces of ancient glacial deposits and alluvium from nearby steeper slopes and mountains. The vegetation here is dominated by enormous stretches of the tussock tundra that is widely developed over much of northern and western Alaska. In its purest form, this type of vegetation is nearly totally dominated by a single species, the tussock-forming cottongrass *Eriophorum vaginatum,* which is accompanied by a nonvascular community rich in bryophytes but poor in lichens. Noatak Preserve therefore represents a midpoint of a nonvascular gradient between CAKR (dominated by bryophytes) and GAAR (dominated by lichens).

This is the infamous tussock field that looks innocuous from a distance, but which consists of unstable clumps of cottongrass, generally 20 to 30 cm in diameter and separated by ditches of equivalent width and depth. The ditches often contain water, providing a breeding ground for mosquitos. Tussock tundra is one of the few types of tundra that are regularly subject to fire. In some areas, tussock tundra may actually be a fire climax vegetation. Over time, the tussocks and interstices may be invaded by other species, notably dwarf birch (*Betula nana*), willows (mainly *Salix pulchra*), and several species of sedge. These plants, especially the birch, are highly flammable, but they are largely eliminated by intense fire, which merely trims and rejuvenates the tussocks. Tussock fields also are especially thrifty in areas where there is intense stirring of the soil by frost action. The Noatak Preserve contains an enormous array of treeless vegetation types that can be generally lumped under the term alpine tundra. It has long been accepted that the flora of northern and western Alaska is exceptionally rich compared to other arctic regions, especially in North America. This richness is the result of a number of factors: the broad array of soil and other substrate types, the presence of unglaciated refugia; the relatively mild, continental climate, and the continuity of several mountain chains in North America and Asia that converge on the Beringian region, providing pathways for migration of plants from the interior of the continents.

The classification of alpine tundra vegetation is complex. It usually involves concern with the rock type of the substrate (carbonate versus noncarbonate, plus special types such as serpentine), exposure and drainage (e.g., snowbed and seepage areas versus dry ridges and scree), and climatic factors based on elevation and latitude. It is accurate to say that the Noatak Preserve contains as broad an array of alpine tundra types as can be found anywhere in the Arctic. Open slopes immediately above the tree and brush line support a rich complex of graminoids and forbs, which include all or most of the characteristic circumpolar low-arctic species as well as many of the more narrowly endemic "Beringian" plants. Examples of the former are grasses such as *Arctagrostis latifolia, Deschampsia caespitosa,* and many *Calamagrostis, Poa,* and *Festuca* species, sedges such as the cottongrasses (*Eriophorum* species) and many true sedges (*Carex* species). Dwarf shrubs such as *Ledum* (Labrador tea) species, *Vaccinium uliginosum* (tundra blueberry), *V. vitis-idaea* (mountain cranberry), *Arctostaphylos* (bearberry) species, and arctic heather (*Cassiope tetragona*) are common in lower and less exposed sites. Forbs include many species of *Ranunculus* (buttercup), *Saxifraga* (saxifrage), *Potentilla* (cinquefoil), *Pedicularis* (lousewort), and *Senecio* (groundsel). The long list of Beringian endemics would include *Cardamine purpurea, Saxifraga Eschscholtzii,* and *Douglasia ochotensis.*

At the higher elevations and in more exposed areas, the narrower array of circumpolar high-arctic species is well represented, as are the characteristic lichens and mosses of the polar desert. NOAT's lichens have been grazed extensively during the past few decades by the western arctic caribou herd, and many areas show extreme degradation.

Fauna

Lynx (*Lynx canadensis*) inhabit the region, occurring in the forested areas of the lower Noatak. Six members of the weasel family inhabit the preserve, including the wolverine (*Gulo gulo*), ermine (*Mustela erminea*), river otter (*Lontra canadensis*), marten (*Martes americana*), least weasel (*Mustela nivalis*), and mink (*Mustela vison*). Beaver (*Castor canadensis*) distribution within the Noatak drainage is not well known, although their population size is considered to be increasing regionally. Muskrats are known to exist in small numbers in the Noatak valley, with a prime habitat area on the lower Noatak flats south and east of Noatak village. Other mammals present in the preserve include snowshoe hare (*Lepus americanus*), arctic ground squirrel (*Spermophilus parryii*), and porcupine (*Erethizon dorsatum*).

Wolves (*Canis lupus*), wolverine (*Gulo gulo*), coyotes (*Canis latrans*), and arctic fox (*Alopex lagopus*) occur within the preserve. Wolves are predators of caribou (*Rangifer tarandus*) and moose (*Alces alces*) and travel near migrating caribou in the spring and fall (Resource Analysts 1983). Wolves are present within all major drainages, as are coyotes and red fox. The arctic fox generally prefers coastal and delta areas mostly within the Arctic Slope area but is wide ranging in its feeding activities.

Grizzly bears (*Ursus arctos*) frequent moist tundra and shrub associations and are found along riverbanks throughout northwest Alaska. Within the preserve, significant grizzly bear habitat occurs along the Cutler River. Black bears (*Ursus americanus*) generally prefer forested areas and are present within the preserve.

Moose are found within the major drainages of Noatak. The Kugururok River hosts particularly high numbers of the Noatak's moose population. Moose were very scarce within the region until about 50 years ago (Coady 1980), but the population has steadily increased in recent years.

Caribou found within the preserve are part of the western arctic caribou herd, which ranges over the entire region. The herd declined from a population of at least 242,000 in 1970 to an estimated 75,000 in 1976. Since that time the herd has increased in size and was estimated to be 430,000 in 1999 (Western Arctic Caribou Herd Working Group 2003). Summer range is north of the Brooks Range and west to the Chukchi Sea. Winter ranges are to the south and the east of the Noatak drainage.

Dall's sheep are present throughout the Baird and the DeLong mountains and west into the Wulik peaks. Within this region Dall's sheep reach the northwestern limit of their distribution. Important habitats are found north of the Noatak River above the confluence with the Igning River and within the upper Kelly, Kugururok, Eli, and Agashashok river drainages.

The last remaining muskox were killed in Alaska in 1865, but muskox were reintroduced to the state from Greenland in 1936. Thirty-six muskox were released near Cape Thompson (75 miles northwest of Noatak) in 1970, and 30 animals were released in the same area in 1977. Incidental observations of bull and cow muskoxen within the preserve are growing more frequent (Jim Lawler, pers. comm.).

Most birds found in the monument are summer nesters or migrants. Currently it is estimated that 126 bird species have been recorded as present within the preserve (Appendix 2), and another 23 species are thought to occur. The northwest Alaska region provides important bird habitat because it is a major breeding area for migratory birds from as far away as Antarctica. This region encompasses a zone of interchange between the flyways of Asia and North America, and it includes important transitional habitat areas between boreal forest, coastal lands, and tundra.

More than 25 species of waterfowl inhabit Noatak's wetland areas. All four species of loon are found in the Noatak drainage.

Raptors find important habitat within the Noatak drainage. Thirteen species of raptors are known in the preserve. Nesting among rocky cliffs along major drainages are golden eagle, gyrfalcon, and rough-legged hawk. Golden eagles are common on the lower Noatak, and bald eagles are only rarely encountered in the preserve. Goshawk, sharp-shinned hawk, merlin, and American kestrel inhabit the preserve. Osprey occur in the lower Noatak.

Although the Eskimo curlew was reportedly found in the region in the past, no sightings have been made in the past 50 years and it is believed to be extinct.

Of special interest among the remaining birdlife are several Asian species that have extended their ranges into North America along the Bering Land Bridge corridor. These include the wheatear, yellow wagtail, white wagtail, bluethroat, and arctic warbler (Young 1974).

Literature Cited

Coady, J. W. 1980. History of moose in northern Alaska and adjacent regions. *Can. Field Nat.* 94(1): 61-68.

NPSpecies: The National Park Service Biodiversity Database. Secure online version. https://science1.nature.nps.gov/npspecies/ (certified organisms; accessed September 2004).

Resource Analysts, Fall Creek Environmental, LZH Associates. 1983. Biological resource and habitats of the NANA coastal resource service area. Eagle River, AK.

Western Arctic Caribou Herd Working Group. 2003. Western arctic caribou herd cooperative management plan. Nome, AK. 33 pp.

Young, Steven B. 1974. *The environment of the Noatak River Basin, Alaska: results of the Center for Northern Studies biological survey of the Noatak River Valley, 1973.* Contributions from the Center for Northern Studies.

Appendix 1: Draft List of Terrestrial Mammal Species Currently Documented as Present in ARCN Parks

		Observed in				
Scientific Name	**Common Name**	**GAAR**	**NOAT**	**KOVA**	**AKR**	**BELA**
Ovibos moschatus	muskox	X	X	X	X	X
Ovis dalli	Dall's sheep	X	X	X	X	
Alces alces	moose	X	X	X	X	X
Rangifer tarandus	caribou	X	X	X	X	X
Alopex lagopus	Arctic fox	X	X	X		
Canis latrans	coyote	X				
Canis lupus	wolf	X	X	X	X	X
Vulpes vulpes	red fox	X	X	X	X	X
Lynx canadensis	lynx	X	X	X	X	X
Gulo gulo	wolverine	X	X	X	X	X
Lontra canadensis	river otter	X	X	X	X	
Martes americana	marten	X	X	X		
Mustela erminea	ermine	X	X	X	X	X
Mustela nivalis	least weasel	X	X	X	X	
Mustela vison	mink	X	X	X		
Ursus americanus	black bear	X	X	X		
Ursus arctos	grizzly bear	X	X	X	X	X
Sorex arcticus	Arctic shrew	X	X	X		
Sorex cinereus	cinerous shrew	X	X	X	X	X
Sorex hoyi	pygmy shrew	X	X	X		
Sorex monticolus	montane shrew	X	X	X	X	X
Sorex tundrensis	tundra shrew	X	X	X	X	X
Sorex ugyunak	barren ground shrew	X	X	X	X	X
Sorex yukonicus	tiny shrew	X	X	X	X	
Lepus americanus	snowshoe hare	X	X	X	X	
Lepus othus	Arctic hare	X	X			
Castor canadensis	beaver	X	X	X	X	
Erethizon dorsatum	porcupine	X	X	X	X	X
Clethrionomys rutilus	red-backed vole	X	X	X	X	X
Dicrostonyx groenlandicus	collared lemming	X	X	X	X	X
Lemmus trimucronatus	brown lemming	X	X	X	X	X
Microtus miurus	singing vole	X	X	X	X	X
Microtus oeconomus	tundra vole	X	X	X	X	X
Microtus pennsylvanicus	meadow vole	X				
Microtus xanthognathus	yellow-cheeked vole	X	X	X		
Ondatra zibethicus	muskrat	X	X	X	X	X
Synaptomys borealis	northern bog lemming	X	X			
Marmota broweri	Alaska marmot	X	X	X		
Spermophilus parryii	Arctic ground squirrel	X	X	X	X	X
Tamiasciurus hudsonicus	red squirrel	X	X	X	X	

Appendix 2: Draft List of Birds Observed in ARCN Parks

		Observed in:				
Common name	**Scientific name**	**BELA**	**CAKR**	**GAAR**	**KOVA**	**NOAT**
Alder Flycatcher	*Empidonax alnorum*	X		X	X	X
Aleutian Tern	*Sterna aleutica*	X	X			
American Dipper	*Cinclus mexicanus*				X	
American Golden-Plover	*Pluvialis dominica*	X	X	X	X	X
American Kestrel	*Falco sparverius*			X	X	X
American Pipit	*Anthus rubescens*	X	X	X	X	X
American Robin	*Turdus migratorius*	X	X	X	X	X
American Tree Sparrow	*Spizella arborea*	X	X	X	X	X
American Wigeon	*Anas americana*	X		X	X	X
Arctic Tern	*Sterna paradisaea*	X	X	X	X	X
Arctic Warbler	*Phylloscopus borealis*	X	X	X	X	X
Baird's Sandpiper	*Calidris bairdii*	X	X	X	X	X
Bald Eagle	*Haliaeetus leucocephalus*	X	X	X	X	
Bank Swallow	*Riparia riparia*	X	X	X	X	X
Barn Swallow	*Hirundo rustica*	X				
Barrow's Goldeneye	*Bucephala islandica*	X				
Bar-tailed Godwit	*Limosa lapponica*	X	X	X		X
Belted Kingfisher	*Ceryle alcyon*			X	X	X
Black Guillemot	*Cepphus grylle*	X				
Black Scoter	*Melanitta nigra*	X	X	X	X	X
Black Turnstone	*Arenaria melanocephala*	X	X			X
Black-bellied Plover	*Pluvialis squatarola*	X	X	X		X
Black-capped Chickadee	*Parus atricapillus*			X	X	
Black-legged Kittiwake	*Rissa tridactyla*	X	X			
Blackpoll Warbler	*Dendroica striata*	X	X	X	X	X
Bluethroat	*Luscinia svecica*	X	X	X	X	X
Bohemian Waxwing	*Bombycilla garrulous*		X	X	X	X
Bonaparte's Gull	*Larus philadelphia*	X	X	X	X	X
Boreal Chickadee	*Poecile hudsonicus*		X	X	X	X
Boreal Owl	*Aegolius funereus*			X	X	
Brant	*Branta bernicla*	X	X			X
Bristle-thighed Curlew	*Numenius tahitiensis*	X	X			X
Buff-breasted Sandpiper	*Tryngites subruficollis*		X			X
Bufflehead	*Bucephala albeola*	X		X		X
Canada Goose	*Branta canadensis*	X	X	X	X	X
Canvasback	*Aythya valisineria*	X	X	X		X
Cliff Swallow	*Hirundo pyrrhonota*	X		X	X	X
Common Eider	*Somateria mollissima*	X	X			
Common Goldeneye	*Bucephala clangula*	X		X		
Common Loon	*Gavia immer*	X	X	X	X	X
Common Merganser	*Mergus merganser*	X	X	X	X	X
Common Murre	*Uria aalge*	X	X			
Common Raven	*Corvus corax*	X	X	X	X	X
Common Redpoll	*Carduelis flammea*	X	X	X	X	X
Crested Auklet	*Aethia cristatella*	X				
Dark-eyed Junco	*Junco hyemalis*	X	X	X	X	X

		Observed in:				
Common name	**Scientific name**	**BELA**	**CAKR**	**GAAR**	**KOVA**	**NOAT**
Downy Woodpecker	*Picoides pubescens*	X				
Dunlin	*Calidris alpine*	X	X			
Emperor Goose	*Chen canagica*	X				
Eurasian Wigeon	*Anas penelope*	X				
Fox Sparrow	*Passerella iliaca*	X	X	X	X	X
Glaucous Gull	*Larus hyperboreus*	X	X	X	X	X
Glaucous-winged Gull	*Larus glaucescens*	X	X			
Golden Eagle	*Aquila chrysaetos*	X	X	X	X	X
Golden-crowned Sparrow	*Zonotrichia atricapilla*	X	X	X	X	X
Gray Jay	*Perisoreus canadensis*		X	X	X	X
Gray-cheeked Thrush	*Catharus minimus*	X	X	X	X	X
Gray-crowned Rosy-Finch	*Leucosticte tephrocotis*		X	X	X	X
Great Gray Owl	*Strix nebulosa*		X	X	X	
Greater Scaup	*Anas marila*	X	X	X	X	X
Greater White-fronted Goose	*Anser albifrons*	X	X	X	X	X
Greater Yellowlegs	*Tringa melanoleuca*			X		X
Green-winged Teal	*Anas crecca*	X	X	X	X	X
Gyrfalcon	*Falco rusticolus*	X	X	X	X	X
Hairy Woodpecker	*Picoides villosus*			X		
Harlequin Duck	*Histrionicus histrionicus*	X	X	X	X	
Hermit Thrush	*Catharus guttatus*		X			X
Herring Gull	*Larus argentatus*	X	X	X	X	X
Hoary Redpoll	*Carduelis hornemanni*		X	X	X	X
Horned Grebe	*Podiceps auritus*	X	X	X	X	X
Horned Lark	*Eremophila alpestris*	X	X	X	X	X
Horned Puffin	*Fratercula corniculata*	X	X			
Hudsonian Godwit	*Limosa haemastica*	X	X			X
Ivory Gull	*Pagophila eburnea*		X			
King Eider	*Somateria spectabilis*	X	X			
Kittlitz's Murrelet	*Brachyramphus brevirostris*		X			
Lapland Longspur	*Calcarius lapponicus*	X	X	X	X	X
Least Auklet	*Aethia pusilla*	X				
Least Sandpiper	*Calidris minutilla*	X	X	X	X	X
Lesser Scaup	*Aythya affinis*	X	X	X	X	
Lesser Yellowlegs	*Tringa flavipes*		X	X	X	X
Lincoln's Sparrow	*Melospiza lincolnii*	X		X	X	X
Long-billed Dowitcher	*Limnodromous scolopaceus*	X	X	X	X	X
Long-tailed Duck	*Clangula hyemalis*	X	X	X	X	X
Long-tailed Jaeger	*Stercorarius longicaudus*	X	X	X	X	X
Mallard	*Anas platyrhynchos*	X	X	X	X	X
Merlin	*Falco columbarius*	X	X	X	X	X
Mew Gull	*Larus canus*	X	X	X	X	X
Northern Flicker	*Colaptes auratus*	X		X	X	X
Northern Goshawk	*Accipiter gentiles*		X	X		X
Northern Harrier	*Circus cyaneus*	X	X	X	X	X
Northern Hawk Owl	*Surnia ulula*		X	X	X	X
Northern Pintail	*Anas acuta*	X	X	X	X	X
Northern Shoveler	*Anas clypeata*	X	X	X	X	X
Northern Shrike	*Lanius excubitor*	X	X	X	X	X

		Observed in:				
Common name	**Scientific name**	**BELA**	**CAKR**	**GAAR**	**KOVA**	**NOAT**
Northern Waterthrush	*Seiurus noveboracensis*	X	X	X	X	X
Northern Wheatear	*Oenanthe oenanthe*	X	X	X	X	X
Olive-sided Flycatcher	*Contopus cooperi*			X	X	X
Orange-crowned Warbler	*Vermivora celata*	X	X	X	X	X
Osprey	*Pandion haliaetus*	X		X	X	X
Pacific Golden-Plover	*Pluvialis fulva*					X
Pacific Loon	*Gavia pacifica*	X	X	X	X	X
Parakeet Auklet	*Cyclorrhynchus psittacula*	X				
Parasitic Jaeger	*Stercorarius parasiticus*	X	X	X	X	X
Short-tailed Shearwater	*Puffinus tenuirostris*		X			
Pectoral Sandpiper	*Calidris melanotos*	X	X	X	X	X
Pelagic Cormorant	*Phalacrocorax pelagicus*	X	X			
Peregrine Falcon	*Falco peregrinus*	X	X	X	X	X
Pigeon Guillemot	*Cepphus columba*		X			
Pine Grosbeak	*Pinicola enucleator*			X	X	X
Pine Siskin	*Carduelis pinus*			X		
Pomarine Jaeger	*Stercorarius pomarinus*	X	X		X	X
Red Knot	*Calidris canutus*		X	X		X
Red Phalarope	*Phalaropus fulicarius*	X	X	X		
Red-breasted Merganser	*Mergus serrator*	X	X	X	X	X
Red-breasted Nuthatch	*Sitta canadensis*			X		
Redhead	*Aythya americana*	X				
Red-necked Grebe	*Podiceps grisegena*	X	X	X	X	X
Red-necked Phalarope	*Phalaropus lobatus*	X	X	X	X	X
Red-tailed Hawk	*Buteo jamaicensis*			X		X
Red-throated Loon	*Gavia stellata*	X	X	X	X	X
Red-throated Pipit	*Anthus cervinus*	X				
Rock Ptarmigan	*Lagpus mutus*	X	X	X	X	X
Rock Sandpiper	*Calidris ptilocnemis*	X	X			
Rosy Finch	*Leucosticte arctoa*		X	X		X
Rough-legged Hawk	*Buteo lagopus*	X	X	X	X	X
Ruby-crowned Kinglet	*Regulus calendula*		X	X	X	X
Ruddy Turnstone	*Arenaria interpres*	X	X			X
Rusty Blackbird	*Euphagus carolinus*	X	X	X	X	X
Sabine's Gull	*Xema sabini*	X	X			
Sanderling	*Calidris alba*	X	X	X	X	
Sandhill crane	*Grus canadensis*	X	X	X	X	X
Savannah Sparrow	*Passerculus sandwichensis*	X	X	X	X	X
Say's Phoebe	*Sayornis saya*	X	X	X	X	X
Semipalmated Plover	*Charadrius semipalmatus*	X	X	X	X	X
Semipalmated Sandpiper	*Calidris pusila*	X	X		X	X
Sharp-shinned Hawk	*Accipiter striatus*	X			X	X
Sharp-tailed Sandpiper	*Calidris acuminata*		X			
Short-eared Owl	*Asio flammeus*	X	X	X	X	X
Siberian Tit	*Parus cinctus*				X	X
Smith's Longspur	*Calcarius pictus*			X		X
Snow Bunting	*Plectrophenax nivalis*	X	X	X	X	X
Snow Goose	*Chen caerulescens*	X	X	X	X	
Snowy Owl	*Nyctea scandiaca*	X	X	X	X	

		Observed in:				
Common name	**Scientific name**	**BELA**	**CAKR**	**GAAR**	**KOVA**	**NOAT**
Solitary Sandpiper	*Tringa solitaria*			X	X	X
Spectacled Eider	*Somateria fischeri*	X	X			
Spotted Sandpiper	*Actitis macularia*		X	X	X	X
Spruce Grouse	*Falcipennis canadensis*		X	X	X	X
Steller's Eider	*Polysticta stelleri*		X			
Surf Scoter	*Melanitta perspicillata*	X	X	X	X	X
Surfbird	*Aphriza virgata*			X	X	X
Swainson's Thrush	*Catharus ustulatus*			X	X	X
Thick-billed Murre	*Uria lomvia*	X	X			
Three-toed Woodpecker	*Picoides tridactylus*			X		X
Townsend's Solitaire	*Myadestes townsendi*			X		
Tree Swallow	*Tachycineta bicolor*	X	X	X	X	X
Tufted Puffin	*Fratercula cirrhata*		X			
Tundra Swan	*Cygnus columbianus*	X	X	X	X	X
Upland Sandpiper	*Bartramia longicauda*			X		X
Varied Thrush	*Ixoreus naevius*	X	X	X	X	X
Violet-green Swallow	*Tachycineta thalassina*			X	X	
Wandering Tattler	*Heteroscelus incanus*	X	X	X	X	X
Western Sandpiper	*Calidris mauri*	X	X			X
Western Wood-pewee	*Contopus sordidulus*					X
Whimbrel	*Numenius phaeopus*	X	X	X	X	X
White Wagtail	*Motacilla alba*	X	X			
White-crowned Sparrow	*Zonotrichia leucophrys*	X	X	X	X	X
White-winged Crossbill	*Loxia leucoptera*			X	X	
White-winged Scoter	*Melanitta fusca*	X	X	X		X
Willow Ptarmigan	*Lagopus lagopus*	X	X	X	X	X
Wilson's Snipe	*Gallinago delicate*	X	X	X	X	X
Wilson's Warbler	*Wilsonia pusilla*	X	X	X	X	X
Yellow Wagtail	*Motacilla flava*	X	X	X	X	X
Yellow Warbler	*Dendroica petechia*	X	X	X	X	X
Yellow-billed Loon	*Gavia adamsii*	X	X	X		X
Yellow-rumped Warbler	*Dendroica coronata*		X	X	X	X
Totals		129	132	129	114	126