National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Protocol for Monitoring Brown Bears

Arctic Network (ARCN), Version 1.0

Natural Resource Report NPS/AKRO/NRR—2018/1763









ON THIS PAGE
Brown bears observed in Noatak National Preserve.
(NPS/HILLARY ROBISON)

ON THE COVER
A brown bear in Noatak National Park and Preserve.
(NPS/HILLARY ROBISON)

Protocol for Monitoring Brown Bears

Arctic Network (ARCN), Version 1.0

Natural Resource Report NPS/AKRO/NRR—2018/1763

Hillary L. Robison,[1] Joshua H. Schmidt,[2] Kumi L. Rattenbury,[3] Brad S. Shults,[3,4] and Scott D. Miller[3]

[1]National Park Service
Western Arctic National Parklands
P.O. Box 1029
Kotzebue, Alaska 99752

[2]National Park Service
Central Alaska Network
4175 Geist Road
Fairbanks, Alaska 99709

[3]National Park Service
Arctic Network
4175 Geist Road
Fairbanks, Alaska 99709

[4]U.S. Fish and Wildlife Service
Migratory Bird Management
1011 East Tudor Road, MS 201
Anchorage, AK 99503

September 2018

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the NPS Arctic Inventory and Monitoring Network's Brown Bear Vital Signs webpage and the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Robison, H. L., J. H. Schmidt, K. L. Rattenbury, B. S. Shults, and S. D. Miller. 2017. Protocol for monitoring brown bears: Arctic Network (ARKN), version 1.0. Natural Resource Report NPS/AKRO/NRR—2018/1763. National Park Service, Fort Collins, Colorado.

NPS 153/148536, September 2018

Contents

Page

Figures v

Tables vi

Executive Summary vii

Acknowledgments ix

List of Key Acronyms x

Background and Objectives 1

Background and History 1

Rationale for Brown Bear Monitoring 2

Objective 3

Methods 5

Sampling Design 5

Monitoring Schedule and Survey Timing 12

Surveys within the Brooks Range – Lower Noatak River drainage (CAKR/NOAT), Upper Noatak River drainage (NOAT/GAAR), and Gates of the Arctic National Park and Preserve (GAAR) 13

Survey within Bering Land Bridge National Preserve (BELA) 14

Field Methods and Survey Preparation 14

Level of Change That Can Be Detected 17

Data Management 17

NPS Standards 18

Data Quality 18

Freedom of Information Act 19

Records Management 19

Core Functional Model 19

Data Sensitivity Statement 20

The ARCN brown bear monitoring protocol defines the collection of sensitive data and requires special handling procedures. 20

Contents (continued)

Page

Roles and Responsibilities....21
Project Leader....21
Data Manager....21
Data Collection....22
Data Collection Overview....22
Data Entry/Import....23
Quality Assurance....24
Quality Control....25
Product Archival and Documentation....25
IRMA Data Store....25
Reports....26
Certified Dataset....26
Resource Brief....26
Products Publication....27
Metadata....27
Data and Information Security....27
Closeout....27
Certification....28
Analysis and Reporting....29
Analysis....29
Reporting....29
Budget....29
Safety....32
Standard Operating Procedures....34
Literature Cited....38

Figures

Page

Figure 1. Location of the Arctic Network of parklands (ARCN) in northern Alaska, USA: Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Kobuk Valley National Park, Noatak National Preserve and Gates of the Arctic National Park and Preserve 2

Figure 2. The four brown bear survey areas with respect to the five ARCN park units including the Bering Land Bridge, Lower Noatak, Upper Noatak, and Gates of the Arctic brown bear study areas 6

Figure 3. The survey area and location of sample units on the Seward Peninsula, Alaska including Bering Land Bridge National Preserve (BELA 8

Figure 4. The survey area and location of sample units in the Lower Noatak River drainage, Alaska including Noatak National Preserve and Cape Krusenstern National Monument 9

Figure 5. The survey area and location of sample units in the Upper Noatak River drainage, Alaska including Noatak National Preserve and Gates of the Arctic National Park and Preserve 10

Figure 6. The survey area and location of sample units in Gates of the Arctic National Park and Preserve, Alaska 11

Figure 7. Example of a bear that would have been obscured by leaf-out. 12

Figure 8. Example of a bear in patchy snow demonstrating decreased visibility. 13

Figure 9. Examples of the same bear groups 'marked' by the first pilot-observer team (left photos) and re-sighted by the second pilot-observer team (right photos). 15

Figure 10. Long term monitoring project data management life cycle. 18

Figure 11. The ARCN/CAKN Core Functional Model overview. 20

Figure 12. Data products processing and flow diagram 22

Figure 13. Standard ARCN/CAKN Vital Sign Project reference architecture in the IRMA Data Store. 26

Tables

Page

Table 1. Schedule for brown bear surveys in Arctic Network (ARCN) park units including Bering Land Bridge (BELA), Cape Krusenstern National Monument (CAKR), Noatak National Preserve (NOAT), and Gates of the Arctic National Park and Preserve (GAAR).....12

Table 2. Brown bear monitoring data deliverables schedule. 23

Table 3. Estimated costs of brown bear monitoring surveys in ARCN per survey area. 31

Table 4. Standard Operating Procedures required to implement the Protocol for Monitoring Brown Bears in ARCN parks (CAKR, NOAT, BELA, and GAAR) 35

Executive Summary

The National Park Service (NPS) has developed a long-term ecological monitoring program known as "Vital Signs Monitoring" to provide the minimum infrastructure and enable more than 270 national park units, organized into 32 networks nationwide, to identify and implement long-term monitoring of their highest-priority indicators of natural resource condition. The Vital Signs Monitoring Program is a major component of the National Park Service's strategy to improve park management through greater reliance on scientific information. This protocol details the justification and procedures for brown bear (*Ursus arctos*) monitoring, a Vital Sign selected by the Arctic Network (ARCN). The ARCN includes five park units in northern Alaska: Bering Land Bridge National Preserve (BELA), Cape Krusenstern National Monument (CAKR), Noatak National Preserve (NOAT), Kobuk Valley National Park (KOVA), and Gates of the Arctic National Park and Preserve (GAAR).

Preserving the condition of park resources, including wildlife and their habitats, unimpaired in perpetuity is the fundamental management objective of the NPS. This management objective to "maintain unimpaired" captures the essence of the NPS mission and forms the foundation of the NPS long-term ecological monitoring program. Additionally, the enabling legislation for many NPS units in Alaska, the Alaska National Interest Lands Conservation Act (ANILCA), calls for protection of habitat for and populations of wildlife including brown bears in BELA, NOAT, KOVA, CAKR, and GAAR.

Monitoring is defined as the use of repeated surveys to obtain information on wildlife population status and change in status (Sauer and Knutson 2008). Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Fancy et al. 2009).

The purpose of this monitoring protocol, the Protocol for Monitoring Brown Bears for the Arctic Network, is to collect and analyze data and to report information that will help park managers assess the status of and maintain or improve the condition of this resource. Brown bears were chosen as a Vital Sign because they are very sensitive to habitat fragmentation, habitat loss, and human development that directly affects their survival. Because brown bears use a broad range of habitats and require large areas of habitat, they are an "umbrella species" – a species that confers protection to other co-occurring species with smaller spatial habitat requirements (Roberge and Angelstam 2004).

The objective of this monitoring protocol is to determine brown bear population trends and distribution in the ARCN parks by detecting trends in density, abundance, and occupancy over time in each survey area and across ARCN as a whole.

The NPS needs these metrics to inform conservation of populations of brown bears within park units and to manage for human-causes of mortality of brown bears while providing reasonable opportunities for consumptive and non-consumptive activities. In addition, these data will provide

baseline information to mitigate the effects of human development on brown bear populations within and adjacent to NPS park units.

The method is a fixed-wing, aerial survey using a systematic sampling design, double sampling, and photo mark-resight of bear groups and observations of dens to estimate brown bear density, abundance, and occupancy (Schmidt et al. 2017). The survey is conducted in a rotating schedule in each of 4 survey areas. Each of the four survey areas will be sampled once every four to five years during late May and early June.

The Protocol for Monitoring Brown Bears consists of a narrative (this document) and Standard Operating Procedures (SOPs) that outline the specific aspects of the monitoring protocol including the biological and statistical underpinnings of the methods. The latest versions of the SOPs and additional supporting information can be accessed online at the NPS's Arctic Network website and the Integrated Resource Management Applications portal website.

Acknowledgments

The authors would like to thank the many scientists who have focused their career on the conservation of brown bears, upon whose foundational research this protocol was built. Without the thorough treatment of observations, analyses, and reporting provided by past and current professionals, developing and writing this protocol would not have been possible.

We would like to thank Jim Dau, Tony Gorn, and Brandon Saito at the Alaska Department of Fish and Game (ADFG) for fruitful discussions about the methods and implementation of this protocol. We thank the pilots on the surveys used to develop these methods including Eric Sieh of Arctic Backcountry Flying Service, Jesse and Jim Cummings of Golden Eagle Outfitters, Gerald Lee of Basin Airmotive, Lance Williams of Wing and A Prayer Aviation, Andy Greenblatt of Shadow Aviation, Sandy Hamilton of Arctic Air Alaska, Dan Shelden of the NPS, and Jim Dau and Tony Gorn of ADFG. We thank survey observers during development of these methods including Marci Johnson, Brandon Saito, Letty Hughes, William (Bill) Dunker, Colton Sieh, and Alex Lewis. Logistical support was provided by numerous ARCN, CAKN, and WEAR staff and volunteers. Thank you to Regan Sarwas with GIS and data management and Andrew Baltensperger for his assistance with maps. Thank you also to Stacia Backensto and Sara Germain for the assistance with formatting. We thank Dick Shideler and Grant Hilderbrand for reviewing this protocol.

List of Key Acronyms

ANILCA:	Alaska National Interest Lands Conservation Act
ARCN:	Arctic Network, Inventory and Monitoring Program, NPS
BELA:	Bering Land Bridge National Preserve
CAKR:	Cape Krusenstern National Monument
CV:	Coefficient of Variation
DEM:	Digital Elevation Model
GAAR:	Gates of the Arctic National Park and Preserve
I&M:	Inventory and Monitoring Program, NPS
IRMA:	Integrated Resource Management Applications data store, NPS
KOVA:	Kobuk Valley National Park
NED:	National Elevation Dataset
NPS:	National Park Service
NOAT:	Noatak National Preserve
NRTR:	Natural Resources Technical Report
OAS:	Office of Aviation Services, U.S. Department of the Interior
QA/QC:	Quality Assurance and Quality Control of survey data
SOP:	Standard Operating Procedure
WEAR:	Western Arctic National Parklands (NPS unit comprising CAKR, KOVA and NOAT)

Background and Objectives

Background and History

Knowing the condition of natural resources in national parks is fundamental to the National Park Service (NPS) mission to manage park resources "unimpaired for the enjoyment of future generations." Park managers are confronted with increasingly complex and challenging issues that require broad-based understanding of the status and trends of park resources as a basis for making management decisions and working with other agencies and the public for the long-term protection of park ecosystems. The purpose of natural resource monitoring in parks is to collect scientifically sound information regarding 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 (Fancy et al. 2009). Use of monitoring information will improve the ability of park managers to make science-based decisions and address legal and political issues involving parks and park resources for more effective park operations and management. The overarching goals of the NPS monitoring program are to:

1. determine the status and trends of selected indicators of park ecosystem conditions 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; and
5. provide a means of measuring progress towards performance goals.

This protocol outlines the justification and procedures for brown bear (*Ursus arctos*) monitoring within the Arctic Network (ARCN). The ARCN includes five Arctic parks in northern Alaska: Bering Land Bridge National Preserve (BELA), Cape Krusenstern National Monument (CAKR), Noatak National Preserve (NOAT), Kobuk Valley National Park (KOVA), and Gates of the Arctic National Park and Preserve (GAAR) (Figure 1), which collectively represent 19.3 million acres or roughly 25% of the land area of NPS-managed units in the United States (Lawler *et al.* 2009). The ARCN parks contain a broad array of the ecosystems typical of the subarctic (boreal forest and taiga) and arctic (tundra) biomes of northern Alaska, stretching from tundra wetlands and coastline to the mountains. 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 (Lawler et al. 2009).

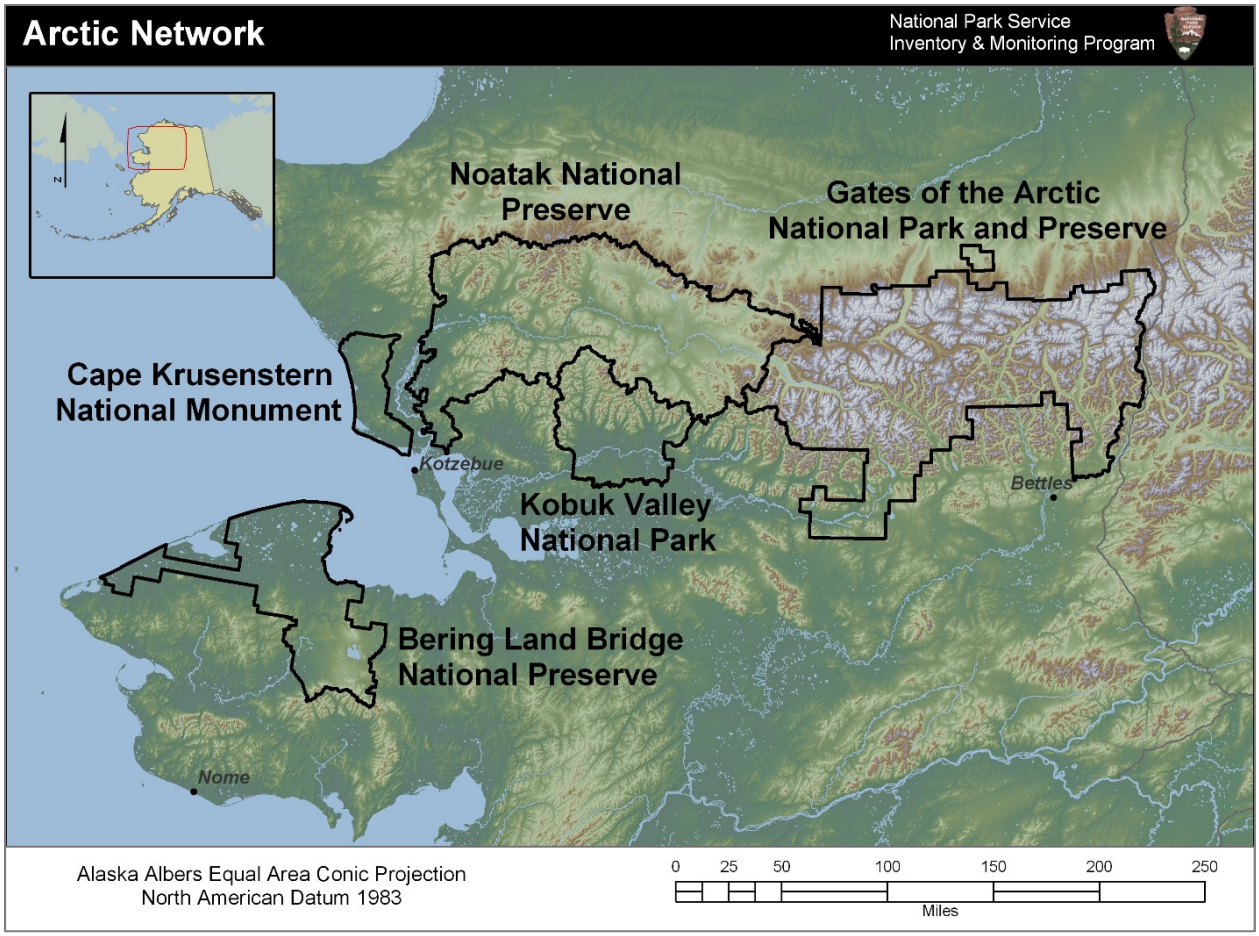


Figure 1. Location of the Arctic Network of parklands (ARCN) in northern Alaska, USA: Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Kobuk Valley National Park, Noatak National Preserve and Gates of the Arctic National Park and Preserve. Brown bears are monitored in four of the five parklands comprising the ARCN.

Rationale for Brown Bear Monitoring

The Alaska National Interest Lands Conservation Act (ANILCA, U. S. Congress 1980) contains enabling legislation and mandates relevant to brown bear conservation in NPS units in the ARCN and elsewhere in Alaska. Management purposes include the protection of habitat for and populations of brown bears. In 2007, brown bear populations in northwestern Alaska were selected for long-term monitoring under the NPS ARCN Vital Signs Monitoring Plan (Lawler et al. 2009).

The brown bear is an iconic species of Alaska's national parks, and its presence symbolizes the wilderness character of these vast landscapes. National Park Service units in Alaska exemplify and promote the simplest conceptual model of brown bear conservation: habitat and human tolerance (Schoen 1990). With both habitat and human tolerance, bear populations can persist, but the loss of either requires substantial efforts to maintain or restore viable bear populations. In spite of the vast habitat protection provided by Alaska's national park units and regulated harvest, however, the vulnerability of brown bear populations to anthropogenic disturbance is high and their resilience to anthropogenic disturbance is minimal (Mattson et al. 1996, Weaver et al. 1996, McLoughlin et al.

2003). Increasing demands for oil, gas, coal, and minerals along with accompanying industrial development (e.g. especially roads [McLellan and Shackleton 1988, McLellan 1990, and Waller and Servheen 2005]) on adjacent private, state, and federal lands may pose a threat to brown bear populations because of habitat fragmentation and human-caused mortality (Audubon Alaska 2003).

In the mid-1980s to early 1990s brown bears were well-studied in Alaska (Miller et al. 1997). These studies used capture-mark-resight (CMR) or home range overlap techniques, which involve handling and chemically immobilizing bears (Miller et al. 1997). Three of these study areas were within or adjacent to the ARCN parks of NOAT and BELA (Miller et al. 1997). The resulting data were used to determine population estimates, vital rates (lambda, survival), and spatial use by bears, but these studies were feasible over relatively small geographic areas due to expense and did not allow inference at larger spatial scales. More recently researchers developed robust methods to non-invasively mark and resight bears to generate population estimates at larger spatial scales and assess trends in bear populations over time (Schmidt et al 2017). These methods are more cost effective for long term monitoring of population trend, but when used alone these data lack the benefit of determining vital rates (lambda, survival) and spatial use by bears that are possible to determine with capture methods.

In spite of recent developments in methodology, since the 1990s wildlife managers have shifted their focus away from rigorously monitoring brown bears in northwestern Alaska meanwhile there are increasing threats from human development, legal and illegal harvest, predator control programs, and global climate change (GCC). While the affects of GCC may not all be adverse for bears (e.g., northward expansion of shrubs could be beneficial if the shrubs are berry-producing plants), understanding brown bear population trends in light of these changes is important to stewardship of this park resource.

This monitoring protocol and the data generated from its implementation will help the NPS rigorously monitor brown bear populations in the ARCN parks, achieve its ANILCA mandates, and pursue responsible management. As stated by Miller et al. (1997), “conservative management is preferable to wishful thinking that results in management errors that may take decades to correct.”

Monitoring the density, abundance, and occupancy of bear brown populations is necessary to understand brown bear population trends and to mitigate the effects of human activities especially those that affect survival within or adjacent to park units (McLellan 1990, Miller and Schoen 1998). Brown bears are an “umbrella species” – a species that confers protection to other co-occurring species with smaller spatial habitat requirements (Roberge and Angelstam 2004). Brown bears, therefore, are an important species to monitor because the effects of GCC on their habitat in the Arctic may occur sooner and be of greater magnitude than any other region on earth and co-occurring species will also be affected by these changes (Martin et al. 2008).

Objective

The monitoring objective of the ARCN brown bear monitoring protocol is to:

1. *Determine brown bear population trends and distribution in the ARCN parks by:*

a. *Detecting trends in density, abundance, and occupancy over time in each survey area and across ARCN as a whole.*

Methods

The method involves an aerial survey technique that uses a photographic mark-resight double-observer approach that relies on the physical characteristics and spatial locations of individual brown bears to temporarily mark individuals over a short revisit interval (Schmidt et al. 2017). This approach is applied along with site-occupancy techniques using bear and den locations to evaluate brown bear populations in the ARCN park units (Schmidt et al. 2017).

Previous to the development of this method, two statistical techniques were predominantly used for monitoring bear abundance in Alaska. The first approach used CMR techniques to estimate abundance and density of both black (*Ursus americanus*) and brown bears and was used widely in Alaska (Miller et al. 1997). The logistical and financial limitation of the CMR approach is that a radio-marked sample of bears must be established and maintained to estimate probability of detecting bears, to monitor movements of bears between the marking and observation period, and ultimately to estimate abundance and density of bears. Therefore, this technique is not feasible for large study areas (e.g. >2,000 km^2) where long-term monitoring is of interest.

The second approach used to estimate bear density has been distance sampling with line transects (Becker and Quang 2009, Becker and Crist 2015). During line transect sampling, a transect is traversed by the aircraft and animals are observed at varying distances. The observation distances are used to model the probability of detecting animals at varying distances from the transect (i.e., detection function) (Quang and Becker 1996, Quang and Becker 1999, Becker and Christ 2015). Like CMR techniques, line-transects have been used to survey bear populations in several areas around Alaska (Becker 2003). The sample size requirements of this method, however, are difficult to meet during one observation period in areas with low densities of bears such as the ARCN park units.

The aerial survey method described by Schmidt et al. (2017) is, therefore, the most rigorous, cost effective method currently available for estimating brown bear population density, abundance, and occupancy throughout the ARCN park units. This method is effective because most of the ARCN park units are predominantly open tundra, rolling hills, and adjacent mountainous areas where vegetation is sparse. The method requires approximately 50 bear group detections per survey to achieve CVs of 20 percent and allow for adequate population monitoring. Additionally, brown bears in northern Alaska occur at lower densities compared to those of coastal populations (Miller et al. 1997, Schwartz et al. 2003), precluding line transect distance sampling approaches which have lower detection rates and higher data requirements (e.g., multiple survey seasons, ≥150 bear group detections per survey [Reynolds et al. 2011]).

Sampling Design

Brown bears inhabiting the ARCN park units are part of a contiguous Arctic population ranging across Canada and Alaska (Servheen et al. 1998). Lacking empirical data to define populations within ARCN park units, we defined subpopulations within the continuous population appropriate for research and management purposes (e.g., park boundaries) (Edwards et al. 2008). The survey areas were, therefore, chosen within each ARCN park unit using a watershed-based approach that encompassed park unit boundaries, but were not arbitrarily confined by those boundaries (Figure 2).

An additional constraint was the extent of forested habitat especially within the southern portion of GAAR and most of KOVA since the method relies on the high visibility of brown bears in open habitats. Also, we wanted to survey areas at the landscape scale so that density estimates would be less influenced by limited study area extent (Smallwood and Schonewald 1998). The size of survey areas was further determined from a compromise between monitoring objectives and logistical, budgetary, weather, and personnel constraints associated with using fixed-wing aircraft and included input from partners such as the Alaska Department of Fish and Game (ADFG).

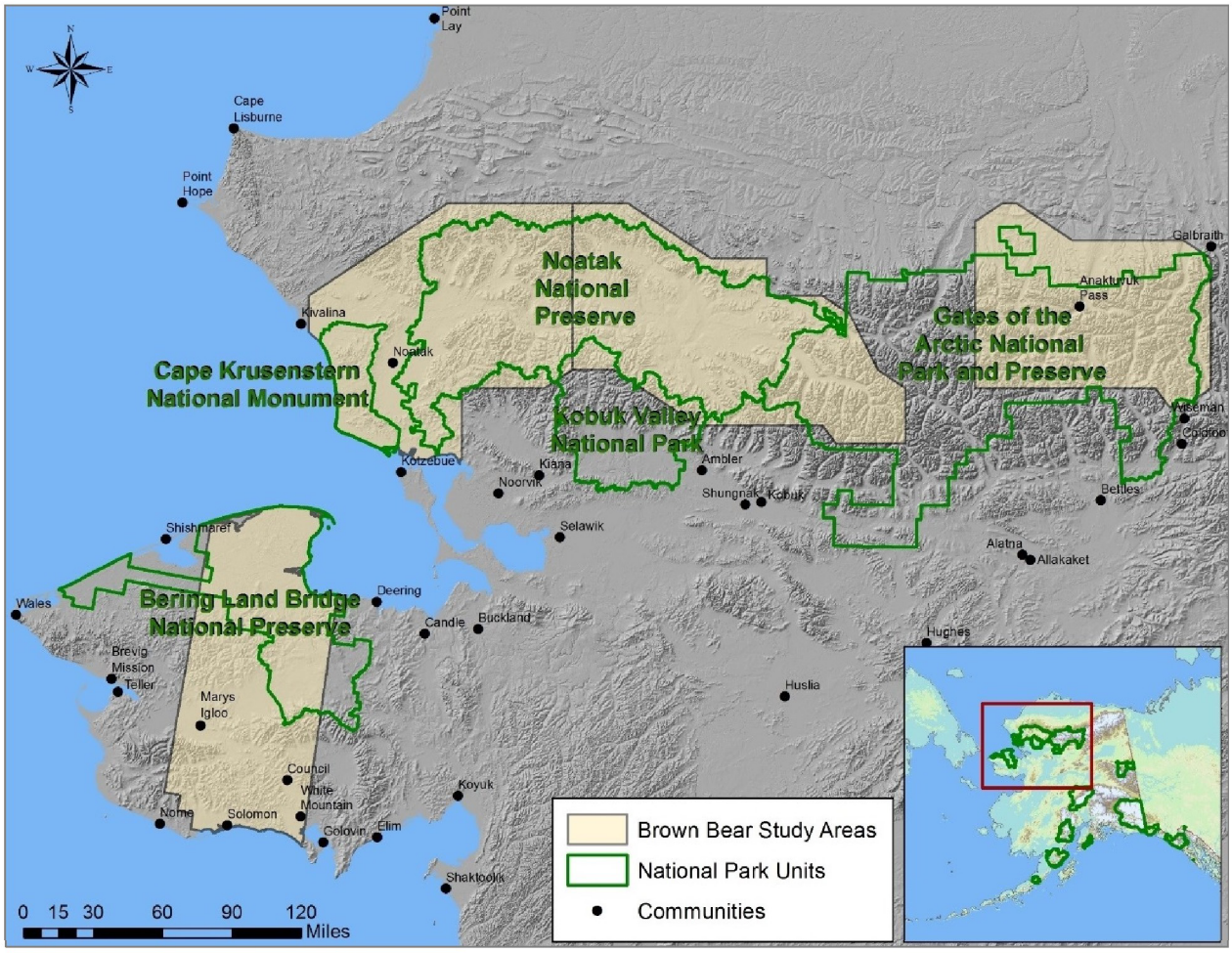


Figure 2. The four brown bear survey areas with respect to the five ARCN park units including the Bering Land Bridge, Lower Noatak, Upper Noatak, and Gates of the Arctic brown bear study areas.

The survey area size that overlaps the ARCN park units are as follows: Bering Land Bridge 19,998 km^2 (BELA), Lower Noatak (NOAT, CAKR) 23,596 km^2, Upper Noatak (NOAT, GAAR) 23,559 km^2, and Gates of the Arctic 18,213 km^2 (GAAR). In each survey area, we used a systematic sampling design to provide uniform coverage over the area and to minimize the movement of bears and bear groups between sampling units during the survey period (Schmidt et al. 2017). We started by generating a systematic grid of 31 km^2 cells across the study areas. The cells represented potential sampling units. The size of the sampling units was chosen based on anticipated bear densities (1-2

bear groups/sampling unit) from past work (Miller et al. 1997), the distance female brown bears in the Noatak River drainage have been found to move during a day (Ballard et al. 1993), and the expected amount of time required to sufficiently search each sampling unit (~1 hour). We selected groups of four adjacent cells, regularly spaced through the survey area to form geographically separated blocks each consisting of four sampling units (Figures 3-6). The geographic separation of the blocks (~11 km) was intended to be large enough to minimize the probability that a bear or bear group could be observed in different blocks on the same or separate days. This design would also allow a plane to sample two blocks per day. As much as practicable, the blocks are surveyed in sequence (e.g., east to west or vice versa) to avoid the potential effects of movement of bears or bear groups among blocks between days.

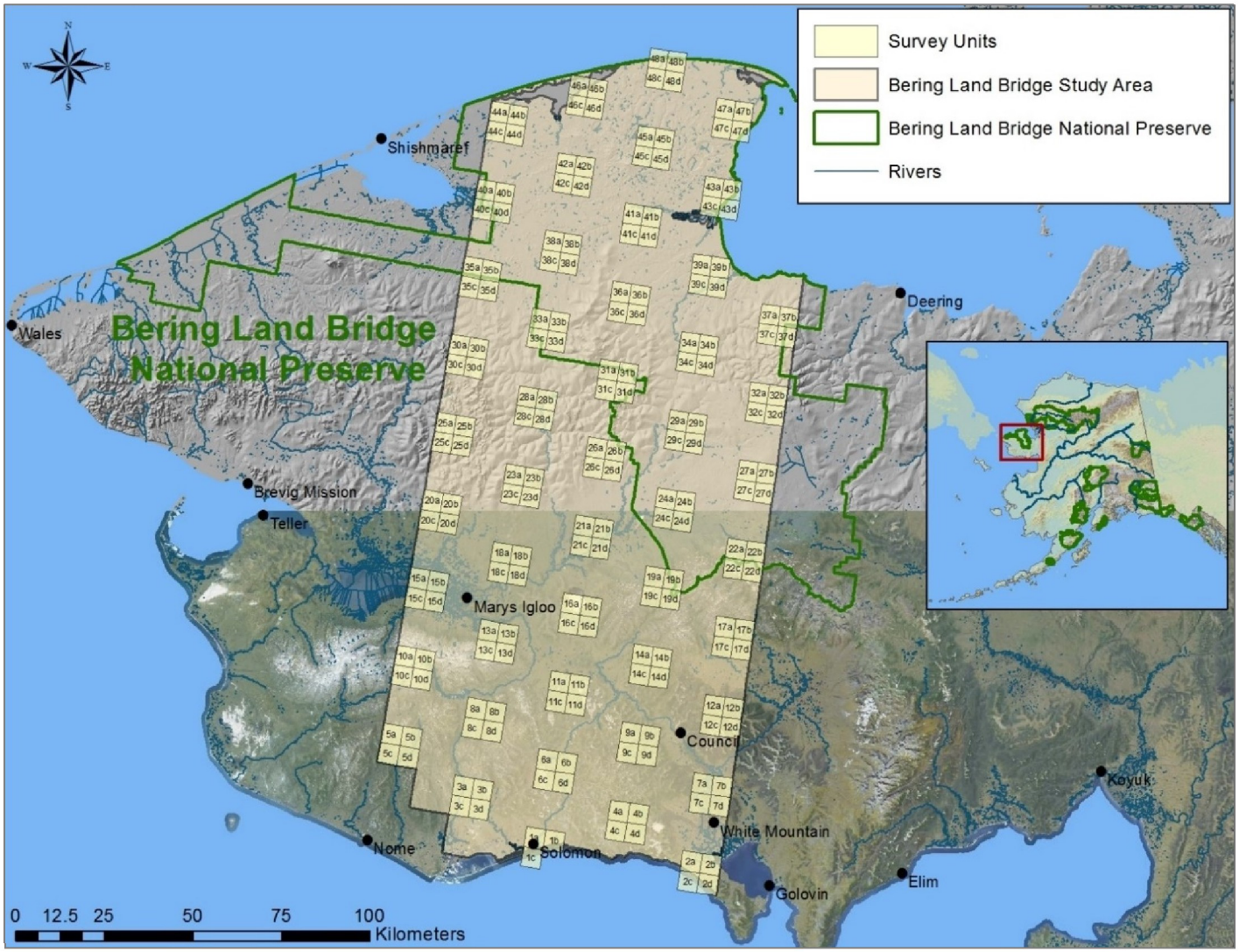


Figure 3. The survey area and location of sample units on the Seward Peninsula, Alaska including Bering Land Bridge National Preserve (BELA). The survey area is 19,998 km^2 in size and contains 191 sampling units. The survey area occurs within state Game Management Units 22B, 22D, and 22E.

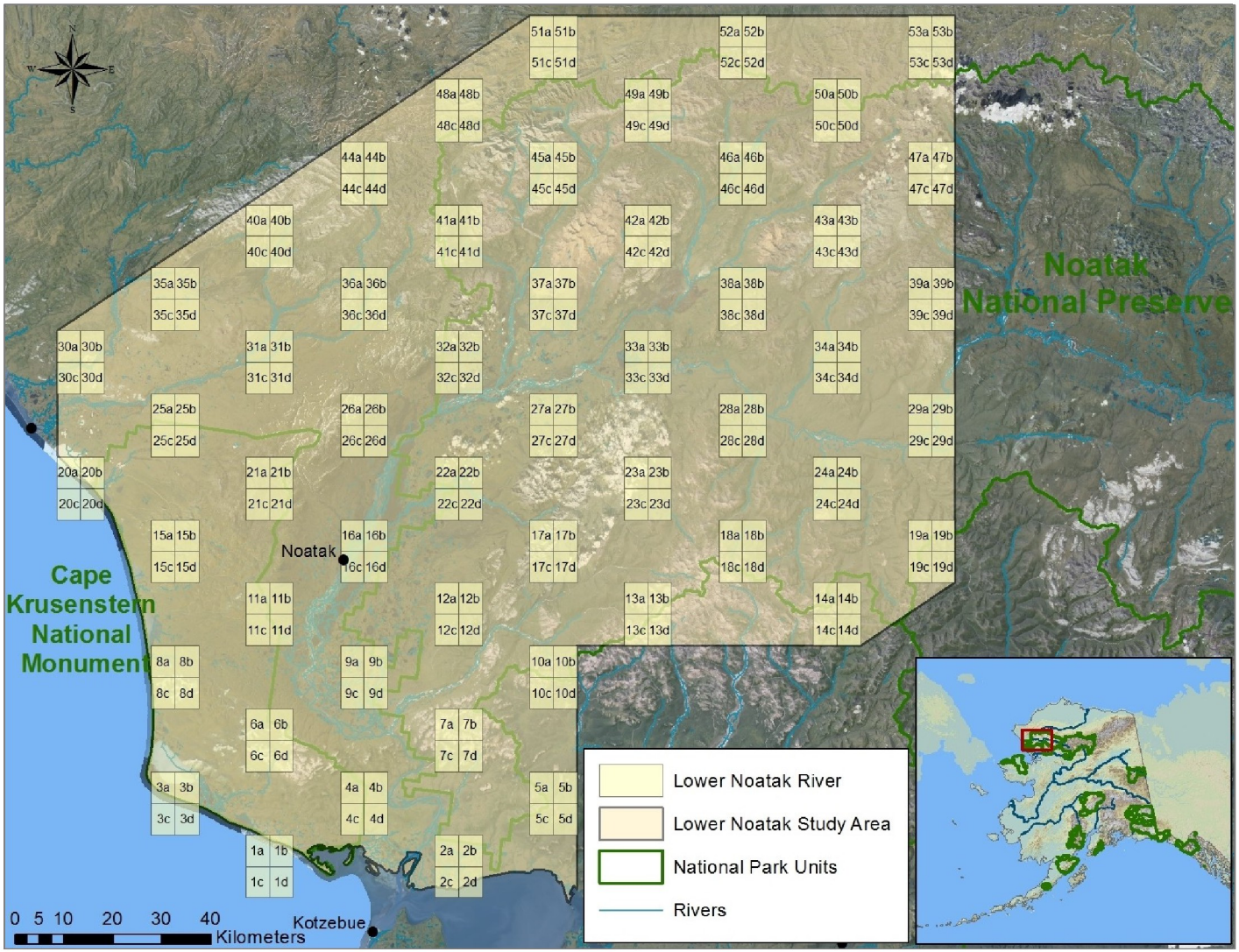


Figure 4. The survey area and location of sample units in the Lower Noatak River drainage, Alaska including Noatak National Preserve and Cape Krusenstern National Monument. The survey area is 23,596 km^2 in size and contains 208 sampling units. The survey area occurs within state Game Management Unit 23.

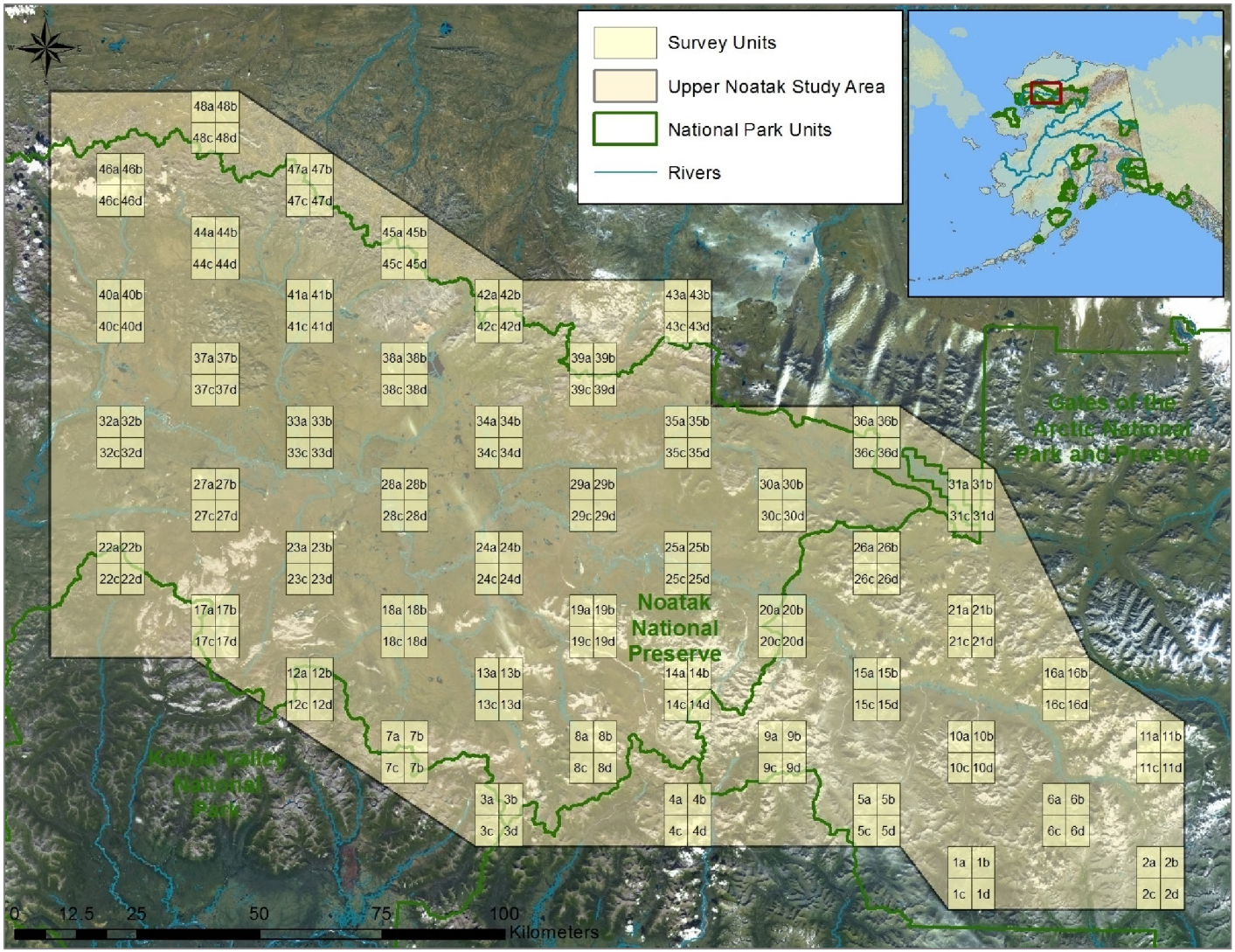


Figure 5. The survey area and location of sample units in the Upper Noatak River drainage, Alaska including Noatak National Preserve and Gates of the Arctic National Park and Preserve. The survey area is 23,559 km^2 in size and contains 192 sampling units. The survey area occurs within state Game Management Unit 23.

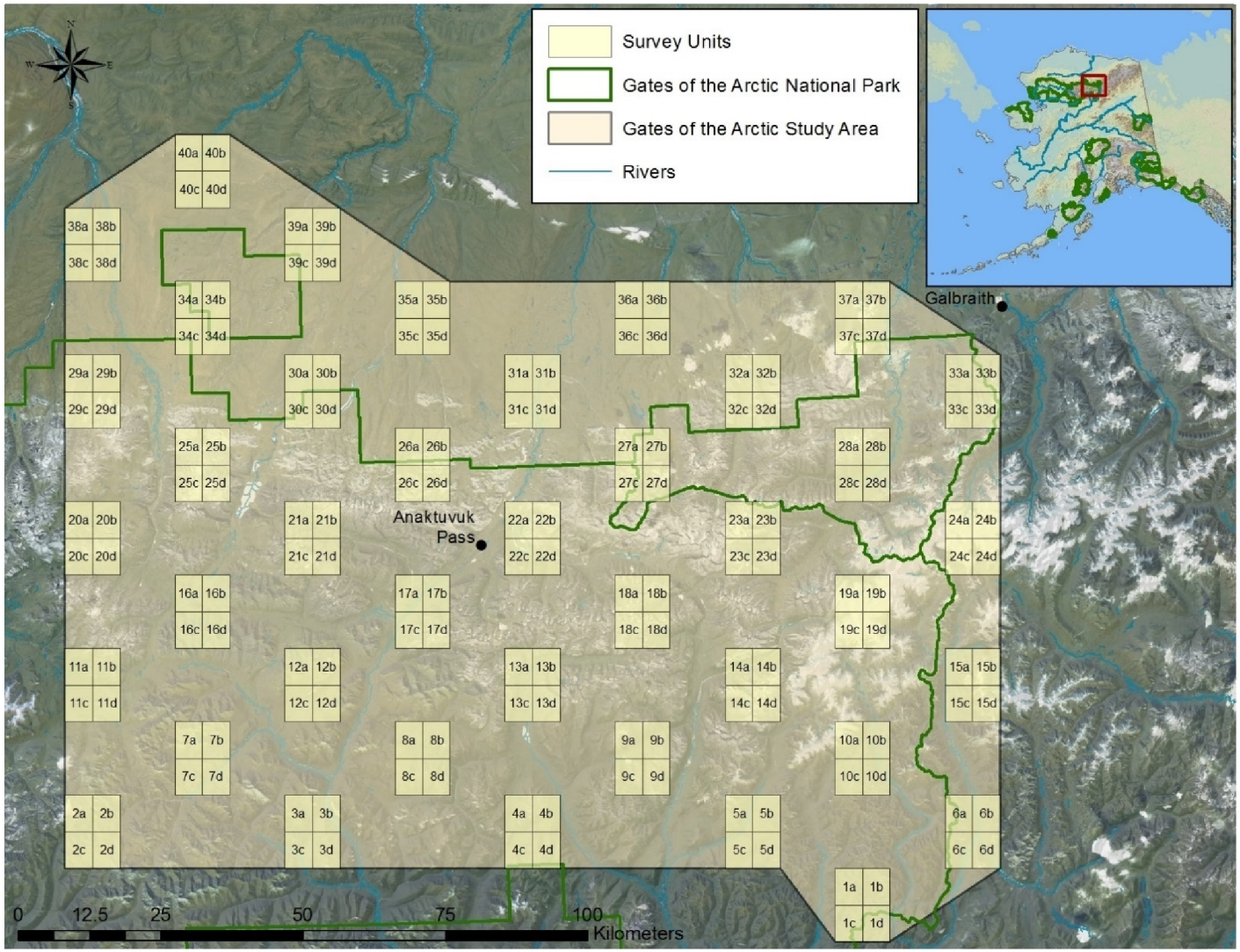


Figure 6. The survey area and location of sample units in Gates of the Arctic National Park and Preserve, Alaska. The survey area is 18,213 km^2 in size and contains 160 sampling units. The survey area occurs within state Game Management Units 24A, 24B, 26A, and 26B.

Monitoring Schedule and Survey Timing

Surveys will be rotated among the four survey areas (Table 1), with the fifth year being an off year dedicated to data analysis and report writing. Only one survey can be completed each year because of staffing, logistical, and cost constraints. A 20-year sampling interval will yield four abundance and occupancy estimates for each survey area. Surveys must be timed after den emergence, before leaf-out, and ideally after snow-melt in lower elevations (i.e., to avoid patchy snow). The onset of green-up in ARCN park units is related to location and air temperature (Swanson 2010). Once the leaves of woody vegetation unfurl, the visibility of bears decreases (Figure 7). Patchy snow cover also decreases the visibility of bears (Figure 8).

Table 1. Schedule for brown bear surveys in Arctic Network (ARCN) park units including Bering Land Bridge (BELA), Cape Krusenstern National Monument (CAKR), Noatak National Preserve (NOAT), and Gates of the Arctic National Park and Preserve (GAAR).

Survey Area/Park Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Seward Peninsula/BELA	X	–	–	–	–	X	–	–	–	–
Lower Noatak (CAKR/NOAT)	–	X	–	–	–	–	X	–	–	–
Upper Noatak (NOAT/GAAR)	–	–	X	–	–	–	–	X	–	–
Gates of the Arctic (GAAR)	–	–	–	X	–	–	–	–	X	–



Figure 7. Example of a bear that would have been obscured by leaf-out.

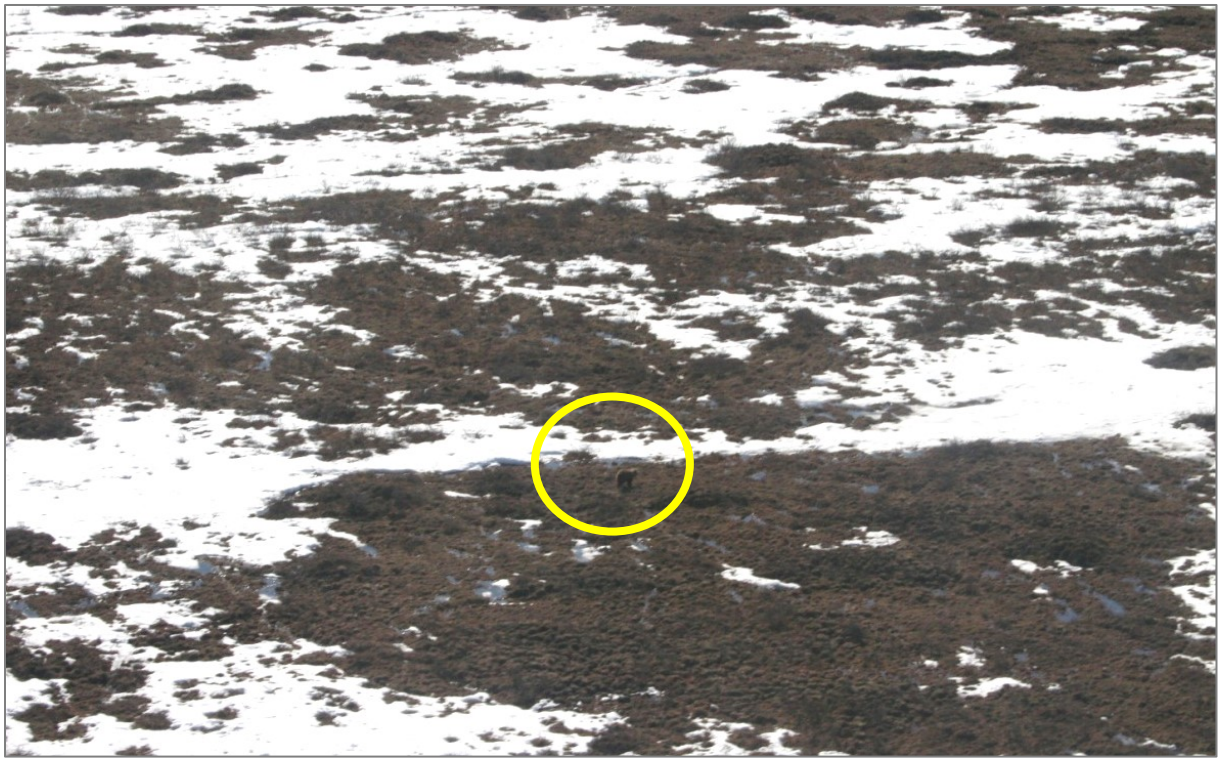


Figure 8. Example of a bear in patchy snow demonstrating decreased visibility.

If a survey is halted prematurely, inference can still be obtained, but from a smaller area than the entire survey area. For example, if all of a survey area is sampled in 2017 and one third of it is sampled in 2022, we can compare the densities in the one third of the study area that was surveyed in both years. If a survey has to be abandoned, if funding allows, the survey can be re-done the next year and the schedule can be adjusted.

Surveys within the Brooks Range – Lower Noatak River drainage (CAKR/NOAT), Upper Noatak River drainage (NOAT/GAAR), and Gates of the Arctic National Park and Preserve (GAAR)

Sows with cubs of the year (COY) emerge latest from their dens (i.e., 18-21 May) and most bears had moved away from their dens prior to 1 June (Ballard et al. 1993). A study conducted in GAAR 2015-2017 found that bears moved away from their dens by 20 May (M. Sorum, unpublished data).

In general, the onset of greenness in the Brooks Range begins around 30 May (C. Markon, unpublished report) and leaf-out is complete by 10 June. The 2015-2017 study in GAAR found that leaf out occurred around 1 June (M. Sorum, personal communication). Based on these data and observations, aerial surveys within the Brooks Range should occur between 16 May and 1 June. Science and local knowledge, however, report that global climate change (GCC) is changing phenology in the Arctic including the timing of snowmelt, green-up, and leaf-out (Swanson 2010) and survey timing may need to be adjusted to adapt to those changes.

Survey within Bering Land Bridge National Preserve (BELA)

Green-up and leaf-out on the northern Seward Peninsula is later than interior areas (Swanson 2010), but is typically snow-free by mid-May. Based on observations, leaf-out is not complete on the northern Seward Peninsula until at least 10 June during most years. In 2015, however, vegetation on the southern Seward Peninsula was beginning to leaf out 25 May. Timing of surveys in BELA will be similar to the surveys in the Brooks Range, except that coastal weather conditions may make it more difficult to predict when the snow will be melted enough to begin the survey and ensure high sightability. Again, GCC may alter the timing of these events and survey timing may need to be adjusted to accommodate this.

Field Methods and Survey Preparation

As described above, aerial surveys are timed to coincide with the end of den-emergence, prior to leaf out of woody vegetation, and after snow melt in lower elevations (i.e., to avoid patchy snow). At present, these conditions occur in late May or early June. The method is a double-observer mark-resight approach. A single pilot and observer fly in a single engine tandem aircraft (e.g., super cub, husky) and form a 'team' given the task of searching sampling units for bears (Schmidt et al. 2017). Each day pairs of teams are assigned two blocks (8 sampling units) to survey (Schmidt et al. 2017). The first team thoroughly searches a sampling unit and 'marks' the bear groups they observe by taking their spatial location and high resolution photos of the bears (Schmidt et al. 2017). Pilots are free to choose the search pattern as long as the entire subunit is covered. The pilot records a track log of their flight path and waypoints of the bears they observe on their GPS unit (e.g., Garmin 296/496). The observer records the flight path and bear observation data on an iPad using the Park Observer application developed by the NPS Alaska Regional Office GIS Team and on paper data sheets as backup. Observers also take high resolution photos of bears with fast action cameras with zoom lenses. After the first team surveys the sampling unit, the second team surveys the sampling unit using the same method and may or may not re-sight the bear groups the first team observed (Schmidt et al. 2017) (Figure 9). Teams search each sampling unit thoroughly for bears and dens with the guideline of spending about 1 h of search time per sampling unit. Each evening, paired teams compare the photographs of and locations of the bear groups and dens they observed throughout the day to determine whether they resighted the same bear groups and to document dens. Each evening, the observers also download and backup the iPad and GPS data and the photos on a field laptop and hard drive. Sightability is averaged across all survey conditions and surveys, however, investigation into potential differences would be possible.



Figure 9. Examples of the same bear groups 'marked' by the first pilot-observer team (left photos) and re-sighted by the second pilot-observer team (right photos).

The survey method is also described in Schmidt et al. (2017) and covered in various parts of the nine Standard Operating Procedures (SOPs) that accompany this narrative. The SOPs also describe the mechanics of how the survey is prepared for, implemented, and the data are collected, prepared and analyzed. The SOPs are available on the Brown Bear Vital Sign page.

SOP 1 "Preparations for the Field Season" describes how to prepare for the aerial surveys (except where specific tasks are covered by other SOPs). The SOP covers and/or introduces: 1) obtaining permits; 2) scheduling personnel; 3) coordinating aircraft, base airstrips and fuel caches; 4) preparing equipment; 5) uploading maps, waypoints, the brown bear survey protocol, and the most recent

version of Park Observer to the iPads for data collection and navigation; 6) aviation requirements such as safety and flight following; and 7) pre-season training.

SOP 2 “Field iPad Set Up” describes how to prepare the iPads with Park Observer to collect field data for brown bear aerial surveys. Some specific related tasks are covered by other SOPs. Park Observer and iPad preparation and training tasks include: 1) installing Park Observer on the iPad, 2) making background maps for the iPad, and 3) setting up the iPad and Park Observer for brown bear surveys.

SOP 3 “Training” describes the annual training procedures required for personnel involved with brown bear monitoring. These include training on aviation safety, basic life support (e.g., CPR and first aid), the survey method, using Park Observer to collect data and navigate with the iPads, camera use, a brief primer on data downloading, and use of paper data sheets.

SOP 4 “GPS Set Up” describes how to create and load the sampling unit grids, waypoints for the SW corner of sampling units, and topographic maps onto the pilots’ GPS units that are used for navigating and marking bear and den locations. The GPS units commonly used by survey pilots at the time of this writing are Garmin 296 and 496 (Olathe, Kansas).

SOP 5 “Field Equipment Lists” outlines lists of gear required by pilots, observers, and the base camp to successfully carry out the survey. There must be enough sets of equipment for each plane (pilot-observer team) participating in the survey. All equipment should be tested for proper function before sending it into the base airstrips for the survey. A morning checklist for observers is provided – this checklist should be reviewed each morning prior to starting a survey flight to ensure that all equipment is accounted for.

SOP 6 “Flying Surveys and Collecting Data” describes the survey method of Schmidt et al. (2017) and the roles and responsibilities of the pilot and the observer when flying aerial surveys and collecting data for brown bear monitoring. The pilot and observer have separate responsibilities, but must communicate frequently and work closely together to fly safely and to search for brown bears, bear dens, and bear tracks while surveying units and collecting data. The SOP describes the flight and search pattern pilots should use (if allowable by conditions) in different types of terrain. The SOP also describes how paired pilot-observer teams should coordinate with each other to ensure safety and proper coverage of the sampling units. The SOP also outlines the equipment each team will need as well as how to use it to collect data (e.g., camera, GPS, iPad and Park Observer, paper data sheets, etc.).

SOP 7 “Data Downloading and Backup” gives the procedures for observers (or the data entry person) to download and backup data at the end of each survey day and to prepare (e.g., recharge) survey equipment for the following survey day. It also includes instructions for some minor editing of the data that may be required.

SOP 8 “Data QA/QC, Formatting, and Archiving” covers field data processing, data quality assurance and quality control (QA/QC), and instructions on how to prepare the data for analysis. These methods closely follow those developed for Dall’s sheep in SOP 11 for the ARCN Dall’s

sheep Vital Sign (Rattenbury and Schmidt 2017). For full protocols regarding brown bear analysis, see SOP 9 (Data Analysis) and Schmidt et al. (2017).

SOP 9 "Data Analysis" describes the assumptions required under the double sampling photo mark-resight framework to insure proper inference. The SOP also details the general processes for analysis of the data.

Level of Change That Can Be Detected

At the time of this writing, previous survey effort has been variable. This fact, when combined with future gains in precision relative to possible population changes, makes it difficult to conduct a meaningful power analysis. However, initial results for the 2015 survey of the Seward Peninsula/BELA area produced occupancy and abundance estimates with CV's of 18% and 23%, respectively (Schmidt et al. 2017). Preliminary analysis of data from the 2016 survey of the Lower Noatak area and the 2017 survey of the Upper Noatak area using informed priors based on the previous years' results produced abundance estimates with CV's of ~16%. The CV's may improve (i.e., decrease) further as additional data are collected, but are comparable to the levels of precision obtained for the Dall's sheep monitoring program (Rattenbury et al. 2017). Based on the findings of Rattenbury et al. (2017), we expect to be able to detect a ≥50% decline between surveys and a ~20% decline over a 20-year period (i.e., after 4-5 surveys across a given survey area have been conducted). Given the life history characteristics of bears, this should be adequate to detect meaningful population-level changes in brown bears across ARCN.

Data Management

Data management for the brown bear monitoring program will proceed through an ongoing life cycle as shown in Figure 10 (NPS 2008a). Major stages of the life cycle include data collection, data entry and import, quality control, data product documentation and archival, seasonal closeout, dataset certification, and data analysis and reporting (NPS 2008b). An overview of major component of the brown bear monitoring data management life cycle follows. Specific procedures are given in the standard operating procedures (SOPs).

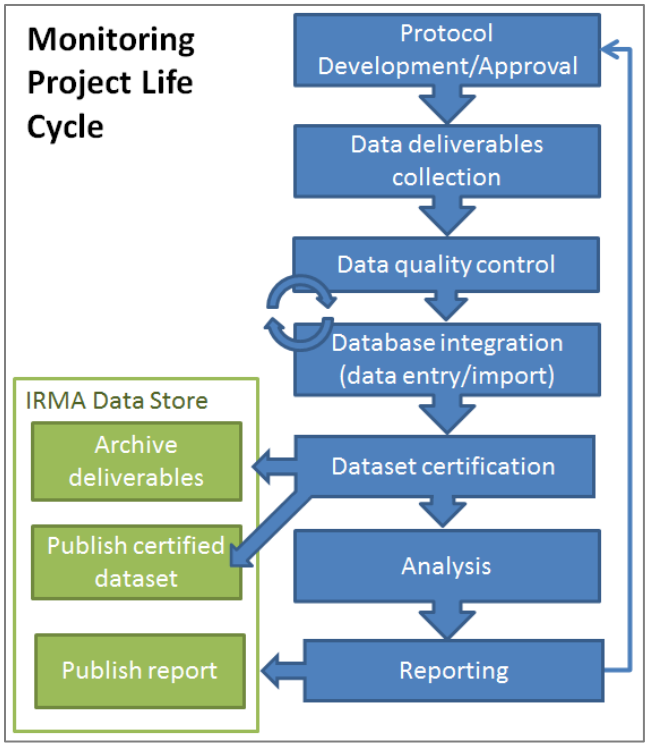


Figure 10. Long term monitoring project data management life cycle.

NPS Standards

Data Quality

Director's Order #11B mandates a high level of information quality from the service's scientific programs:

> *The National Park Service will ensure that information it releases will be developed from reliable data sources and will otherwise ensure information quality at each stage of information development. The NPS's methods for producing quality information will be made transparent, to the maximum extent practicable, through accurate documentation, use of appropriate internal and external review procedures, consultation with experts and users, and verification of the quality of the information disseminated to the public. The NPS will also keep users informed about corrections and revisions.*
>
> *Information will be developed only from reliable data sources based on accepted practices and policies utilizing accepted methods for information collection and verification. It will be reproducible to the extent possible. Influential information will be produced with a high degree of transparency about data and methods. The information should include all pertinent information to allow the public to understand the park's legislative authorities, mission, activities, organization, strategic plan, performance plan, and performance accomplishments.*

Director's Order #11A section 5.8: Data Integrity Standards outlines the NPS policy for accuracy, completeness and review:

> *All information owners will maintain all official NPS records and data in a manner which meets the highest data integrity standards, including timeliness, accuracy and completeness (also see DO #11D). Each information owner will take whatever steps necessary to ensure that NPS systems have sufficient data quality reviews and audits from both an internal system perspective, as well as externally thorough control reviews.*

Adherence to the data management procedures in this monitoring protocol will ensure compliance with DO#11.

Freedom of Information Act

The Network will comply with all FOIA restrictions regarding the release of data and information as instructed in NPS Director's Order #66B.

Records Management

Direction for managing physical and digital materials is provided in NPS Director's Order 11D.

> *The NPS has a strong business need for excellent records management, in that the Service's mission is to care for natural and cultural resources so that they are left "unimpaired" for future generations. This requirement for managing resources in perpetuity sets a high standard for record keeping. No resources can be managed well in the future without complete records of how they were managed in the past. Because the NPS manages some of America's most significant cultural and natural resources, the public also has a significant interest in our records. Section 1.9.2 of NPS Management Policies 2006 (NPS, 2006) states that the future of the Service depends on the availability, management, dissemination, and preservation of information, and directs the agency to implement professional quality programs to manage information resources.*

Core Functional Model

Data generated by the ARCN brown bear monitoring program are managed according to the Core Functional Model described in Figure 11.

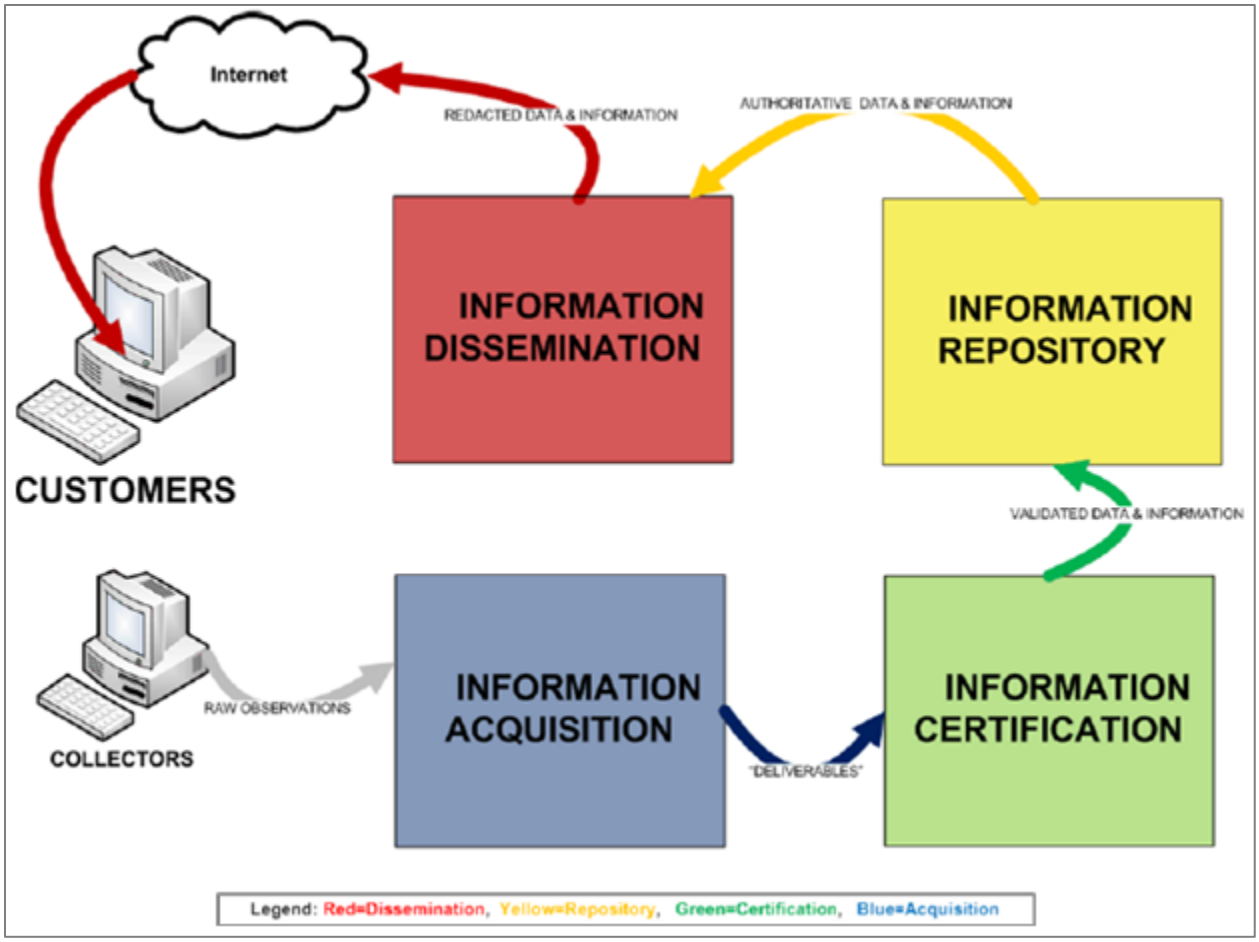


Figure 11. The ARCN/CAKN Core Functional Model overview.

Dissemination services (red, Figure 11) provide all deliverables to all customers using internet web sites and web services through the NPS Integrated Resource Management Applications (IRMA) Data Store. Repositories (yellow) store the certified inventory and monitoring products called for in the protocols. Certification processes (green) assure repositories have the highest quality data and that sensitive items are restricted to authorized users. Data acquisition processes (blue) led by park staff and cooperators include a wide array of tasks, ranging from collecting raw data to composing reports on long-term trends.

Data Sensitivity Statement

The ARCN brown bear monitoring protocol defines the collection of sensitive data and requires special handling procedures.

The justification for this declaration of sensitivity is that the data deals with 'rare, threatened, endangered, or commercially valuable species' (National Parks Omnibus Management Act [1998], NPS 2006). Brown bears are harvested species and are sensitive to anthropogenic affects and to environmental conditions. The sensitivity of bear data aligns with NPS policy 4.1.2 (NPS 2006).

Network staff must ensure that all references to protected information are removed or obscured in any reports, publications, maps, or other public forum. Following the standard for Freedom of Information Act (FOIA) requests, the Network will segregate the non-releasable information and where practical will not withhold associated releasable information. Metadata for datasets and this protocol must be updated in the IRMA citation to reflect that the associated data is sensitive. Network staff must ensure that all references to protected information are removed or obscured in any reports, publications, maps, or other public forum.

The project leader is responsible for maintaining the security of data released to any NPS dataset catalog and ensuring confidentiality agreements are in place before sharing data with any non-NPS entity.

Network staff must ensure that all references to protected information are removed or obscured in any reports, publications, maps, or other public forum. Following the standard for Freedom of Information Act (FOIA) requests, the Network will segregate the non-releasable information and where practical will not withhold associated releasable information. Metadata for that dataset and the IRMA citation must also be updated to reflect that the associated data is sensitive. Network staff must ensure that all references to protected information are removed or obscured in any reports, publications, maps, or other public forum.

The project leader is responsible for maintaining the security of data released to any NPS dataset catalog and ensuring confidentiality agreements are in place before sharing data with any non-NPS entity.

Roles and Responsibilities

Project Leader

- Ensures that the brown bear monitoring protocol and all of its standard operating procedures are current and up to date. If methods must be changed the project leader ensures that the standard operating procedures remain in sync with actual data management operations. Ensures data is collected, processed and integrated with the master database consistently and strictly according to the specifications and methods described in the standard operating procedures. Performs an annual closeout with the Network program manager and data manager.
- Certifies the brown bear monitoring dataset for analysis and publication and assures that the brown bear monitoring standard operating procedures are current and up to date.
- Performs analytical procedures and reports on findings.
- Arranges technicians and budgets for data management costs, such as data entry and processing.

Data Manager

- Provides for the security, longevity and accessibility of the brown bear monitoring dataset.

- Maintains software and hardware for file backups and security, databases, custom and proprietary applications and GIS tools.
- Guides personnel in data processing techniques, metadata generation and product archival in NPS data stores and enterprise databases.

Data Collection

Data Collection Overview

The brown bear monitoring program creates and maintains specific data deliverables (Table 2). Raw data deliverable files are collected during surveys and processed for quality (Figure 12). Processed files are certified by the project leader and analyzed. During seasonal closeout the raw deliverables are archived in private Data Store references while certified data files are archived in the Brown Bear monitoring program's authoritative, public certified Dataset.

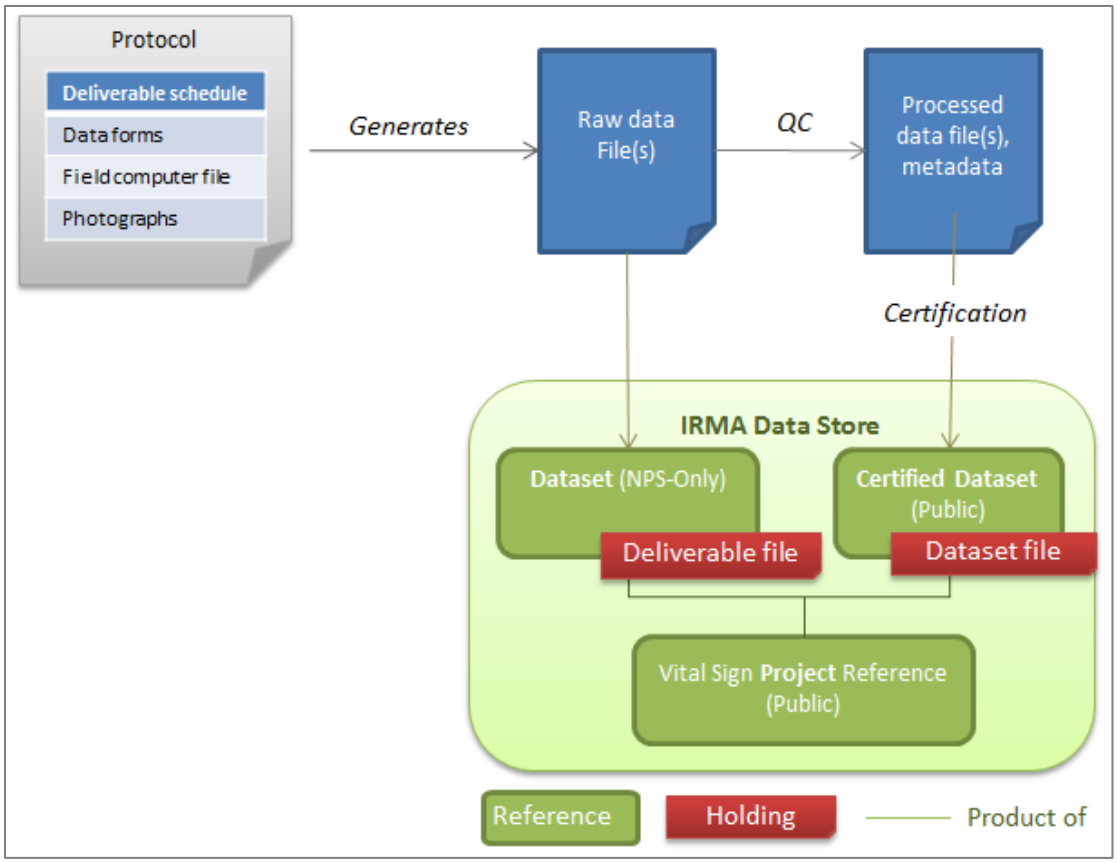


Figure 12. Data products processing and flow diagram. Data deliverables are collected on a cycle, processed to analytical quality, certified, and published to the IRMA Data Store. Raw deliverables are retained in private Dataset references.

Table 2. Brown bear monitoring data deliverables schedule.

Identifier	Deliverable	Format	Schedule	Responsibility	Description
BB01	ARCN_Bears_20xx.gdb	Geospatial layer	Remeasurement + 2 years	PI*	Geodatabase containing QA/QC-checked survey data
BB02	IPad application Survey files	.pov, Shapefiles, CSV equivalent	Remeasurement + 2 years	PI, DM	'Survey' folder containing iPad Park Observer .pov files and shapefiles of the raw, field-collected data prior to processing those data in the ARCN_Bears_20xx.gdb
BB03	Survey waypoints	Shapefile, CSV equivalent	Remeasurement + 2 years	PI	Waypoints collected by the pilot and/or observer during the survey
BB04	Survey tracklogs	Shapefile, CSV equivalent	Remeasurement + 2 years	PI	Tracklogs collected by the pilot and/or observer during the survey
BB05	Survey photographs	.jpg	Remeasurement + 2 years	PI	Photographs generated during the survey
BB06	Survey data collection forms	Physical forms and TIFF or PDF scans	Remeasurement + 2 years	PI	Annotated data collected forms generated during the survey
BB07	Survey units spatial layer	Shapefile, CSV equivalent	Only required if the units change	PI	Spatial layer showing the survey areas and units in ARCN

* PI = Principal Investigator, DM = Data Manager

Each deliverable is disseminated directly from the IRMA Data Store, the single authoritative source for Network products. In the event that a data product ever diverges from that in the IRMA Data Store the latter version should be considered authoritative.

Data Entry/Import

Field data collection involves aerial surveys to collect the majority of the products in the deliverables schedule above. The following is a brief summary of the data downloading, verification and editing processes; details can be found in SOP 7 (Data Downloading and Backup), SOP 8 (Data QA/QC and Formatting, and Archiving), and SOP 9 (Data Analysis).

At the end of each day during a survey, the observers will download their iPad Park Observer data into the geodatabase housed on a laptop. Each pilot-observer team compares the iPad data and photographs and locations of the bear groups and dens they saw throughout the day with the pilot's tracklogs and waypoints and with the other pilot-observer team they were paired with. The observer of the teams will note if the iPad Park Observer data differs greatly from the pilot's tracklogs and waypoints and if the geodatabase needs to be edited in GIS before the final QA/QC and data analysis. Any changes to the datasheets should be crossed out with a line and the new information written below and should also be transferred to the geodatabase.

The project manager will assemble all data following the surveys and perform a final QA/QC (SOP 8). He/she will check all original datasheets for legibility and completeness, or will delegate this to a technician who was not involved with the data collection. Any remaining discrepancies between the pilots' shapefiles, the datasheets and the iPad Park Observer data will be discussed and corrected with the observer. The datasheets will be scanned following the final QA/QC and the tracklogs, waypoints and photographs will be labeled and processed with standardized metadata for incorporation into the IRMA file management system (see Product Archival, Seasonal Closeout and Dataset Certification Procedures for the Arctic and Central Alaska Inventory and Monitoring Networks: ARCN/CAKN Data Management Standard Operating Procedure #1 (Miller 2017). All digital files should be transferred to the appropriate ARCN network drives for permanent storage.

Bear group and den observations within the geodatabase are processed and edited as needed before analysis. The project manager and/or designated technician will verify the geodatabase with the hardcopy data (datasheets and photographs) and the pilots' tracklogs and waypoints and edit the geodatabase as needed using ArcGIS (ESRI, Redlands, CA). The geodatabase, which is now considered certified, is then queried and data are extracted into the file format used to run the WinBUGS or OpenBUGS models to generate estimates of bear abundance and occupancy (Schmidt et al. 2017). Refer to SOPs 7 and 8 for additional details about the data QA/QC, geodatabase editing and formatting that are required for incorporation into the IRMA Data Store.

Brown bear monitoring data is stored in a master IRMA Datastore file base management system.

Quality Assurance

The brown bear Vital Sign plans for high data quality assurance by proactively deploying a system of administrative procedures and technological safeguards including:

- Standard operating procedures designed to minimize the introduction of errors during data collection and processing.
- Field crew training.
- Standard database security and integrity functions and data integrity constraints (Frakes et al., 2015) to enforce compliance with the Vital Sign's logical data model.
- Application level data entry checks and business rule enforcement.
- Periodic data quality audits and reports.

Quality Control

Ensuring high data quality as a priority for the brown bear Vital Sign. Quality control procedures focus on verifying data as well as identifying and correcting errors in final data products. Quality control safeguards include:

- Data verification and/or double data entry procedures
- Spot checking
- Impossible value checking
- Graphical and visual exploratory data analysis
- Statistical error or outlier identification
- Data quality audits and reporting
- Dataset certification

Product Archival and Documentation

Director's Order 11D states that all records of natural and cultural resources and their management are considered mission-critical records (necessary for fulfillment of the NPS mission) and must be permanently archived. Mission critical deliverables are considered to be archived when they are uploaded to the IRMA Data Store. With few exceptions IRMA is the only authoritative repository for mission critical I&M products. Data archiving is done in concert with seasonal close out and data certification (ARCN/CAKN DMSOP-1, Miller 2017).

Brown bear monitoring program data are maintained on the NPS network file share in the Fairbanks Administrative Center (FAC) in Fairbanks, Alaska and backed up to off-site storage at a separate NPS facility in Fairbanks. The NRSS and FAC use enterprise-level business continuity processes to maintain data security. In the event of catastrophe at one site, the original data may be restored from the other.

IRMA Data Store

The NPS IRMA Data Store is the primary organizational repository and publication platform for information related to the brown bear monitoring program. The brown bear Vital Sign has a single master IRMA project reference to which all products are related (Figure 13).

The public Vital Sign web page covering brown bear monitoring will publish the releasable contents of this reference and its related references via web services. It is the joint responsibility of the PI and the data manager to keep the system of related IRMA Data Store references up to date.

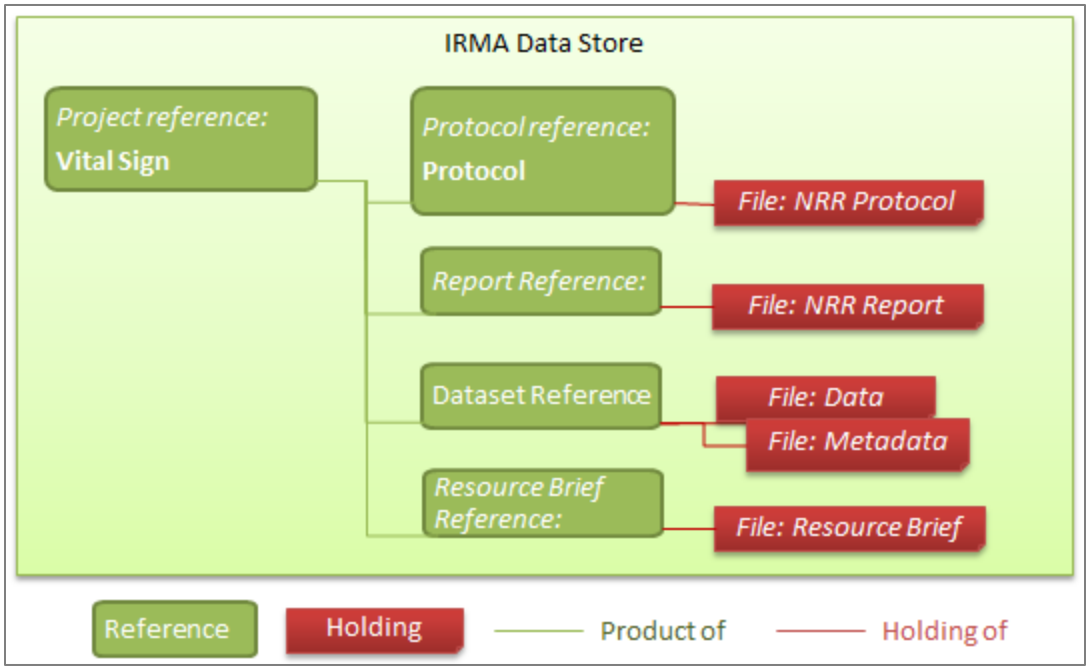


Figure 13. Standard ARCN/CAKN Vital Sign Project reference architecture in the IRMA Data Store.

Reports

Reports are published in the NPS Natural Resource Report publication series or professional journals. Reports and journal articles reporting analytical results will be published in tandem with the dataset that was used.

Natural Resource Reports are automatically tracked and announced to Network program managers and data managers but journal articles are not. The PI will create Data Store references for journal articles related to monitoring, link them to the Vital Sign's IRMA Project reference and notify Network staff of their presence.

Certified Dataset

All reports providing statistical results will also publish the data on which they were based. Metadata will be provided as well as a link to the certified original dataset (NPS, 2005). Data are made available through IRMA in machine readable formats according to Director's Order #11A and as mandated by the Federal Open Data Initiative (Executive Order No. 13642).

The brown bear Vital Sign will have a single public dataset reference in the IRMA Data Store to which certified data will be published (Figure 13). This reference will be the only authoritative data source available to the public.

Resource Brief

The I&M resource brief is the primary outreach document for the brown bear monitoring program. The principal investigator will revise any existing resource brief after new findings to reflect current understanding of the resource's trend and implications for park management. Resource briefs are

made available on the Network web site through an IRMA Data Store Resource Brief product reference that is attached as a product of the main Vital Sign Project reference.

Products Publication

Reports, datasets and other monitoring products are published through NPS websites using the Vital Sign's master Data Store Project reference via web services exposed by the IRMA Data Store. Authoritative products will only be distributed through the IRMA Data Store.

Metadata

All project datasets, including spatial and non-spatial data, are archived in the IRMA data store with metadata (NPS 2005). The mandate for adequate metadata comes from Director's Order #11A:

> *All NPS data systems will develop data dictionaries and conform to available NPS organization-wide dictionaries. Geographic Information and Metadata must meet all Federal standards, DOI standards and NPS standards.*

Preferred metadata formats include Federal Geographic Data Committee (FGDC) and Ecological Metadata Language (KNB 2017).

Data and Information Security

Digital products produced by the brown bear monitoring program will be stored in the IRMA Data Store in a file based management system on I&M and/or local servers. Under no circumstances will any mission-critical information reside on individual I&M staff computers whether they are assigned to monitoring personnel by the NPS or not. Project materials will be secured and available on I&M servers at all times. The data manager, in conjunction with IT staff at FAC, and with the Network support office in Ft. Collins, CO is responsible for backups, security and longevity of monitoring data.

Closeout

Closeout is the part of the brown bear monitoring data management life cycle through which seasonal data deliverables and certified data are archived in the IRMA Data Store (Figure 13). Closeout happens after a remeasurement cycle when data files have been collected, processed and certified. Deliverables and the certified dataset are archived as holdings of private and public Dataset References in Data Store (Figure 13, Miller 2017). Closeout is complete when seasonal Dataset holdings reconcile with the deliverables schedule.

The closeout method described above will ensure that all data objects collected during a re-measurement cycle are accounted for, documented and available for perpetuity should the need arise to re-use or revisit the data. Closeout and dataset certification is described more fully in 'Product Archival, Seasonal Closeout and Dataset Certification Procedures for the Arctic and Central Alaska Inventory and Monitoring Networks: ARCN/CAKN Data Management Standard Operating Procedure #1 (Miller 2017).

Certification

Certification is the phase of the brown bear monitoring data management life cycle where the principal investigator formally confirms that the Vital Sign's dataset is ready for analysis (NPS 2016). Certification also affirms the scientific, administrative and technical integrity of the program including:

- The protocol and standard operating procedures are current. All technical changes are up to date and documented.
- Raw and intermediate data deliverables have been processed via quality control procedures, have been integrated with the vital sign's database or data management system and have been archived and documented appropriately for posterity.
- Each data record is traceable to the protocol version and SOP version that guided its collection.
- All closeout activities have been performed.
- The certified database or data files have been published to the Vital Sign's public Dataset reference in the IRMA Data Store.
- The Vital Sign's IRMA Data Store references and cross-links are complete.
- The dataset is of sufficient quality that analyses may be performed on it and the results published.

Certification procedures will follow the procedures described in 'Product Archival, Seasonal Closeout and Dataset Certification Procedures for the Arctic and Central Alaska Inventory and Monitoring Networks: ARCN/CAKN Data Management Standard Operating Procedure #1 (Miller 2017). It provides more details on certifying final data sets and uploading them to the IRMA Data Store.

Analysis and Reporting

Analysis

Data analysis procedures are described in detail by Schmidt et al. (2017) and in SOP 9. A mark-re-sight double-observer model is used to generate abundance and density estimates and a site occupancy model is used to generate occupancy estimates (Schmidt et al. 2017). All analyses are conducted in Bayesian framework (Schmidt et al. 2017, SOP 9). Estimates for detection parameters from previous surveys can be used as informed priors in the analysis of subsequent years' data, thereby incorporating building upon past data to improve annual estimates (see SOP 9). Estimates will be presented as means with 95% Bayesian credible intervals. After multiple surveys have been conducted in each area, trend analyses will be possible. The existing model structure can be easily extended to include trend terms and the larger dataset can then be reanalyzed to assess population change over time. When this is done, all survey data may be used to inform the detection process, thereby increasing the precision of the resulting trend estimates.

Reporting

Written reports will consist of: 1) survey summary reports, 2) annual administrative reports, 3) resource briefs, and 4) peer-reviewed articles in scientific journals or the NPS Natural Resources Technical Report series (NRTR). These reports may be written by the PI and/or ARCN and park unit staff. Oral reporting may consist of presentations to the ARCN technical committee, subsistence committees, and presentations at scientific conferences. Detailed interpretation of estimates, including trend estimates, will occur at longer time intervals (e.g., after a survey is completed in each of the four survey areas), and will be published as peer-reviewed articles or as NRTR reports. The target audience for these more comprehensive publications will be the scientific community. Such publications will document long-term trends or further methodological advances and will include maps, graphs, figures, and other visuals to facilitate comprehension of findings. All products will be made available on the IRMA data store.

Budget

The estimated annual cost depends on various factors including on the size of the survey area, the remoteness of the survey area, whether NPS fleet or NPS contracted planes are used, whether cooperators such as the Alaska Department of Fish and Game (ADFG) provide aircraft and observers, the cost of fuel (which varies by location), and how many of the sampling units are double- and/or single-sampled. For example, in general, the Lower Noatak survey, which is based in Kotzebue will be cheaper to implement (per sampling unit) than the Seward Peninsula/BELA survey, which is based out of Quartz Creek, because fuel is cheaper to obtain in Kotzebue than at Quartz Creek where it needs to be flown in or transported via truck from Nome.

Estimates, based on FY2017 dollars, of implementing the brown bear monitoring protocol is presented in Table 3. The budget is based on estimated sampling costs of six pilot-observer teams and one to two alternate observer-data managers. Not included in these costs are bunkhouse housing,

various types of equipment that are bought as needed (e.g., fuel filters, batteries), overtime or hazard pay for observers, transporting fuel to remote locations, the cost of pilot/plane availability on weather days (which could be as much as $3,000/day for six planes), and the cost of ferry time for pilots/planes to survey bases (which can be anywhere between two and 10 hours). Assistance from cooperators (e.g., ADFG staff, vendor pilots) may increase costs when contracts and agreements are required, but heretofore no agreements have been required and their contribution of aircraft and observers has served to decrease costs. For example, during the 2015 survey of the Seward Peninsula/BELA area ADFG provided three aircraft and 3 observers and 181 sampling units were double sampled and four were single sampled – the survey cost to the NPS that year was $124,000. Parks may provide support for monitoring, including some funding, staff participation in sampling, logistical support, and housing.

Table 3. Estimated costs of brown bear monitoring surveys in ARCN per survey area.

Survey Area	Sampling Units	Hours without ferry time	Plane hourly rate	Gallons of AvGas	AvGas per gallon*	Plane-days	Daily availability for planes	Plane cost	Fuel cost	Crew food	Aviation and fuel costs	Total Survey Costs
Seward Peninsula/ BELA	191	384	$235	$3,456	$12	48	$500	$114,240	$41,472	$4,200	$155,712	$159,912
Lower Noatak	208	416	$235	$3,744	$9	52	$500	$123,760	$33,696	$4,200	$157,456	$161,656
Upper Noatak	192	384	$235	$3,456	$12	48	$500	$114,240	$41,472	$4,200	$155,712	$159,912
Gates of the Arctic	160	320	$235	$2,880	$10	40	$500	$95,200	$28,800	$4,200	$124,000	$128,200

* Variable depending on location

Safety

Implementation of this protocol has multiple complex risks. Staff will continuously evaluate all risks at the programmatic, personnel, and site level. Programmatic-level safety information is presented here and procedures to mitigate risks associated with specific activities related to protocol implementation (such as safe operations of aircraft, vehicle use and operation, injury reporting and accident reporting) are addressed in standard operating procedures below.

Job Hazard Analyses (JHAs) were completed for all personnel who implement portions of the protocol in which risks and risk abatement strategies (including training needs) were identified. Risks and abatement strategies for all staff were synthesized to develop a protocol-level JHA. The protocol JHA was then used to perform a programmatic-level Green-Amber-Red (GAR) risk analysis to assess whether implementation of this protocol could be accomplished within an acceptable level of risk.

Specific safety concerns include:

- Crew members will spend many hours (and miles) flying in small aircraft in remote and sometimes mountainous terrain.
- Crew members may be working in park areas outside of communications range (either by park radio or by cell phone).
- Crew members will frequently be exposed to extreme inclement weather and will be working for extended periods of time in remote areas with potentially rapidly-changing and severe weather conditions.
- Crew members will be frequently exposed to hazardous wildlife (bears, muskoxen, moose, wolves, etc.), and potentially hazardous materials and equipment (remote aviation fueling).

Injury or loss of life while in transit to and from field sites and during sampling activities within sites as well as while in transit to or from sampling sites via aircraft — are the most significant risks encountered when conducting this activity.

Based on the JHA and associated risk abatement measures it was determined that this protocol can be safely implemented provided that ARCN and partner staff implement it in accordance with the referenced SOPs and recommended risk abatement strategies. In addition to SOPs that have been developed to safely implement this protocol, specific training needs for all staff have been identified including certification in basic and wilderness first aid, aviation training, bear safety and remote communications. To increase the overall level of safety and awareness, obtaining additional levels of training beyond basic certifications will be encouraged.

Safety procedures will be routinely reviewed with Network staff and partners before field operations as prescribed in SOPs. Personnel-level JHAs for staff will be reviewed and revised annually as a part of the performance review cycle. Safety SOPs are reviewed at least annually and updated as necessary to ensure that they adequately mitigate risks to personnel, property, and the public.

In addition to protocol-specific safety procedures and guidelines, ARCN and partner staff will follow the general guidelines set forth in the NPS Occupational Safety and Health Program (Directors Order #50B, September 2008).

Standard Operating Procedures

To ensure consistent implementation of this protocol over time, the following Standard Operating Procedures (SOPs) have been adopted and modified from ARCN Sheep SOPs for use in the brown bear monitoring protocol (Table 4). To the greatest extent possible, SOPs are adopted from procedures approved and implemented programmatically through other monitoring efforts. All approved SOPs will be published in the NPS Natural Resource Report series and the latest approved versions of operational SOPs are always available for download at the NPS Integrated Resource Management Applications portal. The SOPs will exist as separate stand-alone documents on the master IRMA data store in a file data management system.

Table 4. Standard Operating Procedures required to implement the Protocol for Monitoring Brown Bears in ARCN parks (CAKR, NOAT, BELA, and GAAR). The table lists SOPs by task category.

Subject	SOP	Citation	Notes	Link to Published Document / IRMA Records
Field Prep	1	Robison, H.L.,K.L. Rattenbury, and E. S. Boyd. 2017. Standard Operating Procedure (SOP) 1: Preparations for Field Season, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from SOP1, ARCN Sheep: Rattenbury, K. L., and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 1: Preparations for the Field Season, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	https://irma.nps.gov/DataStore/Reference/Profile/2210687
Field iPad Setup	2	Robison, H.L., K.L. Rattenbury, and E,S, Boyd. 2017. Standard Operating Procedure (SOP) 2: Field iPad Set up, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from http://akrgis.nps.gov/observer/no-wifi.htm and SOP3, ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 3: Field Computer Setup, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	https://irma.nps.gov/DataStore/Reference/Profile/2210687
Training	3	H. L. Robison, K. L. Rattenbury, and E. S. Boyd. 2017. Standard Operating Procedure (SOP) 3: Training, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from SOP5, ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 5: Training Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	https://irma.nps.gov/DataStore/Reference/Profile/2210687

Table 4 (continued). Standard Operating Procedures required to implement the Protocol for Monitoring Brown Bears in ARCN parks (CAKR, NOAT, BELA, and GAAR). The table lists SOPs by task category.

Subject	SOP	Citation	Notes	Link to Published Document / IRMA Records
GPS Setup	4	Robison, H.L., K.L. Rattenbury, E. S. Boyd, J. H. Schmidt and S. Miller. 2017. Standard Operating Procedure (SOP) 4: GPS Setup, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from SOP4, ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 4: GPS Setup, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	https://irma.nps.gov/DataStore/Reference/Profile/2210687
Equipment Lists	5	H. L. Robison, K. L. Rattenbury, and E. S. Boyd. 2017. Standard Operating Procedure (SOP) 5: Field Equipment Lists, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from SOP6, ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 6: Field Equipment Lists, Version 1.2. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	https://irma.nps.gov/DataStore/Reference/Profile/2210687
Flying Surveys and Collecting Data	6	H. L. Robison, K. L. Rattenbury, and E. S. Boyd. 2017. Standard Operating Procedure (SOP) 6: Flying Surveys and Collecting Data, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from SOP7, ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 7: Flying Transects, Version 1.0. and Standard Operating Procedure (SOP) 8: Data Collection, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	https://irma.nps.gov/DataStore/Reference/Profile/2210687

Table 4 (continued). Standard Operating Procedures required to implement the Protocol for Monitoring Brown Bears in ARCN parks (CAKR, NOAT, BELA, and GAAR). The table lists SOPs by task category.

Subject	SOP	Citation	Notes	Link to Published Document / IRMA Records
Data Down-loading And Backup	7	H. L. Robison, K. L. Rattenbury, and E. S. Boyd.. 2017. Standard Operating Procedure (SOP) 8: Data Downloading and Backup, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from SOP9, ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 9: Data Downloading and Backup, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	In Press
Data QA/QC, Formatting, and Archiving	8	H. L. Robison, K. L. Rattenbury, J. H. Schmidt, and E. S. Boyd. 2017. Standard Operating Procedure (SOP) 8: Data QA/QC, Formatting, and Archiving, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from ARCN Sheep: Rattenbury, K. L.,J. H. Schmidt, and S. D. Miller. 2017. Standard Operating Procedure (SOP) 11: Data QA/QC, Formatting and Archiving, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	In Press
Data Analysis	9	J. H. Schmidt, H. L. Robison, and K. L. Rattenbury. 2017. Standard Operating Procedure (SOP) 9: Data Analysis, Version 1.0. Protocol for Monitoring Brown Bears in Arctic (ARCN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at	Modified from ARCN Sheep: Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 12: Data Analysis, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983	In Press

Literature Cited

Alaska National Interest Lands Conservation Act (ANILCA). P.L. 96-487. Section 201 (4)(a), December 2, 1980.

Audubon Alaska. 2003. Alaska's western arctic: a resource synthesis and conservation strategy. Available at: http://www.audubon.org/sites/default/files/documents/alaskas_western_arctic_resource_synthesis_and_conservation_strategy1.pdf. Accessed 31 August 2018.

Ballard, W. B., L. Ayres, D. J. Reed, S. G. Fancy, K. E. Roney. 1993. Demography of grizzly bears in relation to hunting and mining development in northwestern Alaska. Scientific Monograph NPS/NRARO/NRSM-92/23. U. S. Department of the Interior, National Park Service, Denver, Colorado, USA.

Becker, E. 2003. Brown bear line transect technique development. Unpublished report, Alaska Department of Fish and Game, Juneau, AK.

Becker, E. F. and P. X. Quang. 2009. A gamma-shaped detection function for line-transect surveys with mark-recapture and covariate data. Journal of Agricultural, Biological, and Environmental Statistics 14: 207-223.

Becker, E. F. and A. M. Christ. 2015. A unimodal model for double observer distance sampling surveys. PLoS One. 10(8): 1-18. doi:10.1371/journal.pone.0136403

Edwards, M. A., J. A. Nagy, and A. E. Derocher. 2008. Using subpopulation structure for barren-ground grizzly bear management. Ursus 19: 91-104.

Fancy, S. G., J. E. Gross, S. L. Carter. 2009. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment 151: 161-174.

Frakes, B., S. Kingston, and M. Beer. 2015. Inventory and Monitoring Division database standards: September 11, 2015. Natural Resource Report NPS/NRSS/NRR—2015/1035. National Park Service, Fort Collins, Colorado.

Johnson, B. L. 1999. The role of adaptive management as an operational approach for resource management agencies. Conservation Ecology 3(2): 8.

KNB. 2017. Ecological Metadata Language (EML). Knowledge Network for Biocomplexity. Available at: https://knb.ecoinformatics.org/#external//emlparser/docs/index.html. 2017-03-06 (accessed 13 August 2018).

Lawler, J. P., S. D. Miller, D. M. Sanzone, J. Ver Hoef, and S. B. Young. 2009. Arctic Network vital signs monitoring plan. Natural Resource Report NPS/ARCN/NRR-2009/088. National Park Service, Fort Collins, Colorado.

Martin, P. D., J. L. Jenkins, F. J. Adams, M. T. Jorgenson, A. C. Matz, D. C. Payer, P. E. Reynolds, A. C. Tidwell, and J. R. Zelenak. 2008. Wildlife Response to Environmental Arctic Change: Predicting future habitats of arctic Alaska. U. S. Fish and Wildlife Service, Fairbanks, Alaska, USA. https://archive.arcus.org/alaskafws/downloads/pdf/WildREACH_Workshop_Report_Final.pdf Accessed 31 August 2018.

Mattson, D. J., S. Herrero, R. G. Wright, and C. M. Pease. 1996. Science and management of Rocky mountain grizzly bears. Conservation Biology 10: 1013-1025.

McLellan, B. N. and D. M. Shackleton.1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25: 451-460.

McLellan, B. N. 1990. Relationships between human industrial activity and grizzly bears. Bears Their Biology and Management 8: 57-64

McLoughlin, P. D., M. K. Taylor, H. D. Cluff, R. J. Gau, R. Mulders, R. L. Case, and F. Messier. 2003. Population viability of barren-ground grizzly bears in Nunavut and the Northwest Territories. Arctic 56: 185-190.

Miller, S. D. 2017. Product Archival, Seasonal Closeout and Dataset Certification Procedures for the Arctic and Central Alaska Inventory and Monitoring Networks: ARCN/CAKN Data Management Standard Operating Procedure #1

Miller, S. D. and J. Schoen. 1998. Status and management of the brown bear in Alaska. Pages 40-46 *in* C. Servheen, S. Herrero, and B. Peyton, editors. Bears: status survey and conservation action plan. International Union for conservation of Nature/Species Survival Commission, Bear and Polar Bear Specialist Groups. International Union for Conservation of Nature, Gland, Switzerland, and Cambridge, United Kingdom.

Miller, S.D., G.C. White, R.A. Sellers, H.V. Reynolds, J.W. Schoen, K. Titus, V.C. Barnes Jr., R.B. Smith, R.R. Nelson, W.B. Ballard, and C.C. Schwartz. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. Wildlife Monograph No. 133.

National Park Service (NPS). 1998. National Parks Omnibus Act. Public Law 105-391. https://www.gpo.gov/fdsys/pkg/PLAW-105publ391/content-detail.html Accessed 31 August 2018.

National Park Service (NPS). 2005. Director's Order #11A: Information and technology management. National Park Service. http://www.nps.gov/policy/DOrders/DO_11A.pdf. Retrieved 2015-08-20.

National Park Service (NPS). 2006. Management Policies 2006. https://www.nps.gov/policy/MP_2006.pdf Accessed 31 August 2018.

National Park Service (NPS). 2008a. Data and information management plan: Arctic Network Inventory and Monitoring Program. Natural Resource Report NPS/ARCN/NRR-2008/053. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2008b. Data management guidelines for inventory and monitoring networks. Natural Resource Report NPS/NRPC/NRR-2008/035. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2016. Certification Guidelines for Inventory and Monitoring Data Products. National Park Service, Inventory and Monitoring Division. Fort Collins, CO.

Quang, P.X., and E.F. Becker. 1996. Line transect sampling under varying conditions with application to aerial surveys. Ecology 77:1297-1302.

Quang, P.X., and E.F. Becker. 1999. Aerial survey sampling of contour transects using double-count and covariate data. Pages 87-97 in G.W. Garner, S.C. Armstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson, eds. Marine mammal survey and assessment methods. A.A. Balema, Rotterdam, Holland. 287.

Rattenbury, K. L., J. H. Schmidt and S. D. Miller. 2017. Protocol for monitoring Dall's sheep: Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks, version 1.0. Natural Resource Report NPS/AKRO/NRR—2017/1413. National Park Service, Fort Collins, Colorado. Rattenbury, K. L., and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 1: Preparations for the Field Season, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 3: Field Computer Setup, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 4: GPS Setup, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 5: Training Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 6: Field Equipment Lists, Version 1.2. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska

(CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 7: Flying Transects, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 8: Data Collection, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 9: Data Downloading and Backup, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L.,J. H. Schmidt, and S. D. Miller. 2017. Standard Operating Procedure (SOP) 11: Data QA/QC, Formatting and Archiving, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 12: Data Analysis, Version 1.0. Dall's Sheep Monitoring Protocol Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at https://irma.nps.gov/App/Reference/Profile/2214983

Roberge, J. and P. Angelstam. 2004. Usefulness of the umbrella species concept as a conservation tool. Conservation Biology 18: 76-85.

Sauer, J. R. and M. G. Knutson. 2008. Objectives and metrics for wildlife monitoring. Journal of Wildlife Management 72: 1663-1664.

Schmidt, J. H., K. L. Rattenbury, H. L. Robison, T. S. Gorn, and B. S. Shults. 2017. Using non-invasive mark-resight and sign occupancy surveys to monitor low-density brown bear populations across large landscapes. Biological Conservation 207:47-54.

Schoen, J. W. 1990. Bear habitat management: A review and future perspective. International Conference on Bear Research and Management 8: 143-154.

Schwartz, C. C., S. D. Miller, and M. A. Haroldson. 2003. Grizzly bear. Pages 556-586 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. Second edition. Johns Hopkins University Press. Baltimore, Maryland, USA.

Servheen, C., S. Herrero, and B. Peyton. 1998. Bears. Status survey and conservation action plan. IUCN/SSC Bear and Polar Bear Specialist Groups. IUCN, Gland, Switzerland and Cambridge, UK. x + 309pp.

Smallwood, K. S. and C. Schonewald. 1998. Study design and interpretation of mammalian carnivore density estimates. Oecologia 113: 474-491.

Swanson, D. K. 2010. Satellite greenness data summary for the Arctic Inventory and Monitoring Network, 1990-2009. Natural Resource Data Series NPS/ARCN/NRDS—2010/124. National Park Service, Fort Collins, Colorado.

Waller, J. S. and C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69: 985-1000.

Weaver, J. L., P. C. Paquet, and L. F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky mountains. Conservation Biology 10: 964-976.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS XXXXXX, Month Year (The Fort Collins Support Office will fill out this line for you)



Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525