



Protocol for Monitoring Brown Bears — Version 1.0

Southwest Alaska Inventory and Monitoring Network

Natural Resource Report NPS/SWAN/NRR—2010/275



ON THE COVER

Brown bears in a coastal meadow, Tuxedni Bay, Lake Clark National Park and Preserve.

Photograph by: Buck Mangipane, National Park Service, Lake Clark National Park and Preserve.

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Revision History Log

All edits and amendments made to this document since its inception should be recorded in the table below. Users of this protocol should promptly notify the project leader of the terrestrial wildlife monitoring program of recommended edits or changes. The project leader will review and incorporate suggested changes as necessary, record these changes in the revision history log, and modify the date and version number on the title page of this document to reflect these changes. For more details, please refer to Appendix A, SOP #8.

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

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Executive Summary

This protocol narrative and associated standard operating procedures (SOPs) provide detailed information on monitoring brown bears (*Ursus arctos*) in four national park units in the Southwest Alaska Network (SWAN): Alagnak Wild River, Aniakchak National Monument and Preserve, Katmai National Park and Preserve (KATM) and Lake Clark National Park and Preserve (LACL). The protocol narrative provides a general overview of the history, justification, sampling methods and procedures for performing monitoring. SOPs offer step-by-step instructions for performing the various monitoring tasks and are more detailed in nature than the protocol narrative.

The National Park Service initiated the “vital signs monitoring” program to address the need to observe and understand the condition of park natural resources. Vital signs can be physical, chemical, and biological elements and processes that represent the condition of a park. Brown bears were ranked as “essential” during the SWAN vital signs selection process due to their importance to ecosystem functions, usefulness as an indicator, strong linkages to other attributes in network ecosystem models and high relevance to park resource management and protection. Their ecological and management significance necessitated development of a long-term brown bear monitoring strategy for SWAN parks.

The vast size, remoteness, and mountainous terrain of SWAN parks preclude ground survey methods to monitor brown bears because of extreme costs and accessibility issues. Therefore, a double-count, aerial line transect survey method modified to be conducted along elevational contours (Becker and Quang 2009) will be employed to estimate distribution, abundance, and density of brown bears in four SWAN park units. This survey technique has undergone 13 years of refinement by its developers since the first model was discussed in Quang and Becker (1996), and has been used to estimate brown bear populations in different areas in southcentral and southwestern Alaska (Becker 2003), including recent surveys by Alaska Department of Fish & Game (ADF&G) and park staffs in the ADF&G Game Management Units containing KATM and LACL during 2003-2005.

A stratified random sampling design will be used to select transects primarily along elevational contours. Stratification criteria include physical features related to perceived densities of bears. Simulations based on coefficients of variation of 10%-13.5% and sampling every five years indicated a 75%-80% chance of detecting about a 1% annual decline with 90% confidence when the true annual decline was 3% during a 21-22 year period, which is the target level of detectable change. Depending on bear densities, park resources (staffing and availability of pilots), size of survey area of interest, and weather conditions, an entire survey will usually take one to three spring sessions (years) to complete. Timing of sampling will occur in May after bears have emerged from dens, but prior to leaf-out because the probability of detecting bears is highest at this time.

Program GammaMRDS (Appendix B) will be used to estimate abundance and density of brown bears for the areas of interest within SWAN parks. This program will be converted to a Bayesian hierarchical modeling framework to estimate trends in abundance and density. Estimates of trend in brown bear distribution also will derive from the Bayesian hierarchical modeling framework.

Estimates of density from surveyed transect strips will be linked to existing landcover data layers containing landcover class (vegetation) codes, elevation and slope to produce a bear density surface for the area of interest. A composite change surface indicating spatially explicit increases, decreases or stable densities will be produced based on previous and current surveys to quantify changes in spatial distribution of bear densities across time, which is analogous to change detection in a time series of vegetation images.

All data will be subjected to rigorous quality assurance/quality control procedures. Metadata for geospatial data will be fully compliant with the Federal Geographic Data Committee standards. These metadata standards also will be applied to non-spatial data to the extent possible and relevant. Long-term archiving of brown bear data will occur at the Alaska Regional Curation Center located at the National Park Service Alaska Regional Office in Anchorage.

Acknowledgments

Development of the brown bear protocol narrative and SOPs involved important contributions from numerous individuals. Earl Becker and Becky Strauch of the Alaska Department of Fish and Game provided very helpful information on GIS procedures, data management and statistical analyses. Their hard work and interagency cooperative spirit have created a robust bear survey method for state and federal agencies across Alaska. Tammy Olson (formerly Katmai National Park and Preserve) and Judy Putera (Wrangell-St. Elias National Park and Preserve) offered much useful information to and review comments on previous drafts. Their report on aerial line-transect surveys of bears in Katmai and Lake Clark National Parks and Preserves served as an invaluable starting point for this document. Gail Collins, United States Fish and Wildlife Service at Tetlin National Wildlife Refuge, generously shared survey procedure guidelines gleaned from associated survey efforts on Refuge lands. Pat Walsh, United States Fish and Wildlife Service at Togiak National Wildlife Refuge, provided additional details on associated Refuge land surveys and several helpful figures. Dorothy Mortenson, formerly with the Southwest Alaska Network, provided helpful suggestions related to data management and comments on an earlier draft. Dave Bush and Kirmanie Ravariere of GeoNorth (Anchorage, Alaska) wrote the ArcPad 7.1 data entry applet and the ArcGIS 9.3 extension for generating random transects as well as provided the draft protocol and training session on their use as part of a contract with the Southwest Alaska Network. Thanks to Cuyler Smith of the Southwest Alaska Network for editing this training video and converted it to several viewable formats on DVD. Colleen Matt, formerly with Lake Clark National Park and Preserve, offered useful assistance at the project inception. Our sincere thanks to T. DeBruyn, J. Schmidt, E. Becker, and G. Pendleton for their many helpful suggestions that improved this protocol. Finally, thanks to Joel Reynolds and Brook Russell of the United States Fish and Wildlife Service, Earl Becker, and Pham Quang (emeritus) of the University of Alaska-Fairbanks for allowing the inclusion of their user's guide for the GammaMRDS program as an important component of Appendix A, SOP #5 (Data Analysis).

1 Background and Objectives

1.1 Introduction

The purpose of this document is to describe the protocol used to monitor brown bears (*Ursus arctos*) in four National Park Service (NPS) units in southwest Alaska, namely,

1. Katmai National Park and Preserve (KATM) managed by the KATM office in King Salmon
2. Alagnak Wild River (ALAG) managed by the KATM office
3. Aniakchak National Monument and Preserve (ANIA) managed by the KATM office
4. Lake Clark National Park and Preserve (LACL) managed by offices in Port Alsworth, Anchorage and Homer.

These park units fall within the Southwest Alaska Network (SWAN) of the NPS Inventory and Monitoring (I&M) Program (Figure 1.1). SWAN identified brown bears as an essential vital sign to monitor within the I&M program (Bennett et al. 2006). Brown bears were not selected as a vital sign in Kenai Fjords National Park, the fifth park unit within SWAN (Figure 1.1), because historic and current populations are too low to warrant monitoring. This protocol narrative, along with eight standard operating procedures (SOPs; Appendix A), explain the processes for successful execution of the brown bear monitoring program in SWAN park units.

NPS initiated the “vital signs monitoring” program to address the need to observe and understand the condition of park natural resources. A vital sign is defined as “a set of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, and/or are of value to humans” (Bennett et al. 2006:45). Vital signs monitoring gathers scientifically sound information on the status and long-term trends of park ecosystems and evaluates how well current management practices are sustaining those ecosystems (Bennett et al. 2006).

The ecosystems within SWAN parks are important because they have intact populations of wilderness-dependent large mammal species, naturally functioning terrestrial ecosystems, and historic levels of biodiversity (Bennett et al. 2006). These characteristics of land systems for large carnivores are increasingly rare worldwide. This is particularly true for brown bears. SWAN parks support healthy brown bear populations, whereas bear populations are imperiled in the southern portions of their ranges worldwide, including in the conterminous United States (Kendall et al. 2008). Global bear populations are a fraction of their historic range (Schoen 1989).

Brown bears were ranked as “essential” during the SWAN vital signs selection process. This was due to their importance to ecosystem function, usefulness as an indicator, strong linkages to other attributes in network ecosystem models and high relevance to park resource management and protection. Their ecological and management significance necessitated development of a long-term brown bear monitoring strategy for ALAG, ANIA, KATM, and LACL.

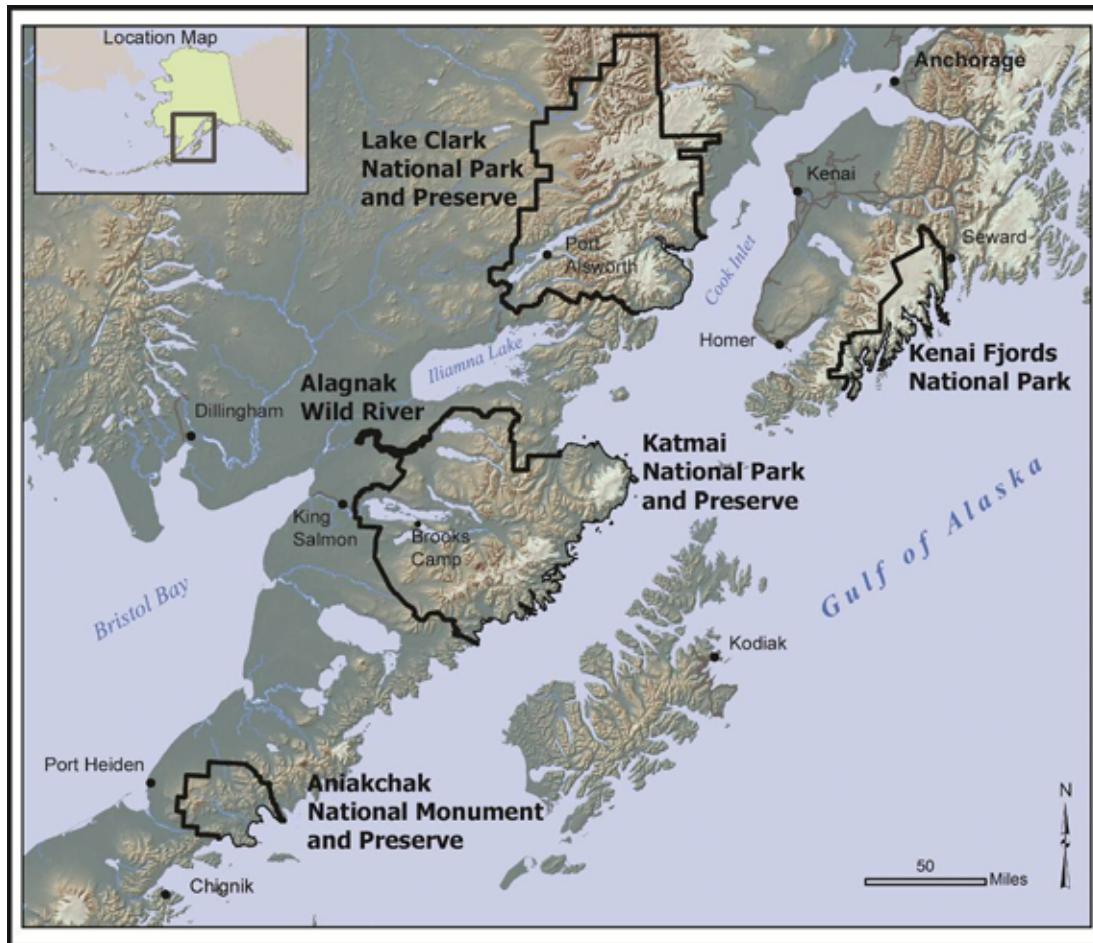


Figure 1.1. The five national park units within SWAN (figure from Bennett et al. 2006).

Monitoring of brown bears in the four park units of SWAN is dependent upon appropriate development and testing of monitoring protocols. This should be based on a well-designed and implemented sampling strategy that includes successful execution of pre-season logistics, preparation of survey transect routes for sampling, completion of aerial surveys for bear count data and quality data management, analysis and reporting. The primary method for monitoring brown bears in SWAN parks will be by aerial survey conducted from fixed-wing aircraft. Estimates of abundance/density and distribution of brown bears will be obtained from these aerial surveys performed at five-year intervals and analyzed for long-term trends.

1.2 Rationale for Monitoring Brown Bears

Brown bears are a fundamental component of ALAG, ANIA, KATM, and LACL parks and are listed in the enabling legislation of ANIA, KATM, and LACL. They are an important species to monitor because they play a key ecological role in their environment (Reimchen 2000). They are integral in ecosystem nutrient cycling (Tardiff and Stanford 1998, Robbins et al. 2004) and serve as a means of nutrient transfer from spawning salmon (*Oncorhynchus* sp.) (Gende et al. 2002) and marine nitrogen (Hilderbrand et al. 1999a) to the terrestrial system. They play important ecological roles as top predators by influencing population dynamics of ecosystem community species. This has been documented between brown bears and moose (*Alces alces*) (Ballard and

Miller 1990), moose calves (Ballard et al. 1981), caribou (*Rangifer tarandus*) (Boertje et al. 1988), other bears (Hessing and Aumiller 1994, Sellers et al. 1998, Ben-David et al. 2004), and salmon (Quinn and Kinnison 1999, Ruggerone et al. 2000, Gende et al. 2004). Further, they are important indicator species for other valuable wide-ranging mammals such as wolves (*Canis lupus*), wolverine (*Gulo gulo*) and lynx (*Lynx canadensis*) (Matz 2000).

From a park management perspective, brown bears are important culturally and recreationally to people in Alaska (Matz 2000). Surveys by the Alaska Department of Fish and Game (ADF&G) have indicated that brown bears are Alaska's most valuable species of wildlife from the perspective of both wildlife viewers and hunters (Matz 2000). They support the livelihood of businesses and have become economic drivers in some communities. Further, they provide valuable resources for subsistence users and are culturally valuable to Native Alaskans (Mogart et al. 1992, Van Daele et al. 2001).

High densities of brown bears exist in ALAG, ANIA, KATM, and LACL. KATM has the highest documented density of brown bears in North America (Sellers et al. 1999). These high bear densities are supported by coastal environments rich in food resources such as marine mammals, clams (*Siliqua* sp., *Protothaca staminea*, *Saxidomus gigantus*), sedges (*Carex* sp.), terrestrial prey species, and salmon. Salmon are of particular importance and have been shown to influence a variety of demographic and life history parameters of brown bears (Hilderbrand 1999b, 1999c, 2004).

These productive coastal regions also attract sport fishers, bear hunters, subsistence users, bear viewers and backcountry recreationalists. Understanding potential pressures from human activities on bear populations is important for management of their long-term viability (Mattson 1989). Human activities are increasing in SWAN parks. Bear viewing has increased in the past two decades (National Park Service 2004) and the demand for bear viewing along western Cook Inlet (including SWAN park units) has exponentially increased in recent years (Matz 2000). Human activities such as sport fishing (Smith 2002) and bear viewing (Olson et al. 1997, Rode et al. 2006a,b, Rode et al. 2007) have been shown to affect bear behavior, with some activities leading to habituation (Smith et al. 2005). Bear hunting and bear take (numbers of bears killed) have also been increasing (Matz 2000). Increases in hunting led to the Alaska Board of Game approving bear hunting on previously protected state and federal lands adjacent to SWAN parks in 2005. Opposition to opening hunting on these lands, led to a reversal in 2007 before the hunting season was initiated. Brown bears are a long-lived species with low recruitment potential and are prone to inadvertent overharvest (Miller 1990). All of these human activities create potential pressures on bears in SWAN parks and understanding more about brown bear populations through monitoring will help facilitate park management efforts.

Long-term monitoring data on brown bears in ALAG, ANIA, KATM, and LACL park units have been lacking in the past and therefore, potential impacts to brown bears from a diverse array of human users are largely unknown. These unknowns, combined with the vital ecological roles brown bears play, creates a pressing need to gain a further understanding of bear distribution and abundance/density in SWAN park units.

1.3 Measurable Objective

Monitoring brown bears in ALAG, ANIA, KATM and LACL is designed to answer the question: are distribution and numbers/densities of brown bears remaining stable in these parks?

The specific measurable objective is:

- Estimate long-term trends in distribution and abundance/density of brown bears from a random sample of relevant elevations and terrains in ALAG, ANIA, KATM, and LACL.

2 Sampling Design

2.1 Rationale for Selecting this Sampling Design over Others

The vast size, remoteness, and mountainous terrain of SWAN parks preclude ground surveys for brown bears because of extreme costs and accessibility issues. Aerial surveys conducted from fixed-wing aircraft are the logical option because they are often the quickest and most cost-effective way to estimate and monitor the status of wildlife populations (Becker 2001). Aerial surveys based on line-transect methods have been used to survey wildlife populations for many years (Drummer et al. 1990, Johnson et al. 1991, Quang and Lanctot 1991) and are an improvement over simple aerial counts because abundance estimates are adjusted for incomplete and variable detection rates of animals, which can be a serious source of bias that confounds both population and trend estimators (Moore and Kendall 2004). Mark-recapture/mark-resight techniques based on a sample of radiotagged individuals also have been used to obtain rigorous estimates of bear abundance in various parts of Alaska (Miller et al. 1997), but are much more labor-intensive and expensive to employ in large, remote wilderness areas than aerial surveys alone.

A double-count, aerial line transect survey method modified to be conducted along elevational contours (Becker and Quang 2009) will be employed to estimate distribution, abundance, and density of brown bears in four SWAN park units. The double-count aerial line-transect survey technique has undergone 13 years of refinement by its developers since the first model was discussed in Quang and Becker (1996) (see also Quang and Becker 1997, 1999). The approach has been used to estimate brown bear populations in different areas in southcentral and southwestern Alaska (Becker 2003), including recent surveys by ADF&G and park staffs in the ADF&G Game Management Units containing KATM and LACL during 2003-2005 (Olson and Putera 2007).

Conventional line transect sampling uses perpendicular distances recorded from randomly chosen lines to detected objects (e.g., bears) to fit a detection function that, in turn, is used to estimate the probability of detection ($\hat{p}$) for the objects within the surveyed area (Buckland et al.

2001). This information is used with the area sampled (a) to estimate density, $\hat{D} = \frac{n}{a \times \hat{p}}$, where

n is the total objects detected and a is twice the width (w) of the survey transects multiplied by their total length (L) (i.e., area of the rectangles on either side of a center line [strip or belt

transect]) (Buckland et al. 2001). This density estimator can be rewritten as $\hat{D} = \frac{n}{(2wL) \times \hat{p}}$, or in

terms of the effective strip half-width, $\hat{\mu} = w\hat{p}$, which yields the general line transect density

estimator, $\hat{D} = \frac{n}{2L\hat{\mu}}$ (Buckland et al. 2001). Multiplying both sides of the equation by the area

sampled (A) generates the corresponding abundance estimator, $\hat{N} = \frac{nA}{2L\hat{\mu}}$ (Buckland et al. 2004).

The effective strip half-width is the distance from the line in which an equal number of objects are detected beyond it as are undetected within it, so the line transect effectively samples the surrounding strip area of size $2L\hat{\mu}$ (Buckland et al. 2004). Three key assumptions of line

transect sampling include 1) all objects exactly on the transect line are detected, 2) objects are detected at their original locations or do not move in response to the observer(s) (i.e., no flight response prior to detection), and 3) perpendicular distances to detected objects are accurately recorded (Buckland et al. 2001). The conventional line transect estimators of density and abundance have been extended to allow for more flexibility, such as incorporating covariates to model the detection function or being combined with mark-recapture estimators to relax the assumption of complete detection on the transect line (Buckland et al. 2004).

Using aerial line transects to survey brown bears in the mountainous terrain of SWAN parks poses challenges for meeting the key assumptions of this approach. First, there is a blind spot underneath the plane (transect line at zero distance); even if the detection function is shifted, not all animals are detected on or near the new "zero distance" line so there is not complete detectability at the peak of the detection function. Second, the peak of a detection function for a conventional line transect model occurs at the line (or shifted position of the zero distance) and usually decreases slowly closer to the line to form a shoulder before decreasing more steeply farther away from the line (e.g., half normal function). Previous aerial line transect surveys of brown bears in southwest and southcentral Alaska have shown that the peak of detection distances, and hence the detection function, occurs some distance away from the line so there is not a shoulder (Figure 2.1). Third, conventional aerial line-transect surveys of wildlife populations (e.g., Johnson et al. 1991) are limited to flat terrain because flying linear transects in

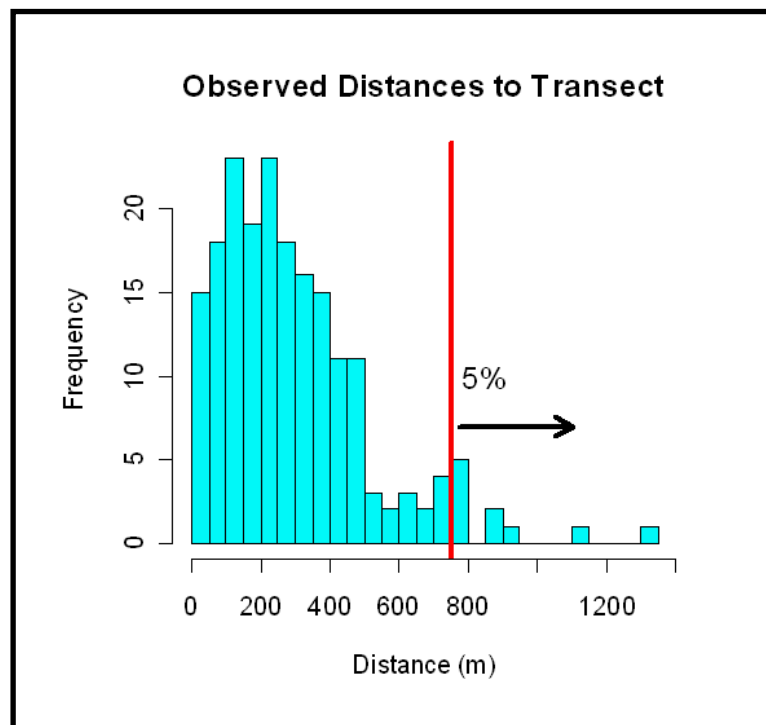


Figure 2.1. Example of a histogram of detection distances recorded during an aerial line transect survey of brown bears in Togiak National Wildlife Refuge and BLM Goodnews Block, southwest Alaska (figure from Walsh et al. 2008). Note the peak of the detection distances occurs away from the line or zero distance. The top 5% of the recorded distances are removed to facilitate modeling of the detection function (see Buckland et al. 2001 for details).

uneven terrain causes the plane's height above ground to constantly shift. This shift causes changes in sightability and eliminates the possibility of using strut marks on the wings as an aid to place sightings into distance classes (Becker 2001).

Becker and Quang (2009) have modified the conventional aerial line transect approach to allow for transects to be surveyed along elevational contours, detection distances to be collected by two independent observers to relax the assumption that all objects (e.g., bears) are sighted on the line or at the peak of the detection function, covariates included to account for additional factors affecting detection rates (or sightability), and a Gamma detection function that is flexible enough to allow for a peak away from zero distance. These modifications also are based on surveying only the uphill side of the transect (Figure 2.2). Thus, the Becker-Quang approach combines the advantages of mark-recapture models (Cook and Jacobson 1979), line transect sampling (Buckland et al. 2001), and sightability models (Steinhorst and Samuel 1989) to adjust for incomplete detection of bears. The assumptions are 1) all bears are potentially observable; 2) aircraft do not influence bear location data; 3) distances recorded to located bears are accurate; 4) data are independent between the two observers; 5) recorded bear group size is accurate; 6) the population of bears being sampled is fixed during the entire survey; and 7) the model reasonably fits data. Further details on this survey method are discussed in Becker and Quang (2009), Appendix A (SOP #4 and #5), and Appendix B.

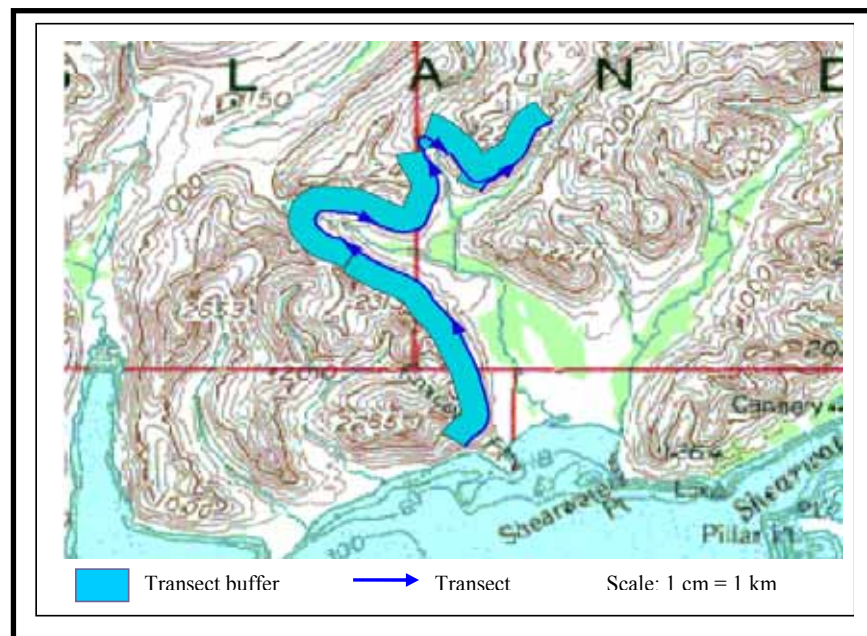


Figure 2.2. Depiction of the uphill strip width w (solid blue) and its area calculation based on the union of right angle translates from the transect line (figure from Becker 2001).

2.2 Choosing Sampling Units

The sample frames coincide with the boundaries of the SWAN park units of interest, i.e., ANIA, KATM/ALAG (combined), and LACL. Potential survey locations are restricted to those areas that could possibly contain bears so, for example, high elevation areas (>914 m) and large lakes (>4 km²; Olson and Putera 2007) are excluded from the sampling universe from which sampling units (transects) are randomly chosen. Survey transects are equal lengths, typically 20 or 25 km. A 500-m buffer will be placed from shorelines into the body of water (e.g., lake, ocean) to ensure adequate sample coverage of this areas that are often used as travel routes by bears. Details of transect delineation are further described in Appendix A, SOP #2.

A stratified random sampling design is used to select transects primarily along elevational contours. Stratification criteria include physical features related to perceived densities of bears. Stratified random sampling allows an unbiased estimator of abundance/density to the larger spatial scale of interest (e.g., parkwide).

2.3 Recommended Number and Location of Sampling Units

The number of transects should be sufficient to ensure enough bears are counted to yield a reasonably precise estimator of abundance or density. Based on previous surveys within Alaska, a minimum of 175 bear groups must be observed to derive a reasonably precise estimator (E. Becker, ADF&G, Anchorage, AK, personal communication). Surveys performed in KATM and LACL during 2003-2005 were part of a larger survey of ADF&G Game Management Units that contain them, so only data from surveyed transects that were within the boundaries of each park were used to obtain abundance estimates. Four hundred thirteen groups of bears were detected along 639, ~25 km-long transects in KATM, which produced an abundance estimate with a coefficient of variation (CV) of 17%, whereas 421 groups were detected along 740 transects in Game Management Unit 9C, which yielded an abundance estimate with a CV of about 13.5%. One hundred thirteen groups of bears were spotted along 365 transects of approximately 20 km in LACL, which yielded an abundance estimate with a CV of 50%.

Simulation results indicated a CV of 13.5% corresponded to about a 75% chance of detecting a trend of a reasonable size if sampling once every five years (Appendix C). Based on these results, a minimum of 750, 25-km transects or equivalent are initially recommended parkwide to achieve a CV of around 13.5% when obtaining an abundance or density estimate every five years in KATM. An additional 10 transects in KATM would improve the precision of the abundance or density estimator so that the chance of detecting a trend may approach 80%. Note that simulation results are approximations only, and the Bayesian hierarchical modeling framework discussed in section 4.6 will likely improve the ability to detect a trend due to its shrinkage properties versus the generalized linear model used to estimate trend in the simulations (Appendix C). This same sampling effort can be used as an initial estimate for LACL, but future surveys there will be focused on its coast where bear densities are high, so less sampling effort will likely be required to achieve the same precision.

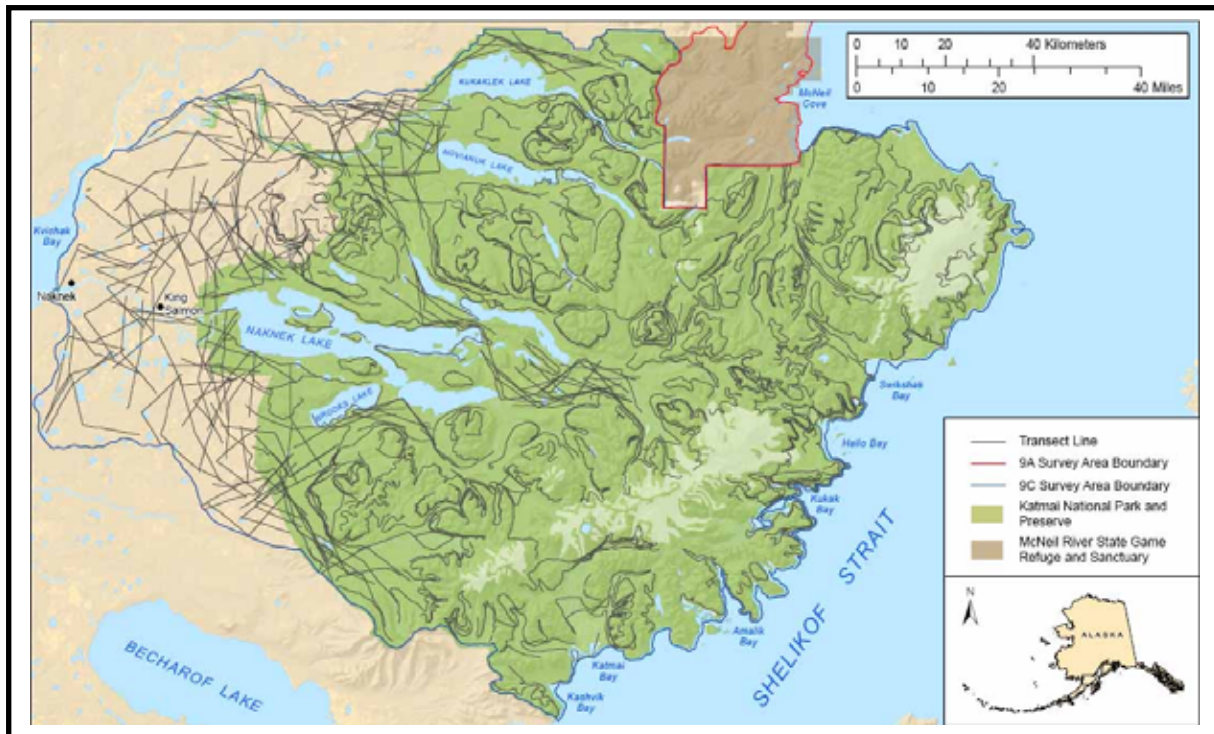


Figure 2.3. Twenty-five km transects that were randomly selected from Game Management Unit 9C (blue outline; KATM shaded in green) and surveyed for brown bears during 2004-2005 (figure from Olson and Putera 2007).

Seventy-five percent of existing survey transects randomly chosen by Olson and Putera (2007) within KATM (Figure 2.3), will be used for monitoring brown bears because the custom selection tool (ADFG_BearTrans; Strauch 2003, 2004) used to generate these transects undersampled valleys. Therefore, 25% of the transects will be randomly re-chosen using a new ArcGIS 9.3 (ESRI, Inc., Redlands, CA) software extension (see Appendix A, SOP #2). A training DVD is available that illustrates use of this software extension (contact the SWAN Terrestrial Wildlife Project Leader at

http://science.nature.nps.gov/im/units/swan/index.cfm?theme=network_staff). In LACL, new transects will be randomly selected within the coastal areas of LACL, which will be their focal area for monitoring brown bears because it is the area of greatest management concern. Brown bear densities within the interior of LACL are too low to be adequately sampled within current funding levels.

Brown bears are subject to harvest in the Preserve portions of ANIA, KATM and LACL. Preserve-specific estimates of bear density or abundance will require more sampling effort within those areas, i.e., random selection of additional transects to supplement existing ones that fell within those areas. More transects also may be needed in non-Preserve portions of parks where bears may be moving outside of park boundaries to areas subject to harvest.

2.4 Recommended Frequency and Timing of Sampling

Depending on bear densities, park resources (staffing and availability of pilots), size of survey area, and weather conditions, an entire survey will usually take one to three spring sessions

(years) to complete. The preferred goal is to complete a survey within one year to ensure population closure, but budgetary and logistical constraints could make such a survey infeasible. A multiyear survey provides a weighted population estimate with the weights proportional to the number of transects surveyed each year (E. Becker, ADF&G, Anchorage, AK, personal communication). A single-year survey would allow useful estimates of status over the short term (e.g., for immediate resource management needs), which may or may not be the case for a multiyear survey, depending on how much the bear population is changing over that time period. Brown bear populations in SWAN parks likely do not change much on an annual basis, so a multiyear survey may suffice for providing useful information on both short-term estimates of status and long-term estimates of trend. However, care should be taken if multiyear surveys are being conducted in areas where harvest rates of bears are considered high, if meaningful short-term estimates of status are required by resources managers.

Bears typically emerge from hibernation dens in April, and by May are available for detection. Vegetation leaf-out generally occurs in late May or early June. Therefore, timing of sampling occurs in May after bears have emerged from dens, but prior to leaf-out because the probability of detecting bears is highest at this time. Timing of emergence of bears from their dens is variable from year to year, though, so care should be taken that surveys are not initiated too early. Proper timing of a survey can be assessed by plotting the bear encounter rate per 100 sampled transects, where a random scatter of points indicates good survey timing (E. Becker, ADF&G, Anchorage, AK, personal communication).

Preliminary surveys of LACL and KATM took 10 days each May during 2003-2005 to derive a population estimate. Thus, flights will be flown daily, weather dependent, for 10-14 days or until the pre-determined number of transects have been surveyed. Transects initially selected at random will be retained throughout the monitoring program and will be re-surveyed every five years (see section 2.5).

2.5 Level of Change that can be Detected

The level of detectable change in a population is dictated by the amount of variability in the abundance or density estimates and by the frequency of surveys. This variability can be further divided into sampling variation from obtaining estimated, rather than true, abundances or densities for each survey and temporal variation from the year-to-year changes (population dynamics) in bear numbers and distribution. Bennett et al. (2006) initially suggested a sampling frequency of 5-10 years. Simulations based on a coefficient of variation (CV) of 13.5% and sampling every five years indicated a 75% chance of detecting about a 1% annual decline with 90% confidence when the true annual decline was 3% during a 21-22 year period, which is the target level of detectable change (see Appendix C for details). Note that surveys of Game Management Unit 9C (Figure 2.3) during 2004-2005 produced a CV of about 13.5%. There were essentially no situations in which a 10-year sampling interval was adequate for detecting trends in abundances, even for a CV of 10%. Future simulations will be conducted based on Bayesian hierarchical models, which should provide more precise estimators of trend and hence the ability to detect smaller changes. Bayesian modeling approaches also use prior survey data, especially for fitting the detection function, so less sampling effort will likely be required for subsequent surveys (to a point).

3 Field Season

3.1 Field Season Preparations and Equipment Set-up

Aerial surveys will be conducted in May. Personnel will be trained, field computers will be checked for proper working order, and data forms, survey routes and maps will be prepared. Details on field season preparation are described in Appendix A, SOP #1 (Preparations for the Field Season), and SOP #3 (Training Observers).

3.2 Sequence of Events During Field Season

The sequence of events during the field season are as follows. More detailed information is included in Appendix A, SOP #s 1-4.

- Review survey maps, transect lists, and determine the transects to be surveyed by each aircraft.
- Gather field equipment at the office prior to meeting survey aircraft. Equipment to bring includes personal gear (e.g., survival gear [vest], NOMEX flight suit, NOMEX or leather gloves, leather boots, helmet, safety equipment, lunch, extra clothes, water) and survey gear (e.g., on-board laptop computer, Global Positioning System (GPS) unit, notebook [data forms], pencils, curtain, light system).
- Meet the pilot and prepare aircraft for survey. Connect the GPS to the laptop via the data cord, ensure the GPS is inputting data into the laptop, and confirm the ArcPad 7.1 (ESRI, Inc., Redlands, CA) application is functioning properly. Load up and take off.
- Data Collection-collect data as detailed in section 3.3 and in Appendix A, SOP #4.
- Upon landing after flight completion, gather all gear from the plane and report back to office. Store gear.
- Perform data verification, download laptop, copy data forms, make back-ups, and record necessary information relevant to the flight.

3.3 Recording Data

A high level of effort will be devoted to accurately recording field measurements. Two primary tools are used to achieve minimal data errors when collecting brown bear monitoring data: properly training observers (Appendix A, SOP #3) and using laptops in conjunction with formatted project specific data forms. Use an ArcPad 7.1 (ESRI, Inc., Redlands, CA) applet (Appendix A, SOP #4) specifically designed for data entry during aerial survey flights, with hard copy data forms along for back up and comments. All data forms should be legible, complete, and printed on acid free paper to prevent fading over time. Refer to the data management plan (Southwest Alaska Network 2006) if changes to data fields become necessary. Refer to Appendix A, SOP #4 for details on conducting aerial surveys and data recording procedures; a training DVD is available that illustrates use of the ArcPad 7.1 (ESRI, Inc., Redlands, CA) applet (contact the SWAN Terrestrial Wildlife Project Leader at http://science.nature.nps.gov/im/units/swan/index.cfm?theme=network_staff).

3.4 Post-collection Processing of Data

Processing of data after their collection during surveys will be composed of the following steps.

- Download all data from the laptop computer, GPS unit and digital camera (if used).
Complete data verification and validation checks as described in Appendix A, SOP #6

and the Southwest Alaska Network (2006). Back-up data and store at an offsite location. Charge electronics as needed.

- Check all original data forms for legibility and completeness. Complete data verification and validation checks on data. Any changes to data forms should be crossed out with a line and the new information written below. No errors should be erased or completely crossed out. Make photocopies of the originals. Copies should be archived in a safe location off site upon survey completion.
- Review all ArcPad (ESRI, Inc., Redlands, CA) shapefiles, note data discrepancies between shapefiles and data sheets. Discuss and correct with observer.
- Stow gear and equipment in appropriate locations.

3.5 End-of-season Procedures

End-of-field-season procedures include performing final organization of data, equipment, budgeting information and preparing data for summaries and analysis. All data forms and data file back-ups should be filed in an organized fashion at park headquarters office as well as an off site location. Long-term archiving of data will be performed at the Alaska Regional Curation Center (ARCC) located at the NPS Alaska Regional Office in Anchorage (see Appendix A, SOP #6). Ensure all hours from aerial surveys are logged and personnel time and effort are recorded for budgeting purposes. Clean, organize and store survey equipment in appropriate locations.

4 Data Handling, Analysis and Reporting

An overview of data handling, analysis and reporting is described in Figure 4.1. Data handling involves collecting data via aerial surveys and processing these data into a usable format for estimating abundance, density and distribution of brown bears for a given survey and their corresponding trends from surveys across time. Findings obtained from these analyses then are interpreted and summarized in reports (see Appendix A, SOP #7).

4.1 Metadata Procedures

Metadata describe the attributes of a data resource, providing users with the who, what, where, why, and how type of information. This documentation also should reference the quality assurance procedures applied to the data and results of data quality reviews. Metadata for geospatial data should be fully compliant with the Federal Geographic Data Committee (FGDC) standards. These metadata standards also will be applied to non-spatial data to the extent possible and relevant. Details of the metadata procedures for the brown bear monitoring protocol are in Appendix A, SOP# 5, whereas SWAN metadata procedures are described in Southwest Alaska Network (2006).

4.2 Overview of Database Design

SWAN is using a survey protocol that also is being used by ADF&G and USFWS for monitoring bear populations. Thus, the Microsoft Access database for aerial survey data will contain variables in common so that they can be linked for a larger analysis, if one occurs. Further, the database will include the necessary input variables and variable names required by program GammaMRDS (Appendix B) to estimate abundance and density. This database is currently under development.

4.3 Data Download, Verification and Editing

Data will be downloaded as soon as possible upon returning from the field. Raw data files are backed-up and the GIS manager verifies that data from ArcPad (ESRI, Inc., Redlands, CA) matches the hardcopy recorded by the observer. The GIS manager edits data to correct discrepancies in ArcGIS (ESRI, Inc., Redlands, CA) and prepares data for processing by arc macro language (AML) scripts. After processing with the AMLs is completed, data are imported into Microsoft Access for combining data from several files by specific queries. The files produced in Access are exported to a file format that can be inputted into GammaMRDS (Appendix B) for abundance and density estimation.

4.4 Routine Data Summaries and Statistical Analyses

Survey-wide estimates of abundance, density and distribution of brown bears will be produced after every complete survey (see section 4.6). These analyses will include descriptive summaries of observations such as displayed in Tables 4.1 and 4.2. Estimates of spatial distribution will be graphically displayed as a density surface, where color shades will denote different densities (see section 4.6). Trend estimates of abundance, density and distribution will be produced after the third complete survey and updated with data collected from each subsequent survey, which should be every five to seven years thereafter (see section 4.6 and Appendix A, SOP #4).

4.5 Report Format

Reporting is the culmination of the brown bear monitoring effort. The main objective of brown bear monitoring efforts in SWAN parks is to track estimates of abundance, density and distribution within parks across time. Therefore, summaries of bear abundance, density, and distribution will be included in monitoring reports. Reports will conform to specific guidelines set by the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). Reports will include maps, graphs, figures and other visuals to facilitate comprehension of findings. An example summary table is shown in Table 4.1. Other summary data may include sex and age class of observed bear groups during annual survey efforts and/or percent cover recorded around bear groups (Table 4-2).

Example figures may include maps detailing bear locations and distribution across the landscape, areas surveyed, cover types observed and sex/age groups observed throughout time, and plots of abundance or density estimates (Figure 4.1). Additional information relevant to reporting is discussed in Appendix A, SOP #7.

Table 4.1. An example summary table for brown bears observed during aerial survey efforts (G. Collins, USFWS, Sheldon Hart National Wildlife Refuge, Lakeview, OR, personal communication).

Date	No. of transects	No. of bear groups	No. of individual bears	Groups/transect
5/19/2004	35	6	9	0.26
5/20/2004	46	11	15	0.33
5/21/2004	49	12	18	0.37
5/22/2004	55	18	22	0.40
5/23/2004	53	14	16	0.30
5/25/2004	21	5	6	0.29
5/26/2004	60	20	26	0.43
5/27/2004	52	19	23	0.44
5/28/2004	36	8	11	0.31

Table 4.2. Example summary table for bears observed by percent cover for brown bear monitoring data (G. Collins, USFWS, Sheldon Hart National Wildlife Refuge, Lakeview, OR, personal communication).

Percent Cover	Number of bear groups	Number of individual bears	Percent bears observed in cover type
0	41	67	35
10	20	34	18
20	11	18	10
30	9	16	8
40	8	9	5
50	7	10	5
60	8	10	5
70	5	8	4
80	6	7	4
90	3	6	3
100	2	4	2

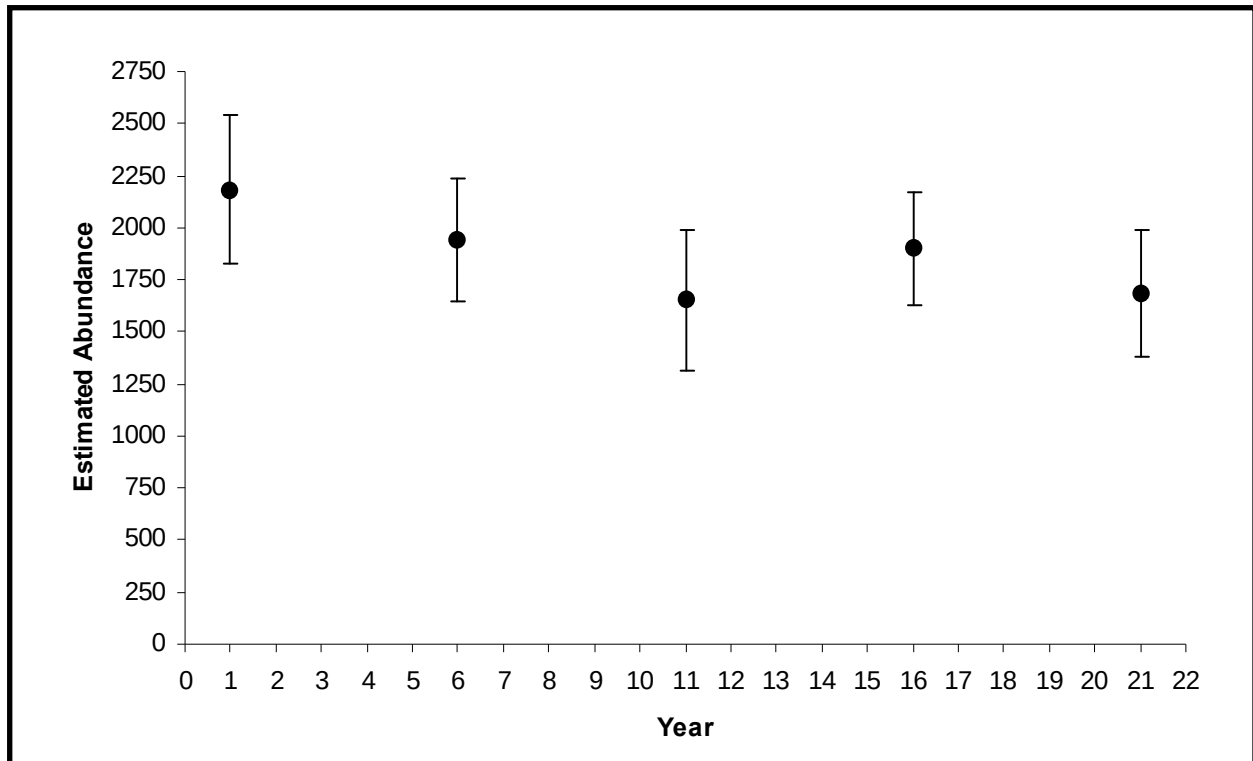


Figure 4.1. Example figure displaying abundance estimates and 90% credible intervals from aerial surveys completed once every five years.

4.6 Methods for Trend Analyses

Program GammaMRDS (Appendix B) can be used as the traditional (strictly likelihood-based) method to estimate abundance and density of brown bears within SWAN parks. This program is written in freely available R code (R Development Core Team 2009). Appendix D contains R code that fits the Becker-Quang model within a Bayesian hierarchical modeling framework (Royle and Dorazio 2008) to estimate trends in abundance and density based on the coefficient of a time (year) variable (and associated measure of precision) included in the hierarchical model. Bayesian hierarchical models offer several advantages over traditional models, including decomposition of the sources of variation into process and observational components, and trend estimators that are often more precise due to "shrinkage" induced by borrowing strength across all estimates (random effect model) and use of prior data (when available). The R code in Appendix D uses the R2WinBUGS library (Sturtz et al. 2005) so that the Markov Chain Monte Carlo (MCMC; Gilks et al. 1996) method required for this approach can be called from within R to run in the freeware program WinBUGS (Lunn et al. 2000). However, the Becker-Quang model used in GammaMRDS and in the R code in Appendix D is biased due to lack of independence in the double-observer component (e.g., see Buckland et al. 2010). A correction is under development and will be implemented in the next version of this protocol.

Estimates of trend in brown bear distribution will derive from the Bayesian hierarchical spatial models (e.g., Johnson et al. 2010). The minimum spatial unit for obtaining a measure of adjacency will have to be defined, but will be larger than a transect and based on the average perceived movements of bears during the survey. Once this spatial unit has been defined, it can

be linked within ArcGIS 9.3 (ESRI, Inc., Redlands, CA) to existing landcover maps and associated data layers containing landcover (vegetation) class codes, elevation and slope for each park (data available from the SWAN Data Manager [contact: http://science.nature.nps.gov/im/units/swan/index.cfm?theme=network_staff]). Relative percentages of slope categories, elevation categories, and landcover classes will be calculated for each surveyed unit (collection of transects) and used as potential predictors to generate an estimated density surface for the entire sampling universe. The final predictive model will be selected based on the DIC criterion (Spiegelhalter et al. 2002) from a set of candidate models comprised of various combinations of percent landcover class, percent slope category, and percent elevation category. If no candidate model is clearly better supported than others, a composite predictive model will be generated by model averaging across all models (Hoeting et al. 1999, Burnham and Anderson 2002). Model convergence and goodness of fit will be evaluated using the Gelman-Rubin statistic (Gelman and Rubin 1992, Brooks and Gelman 1998) and the Bayesian P-value (Gelman et al. 2004). Each complete survey will provide estimated densities from each spatial unit comprising this surface. A composite change surface indicating spatially explicit increases, decreases or stable densities will be produced based on previous and current surveys to quantify changes in spatial distribution of bear densities across time, much akin to change detection in a time series of vegetation images (e.g., Reed et al. 2006). Further details are provided in Appendix A, SOP #5.

4.7 Data Archival Procedures

Long-term archiving of brown bear data will occur at the ARCC. Electronic files related to brown bear monitoring efforts will be stored on the SWAN server. All hard copy materials, such as log books, copies of data forms and other resource materials are considered “mission critical” and will be stored in the long-term archive at the ARCC. Hard copy materials may also be stored at the associated park headquarters facility, such as the KATM or LACL offices. In this case, copies of all materials will be made and sent to the SWAN archive. See Appendix A, SOP #6 for detailed information related to archiving data.

4.8 Reporting

Written reports on monitoring of brown bears in SWAN parks will primarily be: 1) survey reports, 2) newsletters, field season highlights and mid-winter notes; 3) annual administrative reports, 4) resource briefs, and 5) peer-reviewed articles in scientific publications. These reports may be written by the SWAN Terrestrial Project Leader, SWAN park staff, or a combination of both. Oral reporting may consist of presentations to the SWAN technical committee during survey years, either oral or poster presentations at the SWAN Biennial Science Symposium, and either oral or poster presentations at scientific conferences.

Survey reports will be generated by the September following the spring survey; these will be final reports for completed surveys and field season updates (see below) for multiyear partial surveys that have not been completed. Final survey reports will be formatted based on guidelines described on the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). The target audiences for these reports include park staff, and natural resource staff and scientists from other state and federal agencies. They will be posted on the SWAN website

(http://science.nature.nps.gov/im/units/swan/index.cfm?theme=reports_pub) to ensure their public accessibility.

Annual newsletters, field season highlights and mid-winter notes will provide interim summaries of activities and accomplishments associated with the SWAN brown bear monitoring program. The target audiences for these reports will be SWAN park and Alaska Regional Office staffs, collaborators from other state and federal agencies, and the general public. These reports will be publicly available on the SWAN website (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=reports_pub).

The annual administrative report provides a summary of a network's fiscal year activities, accomplishments, and associated budget expenditures to park superintendents, I&M network technical committee members, I&M network staff, I&M regional coordinators, and servicewide program managers. Servicewide program managers use this information in their annual Report to Congress, to respond to inquiries from the budget office, and for other purposes. The format of this report is set by the I&M Washington Office in Fort Collins, CO. Summary information on brown bear monitoring surveys, results and budget expenditures will be included in the annual administrative report during years of partial or complete surveys.

Resource briefs provide one-page summaries describing the importance and issues associated with each SWAN vital sign. They will be updated as new survey data are collected and analyzed. The target audiences for these briefs will be SWAN park staffs, scientists from other state and federal agencies, and the general public. The resource brief for brown bears is publicly available on the SWAN website (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=brown_bear).

Peer-reviewed journal articles may be published from time to time as relevant and appropriate. The target audience for these articles will mainly be the scientific community.

5 Personnel Requirements and Training

5.1 Roles and Responsibilities

The implementation of this protocol requires advanced knowledge of GIS, database applications, survey operations, data management and statistical methods (Table 5.1). Pilots experienced in wildlife survey operations and, when available, seasoned observers will be needed. Experience of observers can vary. Seasoned observers that are experienced in spotting wildlife and comfortable in small aircraft typically detect more bears and wildlife versus new observers. However, if experienced observers are not available, new observers will be trained to prepare them for survey operations (Appendix A, SOP #3). A high level of expertise by a biometrician will be required throughout the duration of the protocol to provide assistance with survey design as needed, to conduct the statistical analysis and to interpret findings.

5.2 Qualifications

A project leader/wildlife biologist, biometrician/quantitative ecologist, GIS specialist and data manager are key personnel required to develop and complete the process of monitoring brown bears in SWAN park units. The project leader/wildlife biologist executes pre-season logistics, conducts aerial surveys to obtain bear count data, manages observer crews, and reporting. The GIS specialist/wildlife biologist performs pre-survey computer and spatial data preparations, data editing, data management, and tracks survey progress. In previous surveys, these individuals

Table 5.1. Work flow and responsibilities for monitoring brown bears. The same pilots and observers will be used across aerial surveys when feasible.

Task	Personnel
Data Acquisition: -Aerial surveys	Project Leader/Wildlife Biologist Project Leader/GIS Specialist Other Park Wildlife Biologists Park Pilots/OAS Contract Pilots Other Observers
Data Management: -Copy new files to central data server -Manage data formats, directory structure, archiving -Maintain consistent data characteristics and software compatibility with other SWAN data sets	Project Leader/Wildlife Biologist Project Leader/GIS Specialist Data Manager Network Coordinator SWAN Project Leader Crew Member/ Biological Technician
Data Analysis and Interpretation: -Manual interpretation of field data -Spatial analyses -Trend analyses -Data summaries	Biometrician/Quantitative Ecologist Project Leader/Wildlife Biologist SWAN Project Leader
Reporting	Biometrician/Quantitative Ecologist Project Leader/Wildlife Biologist SWAN Project Leader
Back-ups	All Users (local) and SWAN data manager (archives). IT Specialist.
Minor Protocol Revisions and Documentation	Project Leader/Wildlife Biologist, Network Coordinator, SWAN Project Leader
Major Protocol Revisions	Work group-designated

Table 5.2. Personnel qualifications for executing the protocol for monitoring brown bears in SWAN park units.

Personnel	Qualifications/Experience
Project Leader/Wildlife Biologist	Experience or ability to conduct aerial surveys and fly in small aircraft for long periods of time Ability to synthesize information from multiple data sets to develop summary reports Experience with wildlife statistical procedures
Project Leader/GIS Specialist	Experience with GIS software to create spatial data Experience editing spatial data using GIS software Experience creating maps using GIS software
Biometrician/Quantitative Ecologist	Extensive experience in all aspects of sampling designs and data analysis associated with monitoring and research, development and application of models, especially Bayesian models Familiarity with model development, biometrics and statistical procedures related to wildlife populations Ability to develop methods for data analysis and refinements related to bear monitoring
Data Manager	Extensive experience with all aspects of data management Ability to work with principal investigators to design appropriate databases for data collection and integration of data

were park wildlife biologists. The SWAN project leader may or may not be the same individual as the project leader/wildlife biologist. If the same individual is not in this position, he/she will be responsible for overall project supervision of the SWAN terrestrial wildlife monitoring program. The biometrician/quantitative ecologist is instrumental in sampling design development and testing as well as assistance with estimating abundance/density and distribution from aerial survey data. Future changes or refinements to the sampling design or monitoring analysis will be performed by the biometrician/quantitative ecologist and designated review group. The data manager will conduct the long-term archival processes related to storing brown bear monitoring data on the SWAN server. Table 5.2 outlines qualifications for personnel necessary to successfully complete bear monitoring efforts.

5.3 Training Procedures

Personnel participating in the brown bear survey will review the protocol narrative and SOPs to familiarize themselves with the tasks their roles requires. Survey personnel will complete aviation safety training as well as training covering the computer data collection equipment. They also will undergo in-air training with experienced observers prior to the survey. Completion of safety training requirements will help ensure safety during survey operations, whereas data collection training will provide observers with experience in collection methods that so as to comply with quality assurance protocols. Specific requirements are listed in Appendix A, SOP #3.

6 Operational Requirements

6.1 Annual Workload and Field Schedule

Pre-season preparations will occur prior to the May survey, typically between January and April. Survey flights will occur in May but the exact timeframe will depend on spring bear emergence from dens and leaf out. Task and workload estimates are in Table 6.1.

Downloading data will occur in the evening after survey flights are conducted. Data analysis and reporting will occur during the fall and winter months following surveys. Data management will occur throughout the year as needed and as detailed in Appendix A, SOP #6.

6.2 Facility and Equipment Needs

Equipment requirements to successfully conduct brown bear monitoring include aircraft for survey flights, sufficient staff to observe and assist in field procedures, flight safety equipment, laptop computers and GPS units for electronic data recording during flights, home base computers (for data management, pre-season transect selection and mapping, and data analysis), a printer and plotter, and hand fuel pumps with associated aircraft fueling equipment. Up to five aircraft may be needed to complete aerial surveys. The number of GPS units and field laptop computers required will coincide with the number of aircraft the project leader deems necessary to complete survey transect allotments in the specified timeframe. At least one spare laptop computer should be available for survey use in case technical issues arise with primary equipment.

Facility needs include an area to base the computer and printer, post survey maps and track transect completion, allow survey crews to meet and coordinate flight plans, storage of

Table 6.1. Estimated workload and schedule for monitoring brown bears in SWAN park units.

Task	Timeframe	Workload
Pre-season tasks -obtaining permits -readying equipment -determining survey routes -printing maps -training observers -contract pilots - reserve housing -locate and supply fuel caches	January-April	5 hours 100 hours 80 hours 10 hours < 1 week 40 hours 8 hours 40 hours
Conducting aerial surveys	May	200 hours of flight time, 10-14 days
Downloading survey data, quality assurance, tracking transects completed, creating compiled transect maps and lists, and computer maintenance	May	100 hours
Post-season data processing	June	80 hours
Analyzing survey data	Oct-Jan	180 hours
Data storage/archiving	On going	100 hours
Reporting	Dec-Feb	160 hours

equipment, data and data back-ups. Stand-alone licenses (with dongle) for ArcGIS 9.3 and ArcPad 7.1. will be required for the survey; the Project Leader should contact the GIS team at the National Park Service, Alaska Regional Office to acquire licenses. Fuel caches for aircraft during survey work will be required (Appendix A, SOP #1 for detailed information on facility and equipment needs.

6.3 Start-up Costs and Budget Considerations

Start-up costs for the preliminary surveys conducted in KATM and LACL during 2003-2005 (Olson and Putera 2007) are included in Table 6.2. Based on this information, the bulk of the budget for future surveys will be associated with aircraft operation and salaries. Expenses for ANIA will be more than other SWAN parks because of its greater remoteness and more extreme weather. Specifically, more fuel will be needed for surveys and the time necessary to complete surveys will also be increased due to longer flying times to reach survey locations. Longer flying times will increase the overall survey effort impacting staff time and associated salary cost increases. Salary estimates are based on a team of five observers who will typically be park biologists and technicians. Some overtime will be required due to the long nature of survey days.

Start-up equipment costs include light systems, curtains, GPS units, antennas, laptop computers, interface cables, port adapters, power converters, light adapters, software, and associated licensing needed for aerial surveys.

Food and housing will be needed for the pilots and staff survey team (8-12 people) for a period of 10-14 days in May. Housing will be provided by the host park in KATM or LACL. Surveys in ANIA will require making housing arrangements in Port Heiden.

Table 6.2. Estimated costs for monitoring brown bears in KATM and LACL.

Estimated Costs	KATM	LACL
Food (\$35/day for 14 days, 12 people)	5,180	5,180
Contract aircraft (2) for 10 days (100 hrs @ 165/hr)	16,500	16,500
DOI agency aircraft (2) for 10 days (100 hrs @ 90/hr)	9,000	9,000
Fuel 1600 gallons @ \$6.00/gal	9,600	9,600
Travel to/from survey area	2,000	2,000
Start-up equipment costs	2,000	500
Salaries including overtime	14,000	14,000
Total	\$58,280	\$56,780

7 Procedures for Revising the Protocol

All edits and amendments made to the protocol narrative and/or SOPs should be recorded in the revision history log table at the beginning of this document. Users of this protocol should promptly notify the project leader of the terrestrial wildlife monitoring program of recommended edits or changes. The project leader will review and incorporate suggested changes as necessary, record these changes in the revision history log, and modify the date and version number on the title page of this document to reflect these changes. For more details, please refer to Appendix A, SOP #8

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Appendix A: Standard Operating Procedures

SOP #1	Preparations for the Field Season
SOP #2	Computer Setup and Survey Transect Development
SOP #3	Training Observers
SOP #4	Aerial Survey Flights
SOP #5	Data Analysis
SOP #6	Data Management
SOP #7	Reporting
SOP #8	Revising the Protocol or SOPs

Preparations for the Field Season

Standard Operating Procedure #1
Version 1.0 (7/12/2009)

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Revision History Log:

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Add rows as needed for each change or set of changes associated with each version.					

1.0 Introduction

This SOP describes how to prepare for the field season. Pre-season field tasks include 1) scheduling personnel, 2) coordinating aircraft, 3) preparing equipment, 4) selecting survey transect routes (when required), 5) mapping these routes (when required), 6) obtaining permits and 7) personnel training (discussed in SOP #3).

1.1 Scheduling Personnel

Up to 12 people will need to be scheduled (or hired) to conduct the data collections from aerial surveys of brown bears. Prior to the field season, project staff will be hired and/or scheduled for a 10-14 day period in May. The exact number of project staff required will depend on survey effort and how many aircraft will be used in survey flights. Each aircraft requires one pilot and one observer will be needed per plane. One to two extra observers and a standby pilot should be available during surveys as a back-up measure in the event other scheduled staff personnel are unable to continue surveys. Project staff used in previous surveys included NPS biologists from SWAN parks and Alaska Department of Fish and Game (ADF&G) personnel.

Housing and food will be required for up to 12 people for 10-14 days where the survey is based. For scheduling pilots and aircraft, see the 'coordinating aircraft' section below.

1.2 Coordinating Aircraft

Up to five survey aircraft will be required to conduct survey flights within the narrow sampling window. The project leader/wildlife biologist and SWAN biological science technician will schedule park and contract biologists during the winter prior to spring survey flights. Experienced pilots book up well in advance so scheduling early is strongly recommended. A combination of Piper SuperCub, Aviat Husky and/or Cessna Bird Dog aircraft should be used for survey operations.

Caching fuel in remote locations is needed to facilitate efficient survey operations. The project leader and SWAN biological science technician will coordinate fuel amounts needed and cache locations for surveys flights. Once fuel cache sites are determined, NPS permits need to be obtained for storing fuel at these sites. The amount of fuel needed will depend on survey aircraft types being used, survey site locations, number of survey aircraft, and location of transects relative to fueling facilities. Arrangements for the purchase of the necessary quantity of fuel should be made early (January) to allow sufficient time for shipment to the drop-off point where pick up and transport to the field will begin. A Beaver or Cessna 206 is required to transport the fuel to cache sites, which will be stored in sealed 208 liter (55 gallon) barrel drums.

Tie down space will be needed for up to five aircraft. Arrangements will be needed to preheat up to five aircraft simultaneously when air temperatures are below -6°C (21°F). Check this temperature with the contracted pilots because they may have specific requirements for their aircraft engines that vary. Ensure extension cables reach to tie down locations if aircraft are based at an airport with power. If remote field camps will be used, portable generators will be needed for preheating.

1.3 Preparing Equipment

Major categories of equipment preparation include electronic survey equipment preparation, other equipment preparation, and data collection equipment organization. More details on each of these are listed below.

1.3.1 Electronic Survey Equipment

Electronic survey equipment includes Global Positioning System (GPS) units and laptop computers. Each aircraft will have one laptop computer and one GPS unit. Total quantities needed for survey operations will depend on the number of aircraft being used. There should be one GPS unit(s) per airplane (in addition to the airplane's own navigation system), as well as two backup units available.

Use a GPS unit to document survey flight paths, bear locations, search distances and other survey related location data. A GPS unit should be equipped with a programmable baud rate setting function, accuracy to within 15 m (50 ft) and equipped with a back-up lithium battery. Use a baud rate setting of 9600. This speed (or faster) is required so the GPS can keep pace with the aircraft flight speed. External receiving antennas with adapters are required to ensure quality satellite reception and accurate position information. GPS to PC interface cables with appropriate ports will be needed so data from the GPS can be transferred into the laptop during flight operations.

The Garmin GPS Model 12 XL was used in 2003/2004/2005 surveys of KATM and LACL, but this model has been discontinued. A newer model, such as the Garmin GPSMap76CSx, can be used instead if the Model 12 XL is no longer in use (a user manual for the Model 12 XL is available at

http://www8.garmin.com/manuals/GPS12XL_OwnersManual_SoftwareVersion4.0andabove_.pdf). The GPSMap76CSx offers a much more sensitive receiving antenna and has a removable microSD memory card that can be upgraded to 2 Gb. A user's manual for the GPSMap76CSx is available at http://www8.garmin.com/manuals/GPSMAP76CSx_OwnersManual.pdf. The GPSMAP76CSx will last up to 18 hours on 2 AA batteries, whereas the 12XL will last up to 24 hours on 4 AA batteries.

The interface page of the GPS unit allows the user to specify formats for connecting external devices. Use the NMEA (National Marine Electronics Association interface and data protocol) format for transferring GPS data into the laptop via the GPS to PC interface cable. The baud rate on each GPS unit will be checked and set to 9600 if this is not the default setting. This can be performed in the interface page of the unit. All GPS units will be individually labeled with a unique number. Should additional cables or adapters be needed for future surveys, refer to the Garmin website for a complete list of external device accessories.

Laptop computers loaded with ArcPad software (version 7.1, ESRI, Inc., Redlands, CA) will be used to record data during surveys. Operating system requirements include Windows XP. Laptop computers are powered during survey flights by using the aircraft power system with fully charged, high-capacity laptop batteries installed. Power adapters and power converters will be required to access the aircraft power source (types depending on laptop and aircraft configurations). Typically a cigarette lighter adapter is used that allows connection to a 12 volt DC cigarette lighter plug located on the instrument panel of the aircraft.

External back-up media, such as USB drives, will be needed for transferring data to the data management computer and backing up survey data. Several of the laptop computers used in previous surveys had USB ports but several other laptops were older and required external zip drives for backing up.

Digital cameras are an optional piece of equipment and may be used for capturing photographs of survey operations for later use in professional presentations or in outreach products.

1.3.2 Equipment List for Electronics

- Garmin GPSMAP76CSx GPS unit or equivalent
- External receiving antennas for the GPS units (e.g., Garmin GA29)
- GPS to PC interface cables with appropriate port (Garmin PC interface cable)
- Serial I/O PC card or USB serial adaptor (if needed)
- Laptop computers for use in aircraft loaded with ArcPad software (7.1) and bear survey program installed.
- PC 12 volt DC power converters
- Cigarette lighter adapters or telemetry system adapters for power-type depending on setup
- USB drives, external zip drives or other preferred back-up media
- Digital camera (optional)

1.3.3 Other Equipment

Other equipment needs include the curtain and light box systems for the aircraft to separate the pilot view from the back-seat observer and vice versa. This system is used to facilitate independence of observations for sighting bears (described in the protocol narrative).

Data forms (Figure A1.1) will need to be printed and photocopied. The exact number of forms will depend on survey effort but up to 200 may be needed. Ensure copies are printed on acid-free paper for archiving purposes. Miscellaneous equipment needs are listed below.

- Light systems (one per aircraft =two lights and two switchboxes)
- Extra fuses for the cigarette plug
- Curtains (one per aircraft) with Velcro for attachment
- Clipboards (one per aircraft)
- Data forms (up to 200 copies printed on acid free paper)
- Survey instructions sheet
- Cover classification sheet
- Transect list with latitude/longitude
- Main study area overview maps and transect maps (see maps section below)
- Field gear list (see below)

Lists of field gear to take on aerial survey flights are shown in Table A1.1. Most equipment was already purchased for surveys performed in KATM and LACL during 2003-2005. However, some routine equipment upgrades will need to be made over time as gear wears out and the

useful life of survey components decrease. Upgrades in computer equipment will need to be made over time as technological advances in electronics are made in future years.

1.4 Obtaining Permits and other Compliance Procedures

1.4.1 Research Permit

An NPS research permit should be obtained before conducting brown bear monitoring efforts on NPS lands. Applications can be submitted online through <http://science.nature.nps.gov/research/ac/ResearchIndex>. A special-use permit is required for remote fuel caches within the parks. These are obtained through the environmental compliance specialist and require the specific cache locations for the evaluation process. Ensure permits are obtained well in advance of survey operations to avoid delays in collecting data. Ensure all personnel have or are scheduled for appropriate training (see SOP #3).

1.4.2 Aviation

Aviation activities will comply with all applicable policies and regulations issued by the Department of the Interior (DOI), the Federal Aviation Administration (FAA), and NPS. Alaska parks have specific regulations concerning fixed-wing aircraft, published at 36 Code of Federal Regulations CFR Part 13 and 43 CFR 36.11(f) (NPS 2006). Additional regulations pertinent to brown bear monitoring are discussed below.

Aerial surveys for brown bear monitoring are considered ‘Special Use’ flights, which are defined as any flight operation other than point to point. These flights require special pilot and aircrew qualifications (see SOP #3), special equipment, and personal protective equipment (Table A1.1) to enhance safe transport of personnel (NPS 2003). Personal protective equipment required for Special Use flights includes fire-retardant clothing (NOMEX), aviator’s protective helmet, gloves made completely of NOMEX or a combination of NOMEX and leather, and leather boots that extend above the ankles. Wearing materials with low temperature melting characteristics, such as synthetic material made of fleece, nylon, polyester, are not approved. First aid and survival kits are mandatory equipment and are the responsibility of the pilot. Pilots will ensure these kits are complete prior to flight operations (the Aviation Life Support Equipment Handbook details equipment lists for these kits, NPS 2003).

Aerial surveys for brown bear monitoring will be conducted at 91 m (300 ft) Above Ground Level (AGL) and are considered ‘Low-Altitude’ flights (below 152 m [500 ft] AGL). Low-altitude flight operations are conducted in accordance with Federal Aviation Regulations FAR 91.119, subpart D of part 135, part 137 or a FAA waiver or grant of exemption, if applicable. Specifications related to transport of hazardous materials and fuel handling are described in Chapter 10 of the Aviation Management Plan (NPS 2003). If caching fuel for aircraft surveys will be necessary, ensure fuel drums are properly stored per DOI regulations.

Flight following for the survey aircraft is required by Operational Procedures (OPM) Memorandum NO. 06-02 (<http://amd.nbc.gov/library/opm/06-02.pdf>). Following requires position report at <1 hour intervals under normal circumstances and parks may require shorter durations between position reports. The presence of Automated Flight Following (AFF) system allows for changes to the following procedures as described in Interagency Aviation Safety Alert

06-05 (http://amd.nbc.gov/safety/alerts/IA_Alert_0605.pdf). Procedures indicates that pilots make contact with local dispatch center as soon as practical after takeoff to confirm radio communication and the AFF status, and upon positive contact, requires no additional radio communication. Dispatch must monitor Web Tracker (AFF program) at a minimum of every 15 minutes for aircraft data. During work hours in May, dispatch will conduct flight following, but arrangements must be made for after-hours and weekend flights. SWAN requires aircraft used in its field projects to be equipped with AFF. The use of satellite phones is also recommended for contracted aircraft.

Literature Cited

NPS. 2003. Aviation Management Reference Manual RM 60. National Park Service, U.S. Department of Interior. Washington, D.C. Available from (http://www.nps.gov/fire/download/fir_avi_RM60.pdf). Accessed 31 July 2009.

Computer Setup and Survey Transect Development

Standard Operating Procedure #2
Version 1.0 (7/13/2009)

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Add rows as needed for each change or set of changes associated with each version.					

2.0 Introduction

This SOP describes how to set up the computers and create transects to use during the surveys. Pre-season tasks include 1) installing necessary software applications and extensions, 2) selecting survey transect routes (when required), 3) mapping these routes (when required), 4) uploading the transects to the field computers. The ArcMap extension tool for generating random transects and the ArcPad applet for entering aerial survey data were designed by Dave Bush and Kirmanie Ravariere of GeoNorth LLC, Anchorage, AK.

2.1 Installation of Transect Generation Tool

The Transect Generation ArcMap Extension can be found in the 'Transect Generation ArcMap Extension' folder. The contents of the folder include the following:

- Transecttool Image file: This image is used as the background image for the Transect tool's ArcMap button.
-
- NPSConfig XML file: This file stores application settings.
-
- NPS_Transect_Tool MXD file: This MXD is where the 'Transect Generation ArcMap Extension' actually resides as VBA (Visual Basic for Applications) scripts.
-
- NPS geodatabase: The geodatabase referenced by layers in the NPS_Transect_Tool MXD file. This geodatabase is where the Transects are stored and eventually where the field data will be stored.
-
- APLs folder: This folder contains the APL (ArcPad Layer) files which define the symbology used to display the Shapefiles in ArcPad.
-

The following are the list of steps required to install the Transect Generation Tool.

1. Copy the 'Transect Generation ArcMap Extension' folder to the desired location.
2. Double click the NPS_Transect_Tool MXD file to start ArcMap.
3. If you are unable to locate an ArcMap button with a blue plane as the background icon then do the following:
 -
 - From ArcMap, navigate to Tools→ Customize→ Commands and select [UIControls] in the right item list. The button 'Project.TransectTool' should now be visible in the 'Commands' item list to the left. If not, make sure the 'Save in' field at the bottom left has the name of the MXD file and not the word 'Normal.mxt'.
 -
 - Drag and drop the Transect Tool's button to any toolbar on the ArcMap window. While the Customize window is still open, right-click on the Transect tool button.
 -
 - Select the 'Image only' option then select 'Change Button Image' to browse to the 'Transect Generation ArcMap Extension' folder and select the Transecttool bitmap image file.

4. Click the Transect tool's button. If you can see the Transect Generation tool's form, the installation was successful.

2.2 Transect generation

Computer/program requirements: ArcGIS 9.3 (ArcMap and ArcCatalog), Transect Generation ArcMap Extension

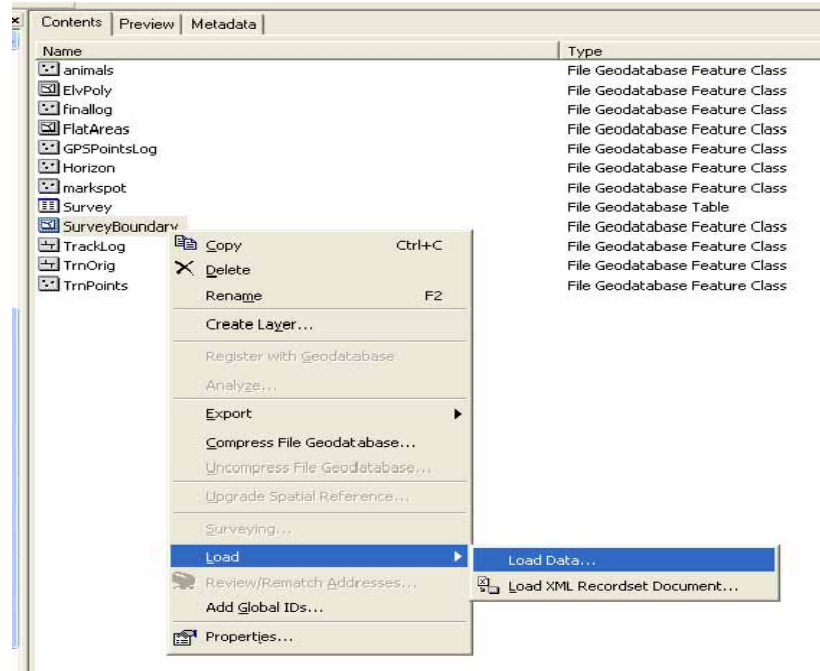
Survey transects will be selected from relevant habitats within each park across a variety of elevations and terrains. Transects will be randomly selected and will be re-sampled on subsequent surveys once established within a study area. Additional transects for these areas may need to be selected for future surveys if effort requirements change or supplementary transects become necessary.

The Transect Generation ArcMap Extension is used to generate random transect lines drawn at random angles and at random locations. The Transect Generation tool is also used for exporting geodatabase content to Shapefiles which are then used to store field data collected via the Animal Tracking ArcPad Applet.

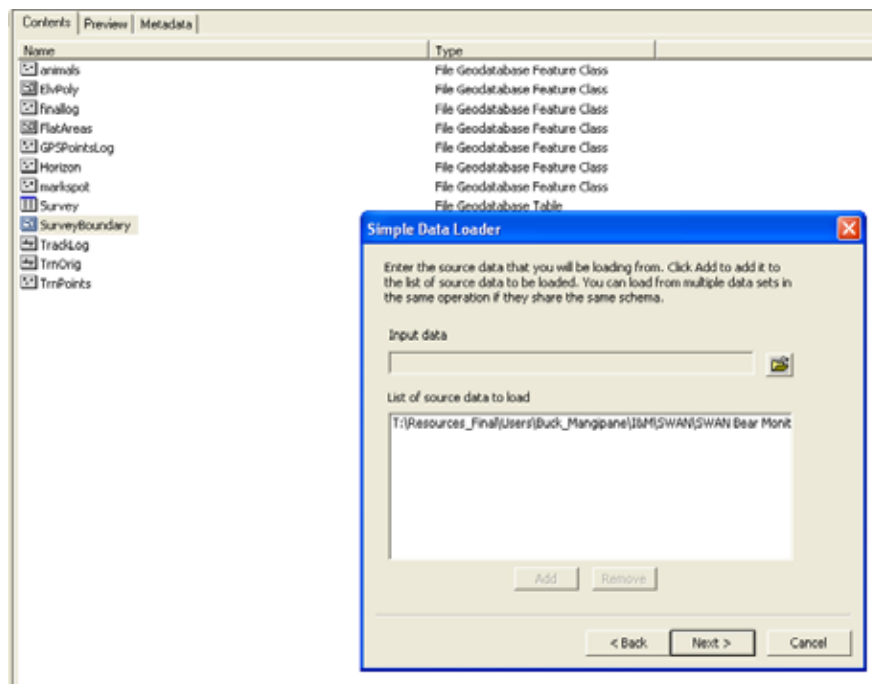
2.2.1 Creating Survey Boundaries

The first step in using the Transect Generation tool is to build a polygon to represent the boundary of the study area. The survey boundary polygon must be stored in the 'SurveyBoundary' FeatureClass ('Survey Boundary' layer in the NPS_Transect_Tool MXD file).

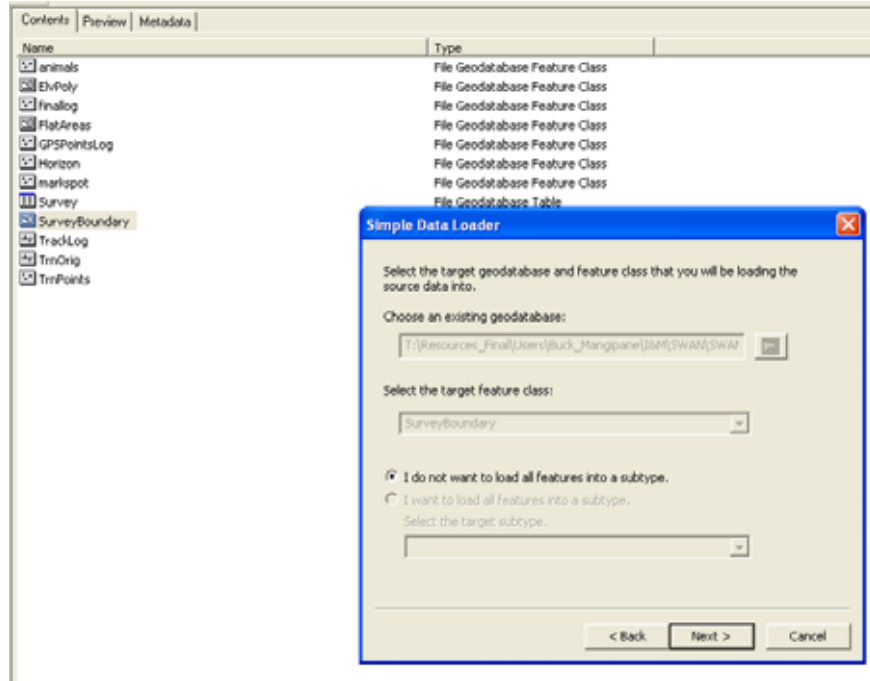
1. Navigate to the NPS.gdb using ArcCatalog, open the geodatabase (by double-clicking) to view the features contained in the database.
2. Find the SurveyBoundary feature, select it, and right click the mouse. From the list of options, select *Load* → *Load Data...* options.



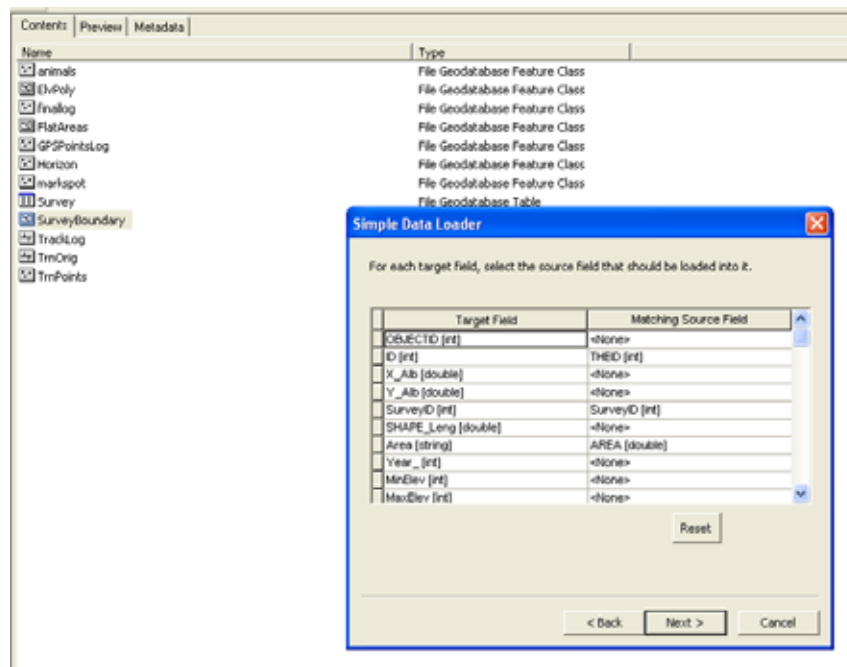
- Using the box that opens (Simple Data Loader), browse to the input data file representing the study area. Once you find it, select the Add option to add it to the List of source data to load.



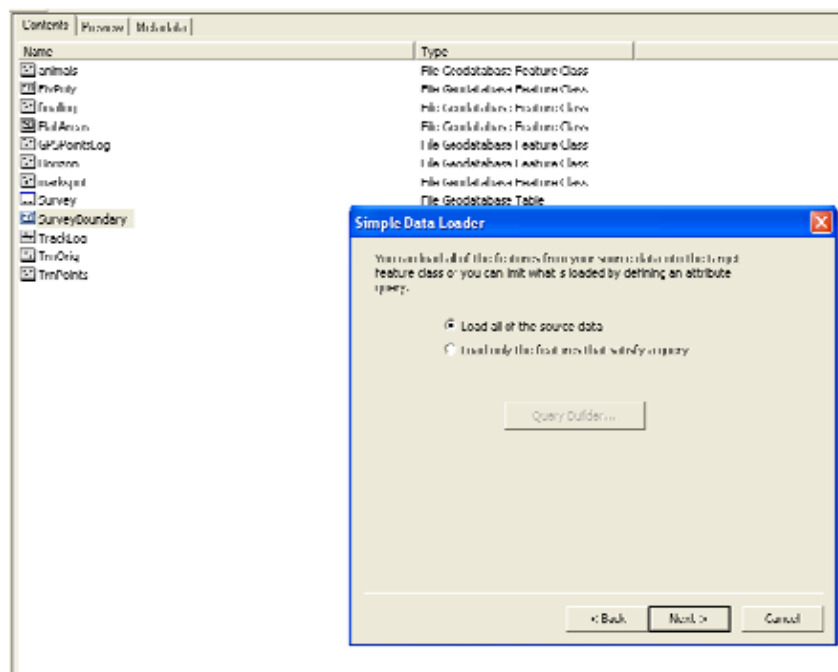
4. Select Next, and on the following screen, verify that the correct geodatabase, target feature class, and the button for *I do not want to load all features into a subtype* is selected. Once these are confirmed, select Next.



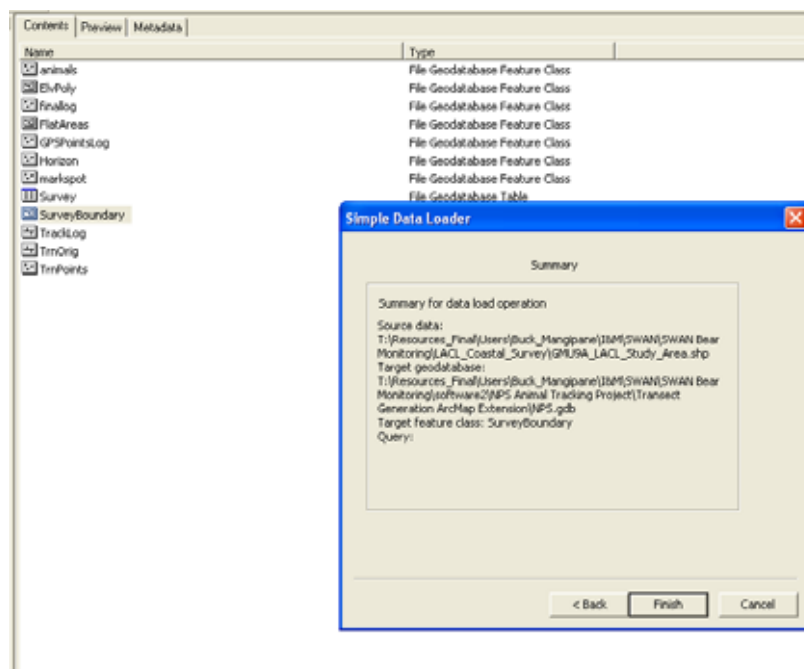
5. Assess the matches for the Target Field and Matching Source Field. Once these are reviewed, select Next.



6. Check the button for *Load all of the source data* and select Next.



7. On the Summary page select Finish.



The next step is to edit the SurveyID field of the new survey boundary feature. The survey boundary feature must be assigned a SurveyID (e.g. '1005') or it will not be selectable from within the Transect Generation tool.

2.2.2 Setting a Digital Elevation Map (DEM)

Another important step in using the Transect Generation tool is ensuring that the tool knows where to find a DEM file. Most of the steps in the Transect Generation tool require a DEM file to generate their results.

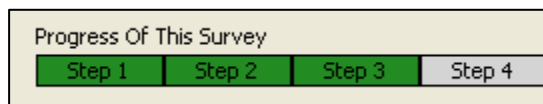
To set the tool's default DEM file, click the 'Config' tab in the Transect tool window. Click the 'Browse' button next to the 'DEM File Path' field and browse to the location of the DEM file you wish to use. Click the DEM file to select it. The path to the DEM file should now be set in the 'DEM File Path' field. It may become necessary to re-project a raster to that of the 'Survey Boundary' FeatureClass projection if the raster does not align with your boundary (the error message 'the boundary polygon for SurveyID [SurveyID] is out of range of the Raster extent' will indicate so).

To re-project the raster, first right click on the *ArcToolbox* and click *Environments*. In the Environment Settings window, click *General Settings* and update the Current Workspace and Scratch Workspace fields to 'C:\Temp' and click OK. This will avoid any security issues that may come up while performing necessary processing on the raster.

Next, from the ArcToolbox, navigate to Data Management Tools→Projections and Transformations→Raster→Project Raster. From the Project Raster window, select the path to your raster and select a path and name for the output raster. Set the output Coordinate System by navigating to and selecting the *Survey Boundary* FeatureClass. Click OK to create your new raster.

2.2.3 Transect Generation Tool Steps

The four main Transect Generation tool steps - 'Generate Excluded Areas', 'Generate Flat Areas', 'Generate Random Points' and 'Generate Transect Lines' – all generate



features for a particular SurveyID. At any point in time, a particular SurveyID may or may not have features generated by one or more of the tool steps. For example, a certain SurveyID may have flat areas generated but no random points while another SurveyID may have flat areas and random points but no Transects generated. This is where the progress bars come in.

Directly above the main tabs (e.g. 'Step 1' tab) are the survey progress bars. Notice that each progress bar shares the same name as the tab it sits directly above. This is because each progress bar indicates the status of the Transect tool step with which it shares its name. The progress bars indicate whether any of the four steps were run for a particular SurveyID (green if features exist for a particular SurveyID and gray if not).

Step 1—Generate Excluded Areas: The 'Generate Excluded Areas' step uses a DEM to generate polygons of areas that are above or below the specified elevation. These polygons will be

deemed as excluded areas and random points and Transect lines will not be generated within these polygons.

1. Pick the *Select Survey ID* number of the survey boundary for which you wish to generate excluded areas. Excluded area polygons will only be generated within the selected survey boundary.
2. Enter an elevation value. The unit of elevation is determined from the DEM that will typically be in meters.
3. Select whether the areas above or below the specified elevation value will be excluded. If *Above Entered Elevation Range* is selected then all areas/cells in the DEM file with elevation values above the specified elevation value will be extracted and converted to polygons and the adjacent polygons aggregated. If *Below Entered Elevation Range* is selected then all areas/cells in the DEM file with elevation values below the specified elevation value will be extracted and converted to polygons and the adjacent polygons aggregated.
4. Check the *Replace All Excluded Areas for This Survey* box if you wish to delete existing *Excluded Area* polygons for this SurveyID.
5. Click the *Execute* button to run the 'Generate Excluded Areas' step. The resulting polygons will be stored in the 'ElvPoly' FeatureClass ('Excluded Areas' layer in the NPS_Transect_Tool MXD file).

Step 2—Generate Flat Areas: The 'Generate Flat Areas' step uses a DEM to generate polygons of areas that are within a specified slope range. These polygons will be deemed as flat areas and only straight Transect lines – not contour lines - will be generated within these polygons.

1. Pick the *Select the SurveyID* number of the survey boundary for which you wish to generate flat areas. Flat area polygons will only be generated within the selected survey boundary.

2. Enter a slope range by entering slope values in the 'From' slope and 'To' slope fields. The 'Generate Flat Areas' step works by running an ESRI tool to calculate a slope value for each cell in a DEM. When the observer clicks the 'Execute' button, the cells with slope values within the specified range will be converted to polygons and the adjacent polygons aggregated.
3. Check the *Replace All Flat Areas for This Survey* box if you wish to delete existing 'Flat Area' polygons for this SurveyID.
4. Click the *Execute* button to run the 'Generate Flat Areas' step. The resulting polygons will be stored in the 'FlatAreas' FeatureClass ('Flat Areas' layer in the NPS_Transect_Tool MXD file).

Step3—Generate Random Points: The 'Generate Random Points' step generates points that are later used as centers of origin for Transect generation. Before points can be generated for a SurveyID, excluded area polygons must already exist for that SurveyID.

The two methods used to generate points are 'Random Generation' and 'Grid Format'. The 'Random Generation' method creates a specified number of points at random locations which fall within the selected SurveyID's boundary but outside of any excluded area polygons. The 'Grid Format' method generates points in a grid with a specified grid spacing distance. The 'Grid Format' method may generate grid points with or without a specified starting point. If no starting point is specified, the 'Grid Format' method will simply generate the grid points using the upper-left corner of the survey boundary's envelope as a starting point. If a starting point is specified, the grid will be generated with the starting point as its center point.

1. First 'Select the SurveyID' of the survey boundary for which you wish to generate random points.
2. To use the 'Random Generation' method, select the Random Generation option and enter the number of points to be generated.

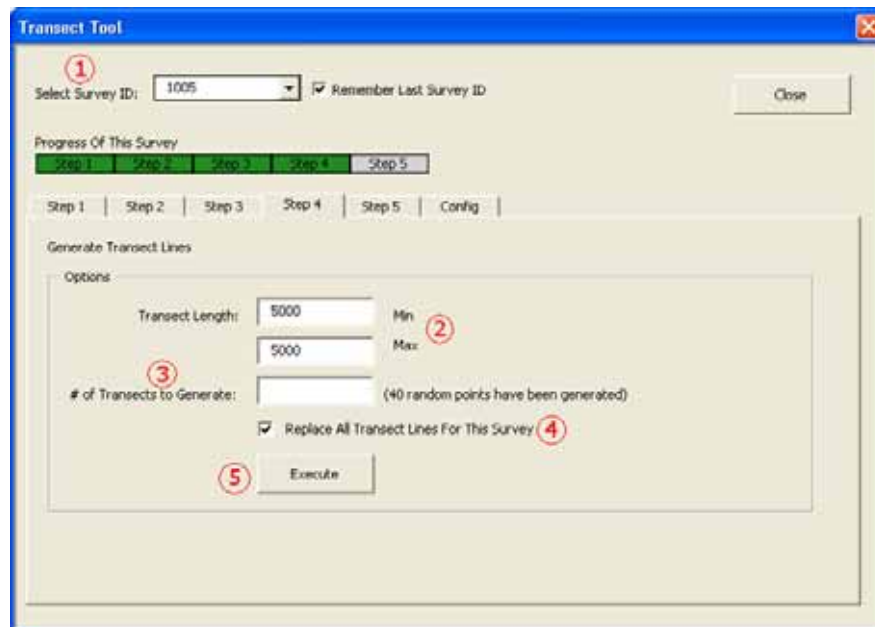
3. To use the 'Grid Format' method, select the Grid Format option, specify a starting X and Y coordinate if desired and set the distance between grid points (point spacing).
4. Check the *Replace All Random Points for This Survey* box if you wish to delete existing random points for this SurveyID.
5. Click the *Execute* button to run the 'Generate Random Points' step. The resulting points will be stored in the 'TrnPoints' FeatureClass ('Random Points' layer in the NPS_Transect_Tool MXD file).

Step 4—Generate Transect Lines: After excluded areas, flat areas and random points have been generated, it is time to build transect lines. Random points are selected and used as points of origin from which transects are drawn. Transect lines may be straight transects or contour transect. Straight Transects are ones that completely fit within the flat area polygons and the survey boundary but are completely outside of the excluded areas. Contour Transects are ones that are completely outside of the flat area polygons and excluded areas polygons but are within the survey boundary.

1. Pick the '*Select the SurveyID*' number of the survey boundary for which you wish to generate transect lines.
2. Specify the minimum and maximum length of the transects to generate. The 'Generate Transect Lines' process attempts to draw transects to the maximum length first and if the resulting transect is invalid (falls within excluded areas or outside the survey boundary) the 'Generate Transect Lines' process will then attempt to draw the transect line at the minimum length. If the transect cannot be drawn at the minimum length, the random point used as the point of origin will then be marked off as abandoned by setting the 'HasTransect' field of the random point feature to 'N'.
3. Specify the number of transect lines to be generated. An observer can only create as many transect lines as there are random points. If the *# of Transects to Generate* field is

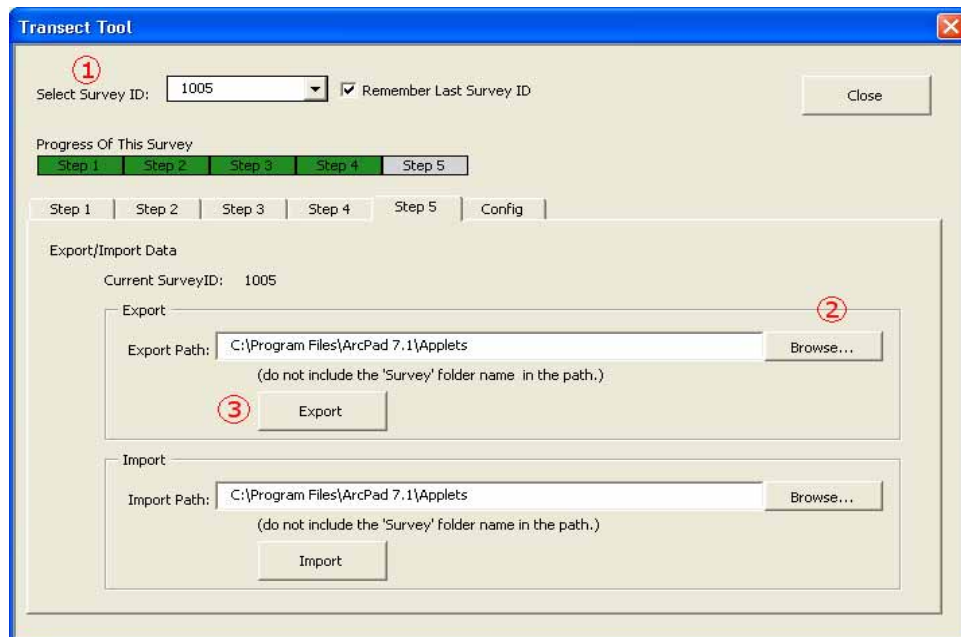
left blank, the 'Generate Transect Lines' process will attempt to generate transects for every random point for the selected SurveyID.

4. Check the *Replace All Transect Lines for This Survey* box if you wish to delete existing 'Transect Lines' polygons for this SurveyID.
5. Click the 'Execute' button to run the 'Generate Transect Lines' step. The resulting polygons will be stored in the 'TrnOrig' FeatureClass ('Generated Transects' layer in the NPS_Transect_Tool MXD file).



Step 5—Export Data: After successfully generating transect lines for a particular SurveyID, these transects may now be exported. The 'Export/Import Data' tab is where the transects can be exported to Shapefiles and the data collected in the field can be imported into the geodatabase.

1. Pick the *Select the SurveyID* number of the survey boundary for which you wish to export data.
2. Click the 'Browse' button next to the *Export Path* field and navigate to the path of the storage device you wish to export to. Click the folder to select it. The path to the folder should now be set in the *Export Path* field.
3. Click the 'Export' button to export the data folder to the specified device or location. The data folder is named 'Survey' and includes the following:
 - 'TrnOrig' shapefile: Has all the transects for the SurveyID that was selected.
 - 'animals' shapefile: An empty shapefile for storing animal sightings.
 - 'Track Log' shapefile: An empty shapefile for storing the actual transect flight path.
 - 'Horizon' shapefile: An empty shapefile for storing horizon marks for animal sightings.
 - 'GPSPointsLog' shapefile: An empty shapefile for storing all GPS points obtained during the entire flight.
 - APL files for each of the shapefiles mentioned above. These APL files contain the symbology for displaying the shapefile features. This includes not only the colors but the symbols used to represent the shapes.



2.3 Installation of the Arcpad Survey Applet

Ensure that ArcPad 7.1 (ESRI, Inc., Redlands, CA) is installed on all laptop computers and that the registration number was entered.

2.3.1 Animal Marking Applet Folder Contents

The Animal Marking ArcPad applet can be found in the 'Animal Tracking ArcPad Applet' folder. The contents of the folder include the following:

- Image Files: These image files are used for the various button icons through the applet.
- Application Files: The files NPSApplet.vbs, NPSApplet.apa and NPSHelper.vbs contain the actual Animal Tracking applet.
- Survey Folder: This folder contains the output shapefiles (more on these later) from the Transect Generation tool.
- DBF files: The 'Point Log' DBF file is used to backup GPS points per transect segment. The 'default values' DBF stores application data.

2.3.2 Animal Marking Applet Installation Steps

There are four steps to installing the Animal Marking applet.

1. Navigate to ArcPad's 'Applets' folder which is in the ArcPad application folder (e.g. path 'C:\Program Files\ArcPad 7.1\Applets'). Please remove any existing Applets and/or other content from this folder.
2. Copy the 'ArcPad Survey Tool' folder's contents to ArcPad's 'Applets' folder.
3. Start ArcPad and ensure you can now see a toolbar with the text 'NPS Animal Marking' visible. This indicates that the installation was successfully.
4. The Animal Marking applet also comes with the well known ArcPad FakeGPS extension. To install the extension, simply copy the 'Fake GPS Extension' folder's contents to the

ArcPad's 'Extensions' folder which is in the ArcPad application folder (e.g. path 'C:\Program Files\ArcPad 7.1\Extensions').

2.3.4 Laptop Setup

Laptops used in aerial surveys should be set up in the following manner.

1. Any screen saver was turned off and power conservation settings are changed so that the monitor and hard drive would not turn off due to inactivity.
2. Test the ArcPad set-up by connecting a GPS receiver running in simulator mode to the laptop, then running an ArcPad session to test the custom survey applet (testing can include simulated transects and recording of hypothetical sightings). The GPS was turned on only after it was connected to the laptop because the computer sometimes otherwise misinterpreted the connection as an external mouse, which resulted in erratic uncontrollable mouse cursor movements.
3. Attach summary instructions sheet to laptop (Figure A2.1)

2.4 Preparing Maps

Once the transect selection process is completed, the next step is to generate maps of the survey routes. Prepare layouts in GIS and print the appropriate number of maps needed for the survey effort. This number may vary depending on survey and project leader requirements. Generally, two sets of maps will be needed for each transect set per aircraft and a wall map depicting each transect set will be needed as well.

The 11x17 maps of the study area and survey transects are used by observers and pilots to navigate and monitor completion of transects. Wall maps are useful for viewing the overall study area at base camp, planning daily survey flights, and recording transects completed. The 11x17 map set subdivides the study area into a workable number of extents with slight overlap making them useable in small aircraft. Use the ArcGIS bookmark feature to save view extents for repeated use. For each transect set, a plotter-sized wall map layout is created in ArcGIS. Lists of transects by transect set are produced from the transect shapefile attribute table and printed for survey crews. These provide starting and ending points to use in navigating to and beginning the survey of the transects.

2.5 Data Management

Prior to the surveys, a Microsoft Access database should be created based upon the compiled transects tables, manually added transects, and random points included. This facilitates tracking the completion of transects during the surveys. Fields in this database table related to surveyed transects should be reviewed at the end of each survey day. This helps prevent resurveying transects and minimizes daily coordination time of the flight crews.

- Power PC & Log on as: _____
- Attach and Turn on GPS; check battery power
- Start Arcpad
- Click  for Take Off/Load Map
- On Take Off tab select “SurveyID number, pilot, observer...”
- On Animals tab select appropriate species
- Click  to activate the Select Transect feature
- Click on a transect to select it, enter direction viewing, weather
 - Click  to start transect
- Switch view side as needed
- Animal sighting occurs, turn on signal light, check partner's, note horizon
- Click  to mark animal
- Mark horizon
- Return to where you departed the transect and resume
 - Click  to end transect
- Click  to land and end session

Figure A2.1. Summary ArcPad survey instructions that should be attached to each aerial survey laptop computer.

Training Observers

Standard Operating Procedure #3
Version 1.0 (7/14/2009)

Kellie Peirce
Fairbanks, Alaska

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

3.0 Introduction

This SOP describes training procedures for personnel conducting aerial surveys for monitoring brown bears in SWAN park units. Personnel will be familiar with the brown bear protocol narrative and SOPs. The use of aircraft within the National Park Service is managed by the Department of Interior, National Business Center, Aviation Management Directorate (<http://amd.nbc.gov/akro/index.htm>). Survey personnel will complete safety training as well as data collection training to comply with quality assurance protocols. Fulfilling safety training requirements will aid in maximizing safety during survey operations; safety is the most important aspect of conducting aerial surveys for monitoring brown bears in SWAN parks. Aerial wildlife surveys are one of the more dangerous occupations for wildlife biologists (Sasse 2003). With this in mind, survey operations will be conducted with safety as the top priority in decision making processes.

3.1 Safety Training

3.1.1 Required Safety Training

B-3 Basic Airplane and Helicopter Safety (8 hours): This class is for those people who have not had previous aviation safety training. Personnel who participate in Special Use flight activities (e.g., flights lower than 152 m [500 ft] Above Ground Level [AGL]) or function as aircrew members (e.g., observe, photographer, radio tracker, survey recorder) must take this class before flying. DOI bureau employees, except USGS, are required to take their initial B3 training in the classroom. Class schedules and locations can be found at https://www.iat.gov/Training/course_list.asp.

B-3 Refresher (8 hours): Employees who have completed the Basic class are required to take a refresher class every 3 years. Topics covered will be similar to the Basic class, but in more specific detail and includes updated aviation safety and policy information. The B-3 Refresher may be completed online at <http://www.iat.gov>. Five modules are required for the B3 online refresher course:

- A101 Aviation Safety
- A105 Aviation Life Support Equipment
- A106 Aviation Mishap Reporting
- A108 Preflight Checklist & Briefing/Debriefing
- A113 Crash Survival

3.1.2 Additional Safety Training

- DOI Underwater Egress (Dunker) Training
- Bear and Firearms Safety Training
- CPR/1st Aid/Wilderness Safety

The project leader must have a basic understanding of aviation management including the use of personal protection equipment (PPE), aircraft contracting, and pilot flight time and duty time limitations. PPE should be available for all persons who fly in the aircraft. The project leader will review the following Department of Interior Manuals and Handbooks, which can be downloaded from <http://amd.nbc.gov/library/index.htm>.

- Departmental Manual (DM) Parts 350-354- Aviation Management
- Aviation Life Support Equipment (ALSE) Handbook

3.1.3 Pilots

Pilots will be required to possess a current Office of Aircraft Services (OAS) certification. Ensure pilots have this certification by checking their OAS card and expiration date. Pilots with an OAS certification have taken additional training and flight exam specifications that are more restrictive than FAA requirements for commercial pilots and therefore have met all other required government certifications and requirements. Local OAS contract aircraft and pilot sources can be found at <http://amd.nbc.gov> under the *Aircraft and Pilot Sources* link.

3.2 Data Collection Training

Typically the project leader will conduct training related to data collection or will designate a team member who is qualified to perform the training. All personnel involved in aerial survey flights will receive data collection training. The data manager will train the project leader to ensure established data quality and verification procedures are followed throughout the survey period and beyond. These procedures are detailed in the Southwest Alaska Network (2006) and discussed further in SOP #6.

Personnel involved in pre-season logistics and field preparation will be trained in transect selection procedures, map creation, GIS, and data management. This will typically be conducted by the project leader or other qualified staff member.

3.3 Survey Technique and Protocol Review

Each team member, including pilots, will review the brown bear protocol narrative and SOPs. The basic survey protocol will be reviewed by survey teams during a pre-survey briefing. A survey methods handout will be provided to crew members and should be available to the observer while in the aircraft. This handout lists general pilot and observer instructions, and the ArcPad program setup and operation instructions.

All team members will review the survey aircraft curtain and light box system procedures to ensure independent double count data.

All team members will review collection of bear sighting covariate data.

- Review proper identification of bear species and sex and age classification.
- Bear location should be marked where the bear was first observed.
- Record covariate data (activity, percent cover and percent snow) where the bear was first observed.
- Estimate percent snow and cover within a 9 m (30 ft) radius of bear. To determine what a 9 m radius looks like from the airplane, place a 189 liter (50 gallon) drum in the center of a 9 m. radius circle made with bright orange paint on the edge of a runway or in an open field. Fly over the circle several times at 91 m (300 ft) AGL. During surveys, use the percent cover diagram to estimate percent cover around the bear as required by the data sheet.

- Marking of the horizon (effective sighting distance) should be explained and discussed with all survey members present so that everyone is interpreting this variable in the same way.

Review use of GPS and proper settings. Provide user manual associated with the particular GPS unit.

Review specific operation and use of the ArcPad Animal Marking applet to collect data during survey flights. The following laptop computer training will detail common functions used to perform data collection procedures during aerial flights (see SOP #2).

- Run the ArcPad applet in an office setting by connecting a GPS receiver to a laptop computer and set the GPS to run in simulator mode. Turn on the computer and use the survey methods handout to run through the ArcPad program setup and operation instructions using the pre programmed function keys or screen displayed buttons to fly hypothetical transects and record hypothetical bear sightings.
- Following the office training, each survey team member will complete a practice aerial survey flight with an experienced pilot to gain familiarity with data collection procedures while in the air. The paper data form should also be used during this practice session

3.4 Use of Paper Data Forms

Training in use of data forms will detail how and when to use these forms. Most data are entered through the pop-up windows associated with the ‘transect set up’ and ‘add animal’ icons or function keys while running the ArcPad applet on the laptop computer. Paper data forms will be used as a back-up in the case of a laptop failure, or to note that a mistake was made while entering data in ArcPad. In situations where many bear sightings occur within a small area (i.e., coastal bear aggregation areas) sighting covariate data can be recorded primarily on paper data forms to expedite data entry if preferred. Observers **must** note on the paper data forms when this occurs and that the paper data form is the primary record. In previous survey efforts, some observers used data forms to record data or used a combination of the laptop and data forms. Training will emphasize the use of the laptop computer as the primary data collection tool. Data forms should be used when necessary, but minimally, to reduce transcription errors and time it takes to verify data at day's end.

3.5 Pilots

The project leader will review survey flight compliance procedures (listed in SOP #1) with pilots. The review will stress the importance of flight procedures that maneuver the aircraft to minimize disturbance to bears and other wildlife. Experienced pilots who perform wildlife surveys have advanced training and many hours of flight time and therefore will already be familiar with these flight procedures. This is of particular importance to the SWAN brown bear survey methodology and statistical model assumptions that require bears to be accurately recorded at their initial locations (i.e., locations of detected bears are recorded prior to responsive movements to aircraft noise or presence, SOP #5).

Literature Cited

Sasse, D. B. 2003. Job-related mortality of wildlife workers in the United States, 1937-2000. *Wildlife Society Bulletin* 31:1015-1020.

Aerial Survey Flights

Standard Operating Procedure #4
Version 1.0 (8/5/2009)

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Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

4.0 Introduction

This SOP explains the processes for collecting and recording data during aerial survey flights for monitoring of brown bears in SWAN parks. Computer/program requirements include: Windows XP with minimum 128 MB RAM and 100 MB free hard disk space; ArcPad version 7.1; and base maps of survey area, study area or park boundaries.

4.1 Conducting Aerial Surveys

There are four main steps to completing aerial survey flights (Figure A4.1). A typical aerial survey flight starts by navigating to the pre-selected transect. The observer will start the laptop computer, the GPS and related software while en route to the survey transect. The pilot will navigate to the survey location, which can take between 15 minutes to over an hour to reach depending on location of departure relative to survey area.

When the aircraft reaches the beginning of the survey transect, the pilot will follow the pre-determined survey route. The observer and pilot will start looking for bears once the pilot begins flying on the survey transect. When a bear (or bear group) is sighted the pilot, observer, or both activates their light switch to indicate to the other that a bear has been observed. The aircraft will leave the transect and will fly over the bear for the observer to record its location and relevant data collection (see below section on *Starting and surveying a transect*, step 14). The plane will then return to the transect departure point and will resume the survey along the designated transect.

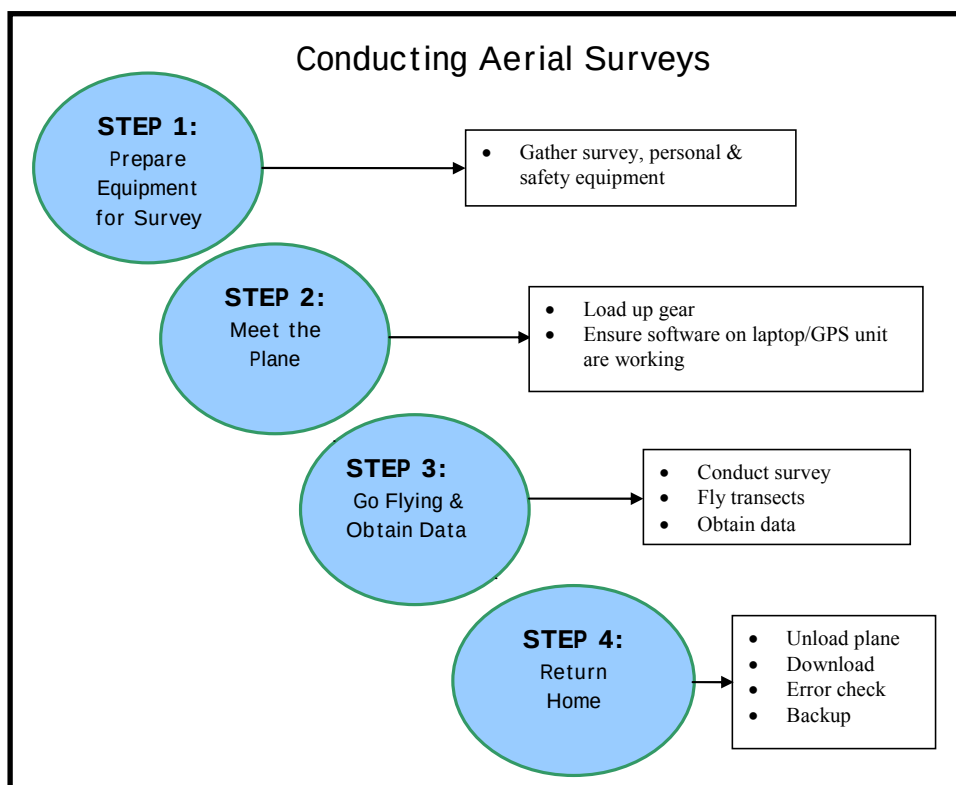


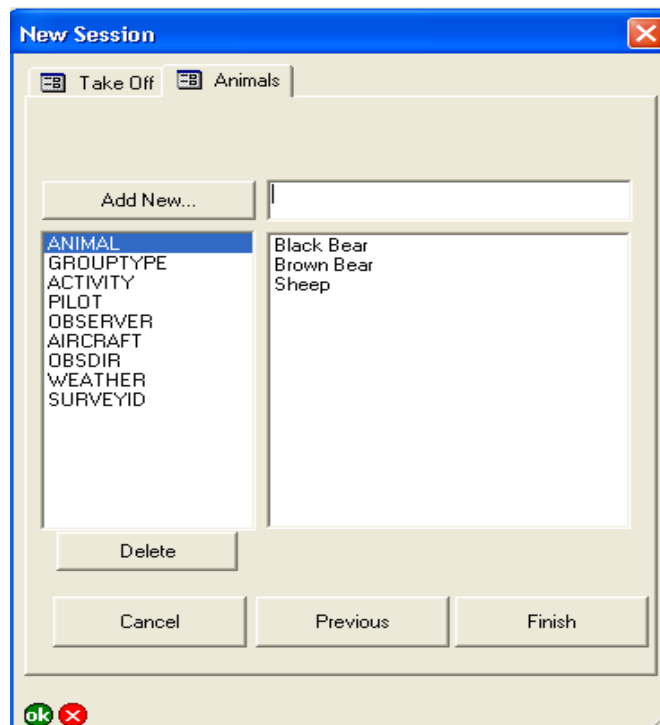
Figure A4.1. Steps in conducting aerial surveys of brown bears.

4.1.1 Procedures for Using Laptop Computers

Data will be collected with laptop computers during aerial surveys. We will use a bear survey applet in ArcPad that is loaded onto the laptop computers. Order of surveying transects will be determined by logistics, weather conditions, aircraft safety, and perceived movements of bears during the survey period. Care will be exercised to avoid confounding of bear movements with spatial ordering of surveyed transects.

4.1.1.1 Getting Started:

1. Use duct tape to connect the computer to the battery via the DC adaptor. Connect the cable from the GPS to the PC via the serial port. Attach the antenna to the GPS. The antenna is placed in a location with a clear view of the sky, typically on the crossbar overhead. Turn on the computer.
2. Turn on the GPS (be sure to start the computer first).
3. Double click on the ArcPad shortcut on the desktop to open the program.
4. Set up a new session using Take Off/Load Map  button.
 - a. Select survey number.
 - b. The pilot and observer names are entered from the lists.
 - c. Select aircraft from pick list.
 - d. Select weather from pick list.
 - e. Click Next.



5. Customizing the pick lists.
 - a. The second tab, called the 'Animals' tab, allows the observer to append list options to the various pick lists used in the Animal Mark form and through the applet.

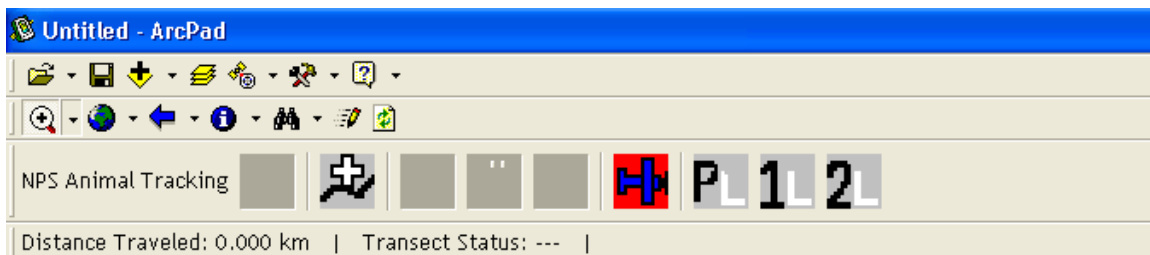
- b. To add a new list option, select the list to be appended to from the right, enter the text for the option in the Add New field and then click the Add New button.
- c. To delete a list option, select the list to be appended to from the right, select the list option to the left and click the Delete button.
- d. Click Finish to complete the Load Map step.

The 'New Session' dialog box contains the following fields and values:

- Survey Number: 1005
- Flown Date: 4/6/2009
- Pilot: Molly
- Observer One: Ravariere
- Observer Two: Bush
- Aircraft: FF4345
- Weather: Overcast

Buttons: Cancel, Next

4.1.1.2 Select a Transect: After completing the New Session form, the Select Transect (gray background) button will become available. The Observe Direction buttons will also appear, which will allow the observer to toggle the observing direction of the pilot and observer(s). The button PL will become PR when clicked which indicates the pilot has now switched from observing out the left side of the plane to observing out the right side. The other two buttons, 1L and 2L, will also change the observing direction (1R and 2R) for observer 1 and, if a second observer was set on the New Session form, observer 2.



To select a Transect, click on the Select Transect (gray background) button. The Select Transect (gray background) button's icon will change to (green background) to indicate it

is now active. Clicking on a Transect will select that Transect, zoom to it and open the New Transect form.

The New Transect form allows the observer to further edit the pilot and observer(s) observing directions as well as set the current weather. Click Finish to complete the Transect setup or Cancel to select another Transect.

4.1.1.3: Starting and Surveying a Transect:

1. After completing the New Session form, you will be able to select a transect.
2. To select a transect click on the Select Transect  button which will turn green  to indicate it is active.
3. Clicking on a transect in the map will select that transect, zoom to it and open the New Transect form. The New Transect form allows the observer to further edit the pilot and observer(s) observing directions (select the uphill side) as well as set the current weather.
4. Click Finish to complete the Transect setup or Cancel to select another Transect
5. After completing the New Transect form, the Start Transect  button will become available.
6. Upon starting a Transect, the Mark Animal  and End Transect  buttons become available while the Start Transect , Take Off /Load Map  and Select Transect  buttons are disabled.
7. Look out the uphill side of the window for bears. Both pilot and observer look out the same sides to ensure obtaining good double- count data. If making a turn in a canyon, look out the downhill side. Make sure to click the pilot and observer observing side

buttons to change sides in this situation. In flat terrain, the viewing side is determined by a coin flip, the seconds on a watch (e.g., 00-29 as right, 30-59 as left), or something similar.

8. After sighting a bear (or group), wait for 5 seconds after the group is beyond the front wing strut of the aircraft and then turn on the light to indicate a sighting.
9. Look at the light to see if the other observer has detected the bear.

New Transect

Transect Number: 2005

Observer	Direction
Pilot	**Left** Right
Ravariere	**Left** Right
Bush	**Left** Right

Weather:

10. Announce your bear sighting.
11. Note which observer saw the bear (or note both if both observers did).
12. Click the Mark Animal  button to move the applet from On-Transect mode to Off-Transect mode. The Mark Animal form will automatically open. A green line will appear showing the on-Transect flight path from the point the Start Transect  button was clicked up until the observer went Off-Transect.
13. The pilot will now fly off the transect over the bear and parallel to the transect line (when safety permits). Click the Mark Animal button to mark the location where the bear was initially observed in the GPS data. This point will later be used to calculate perpendicular distances.
14. Record the following covariate information in the computer on the Mark Animal form and on the paper data forms.
 - a. Bear species (brown or black bear in areas where both occur).
 - b. Group size (number of bears detected at this location).
 - c. Group type (adult-AdultUnk, boar-LrgMale, subadult-AdultSub, female with yearling cubs-FemaleWY, female with cubs of the year-FemaleWC, female with 2 year old cubs-FemaleWY2, breeding pair-Breeding).
 - d. Activity (bedded, sitting, standing, feeding, walking, running).

- e. Percent vegetation cover around the bear or site where it was initially observed (10 m radius). First consult the cover diagrams (see section below).
 - f. Percent snow cover around the bear or site where it was initially observed (10 m radius).
 - g. Which observer detected the bear (pilot, backseat observer or both).
15. Next, an overflight will be made to record the location of the farthest distance that was actively searched (termed horizon location, which will yield the 'effective distance or search distance'). Click the Mark Horizon button to mark this location. In flat terrain, if the horizon location is beyond the maximum observation distance (as determined by analysis of the survey data), then the maximum observation distance will be used.
16. If the horizon is the same as a previous sighting (as can be the case when many bears are concentrated in a salt marsh), click the Use Last Horizon button.

Untitled - ArcPad

NPS Animal Tracking

Distance Traveled: 1.344 km | Transect Status: Off

55°34' 130°40' 3D

Mark Animal

☐ Clear Last Selection

Species: Black Bear, Brown Bear, Sheep

Animal ID: 2

Group Size: 1

Group Type: Female w/ older than yearling(s), Adult-sex unknown, SubAdult-sex unknown, Large Male, Female with cubs/calves, Female with yearling(s), Female with qt yearling(s)

% Cover: 60 % Snow: 60

Activity: Bedded Down, Feeding, Running, Standing, Sitting, Walking

Who saw it?: Pilot

Repeatability Assessment: 9

Buttons: Mark Animal, Prev, Next, Update Position, Mark Horizon, Update Horizon, Use Last Horizon, Hide Form, Resume Transect

17. Other features on the Mark Animal form include:
- a. 'Prev' and 'Next' buttons: These allow the observer to select and edit any other animal mark created on the current off-transect segment. The newly selected feature can be identified by the light blue square around it. The options that were selected for that shape will be reloaded and any changes will be automatically saved by either

creating another animal mark, navigating to another existing one or by simply closing or pausing the form.

- b. 'Update Position' button: This button will adjust the location of the currently selected animal mark to the current position of the GPS device.
 - c. 'Update Horizon' button: This will update the position of the Horizon set for the currently selected animal mark to the current position of the GPS device.
 - d. 'Hide Form' button: This button allows the form to be hidden so the map may be accessed for zooming and panning. During hidden state, the only button available is the 'Mark Animal' tool button which is used to restore the form.
 - e. 'Clear Last Selection' checkbox: When unchecked, the form options will not be cleared when 'Mark Animal' is clicked to create a new animal mark. This allows the information entered for the previous animal mark to be reused for the current animal mark. When checked, the form options will clear each time a new animal mark is created.
18. The plane will now return back to the survey transect to a point just prior to its departure location. Click the Resume Transect button to continue the transect. A read dashed line will now be visible indicating the path flown from the moment the plane went Off-Transect up until the observer clicked the Resume Transect button.

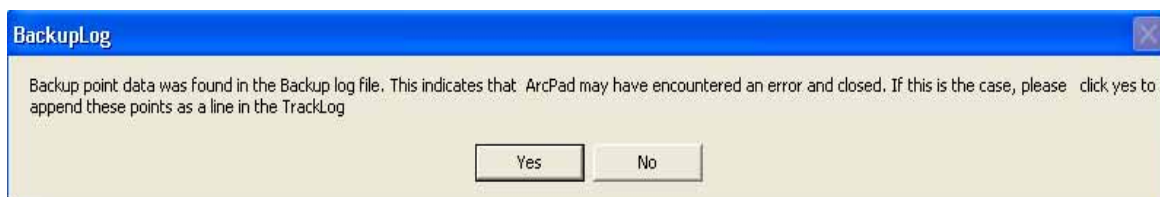


19. Continue along the survey transect recording the above information upon detecting a bear (or bear groups).
20. At the end of the transect, the observer must then click the End Transect  button to mark the Transect as completed.
21. The Transect will change to a gray line to indicate that it has been surveyed. The Start Transect  and Select Transect  buttons will be restored to allow the observer to select and start flying another Transect.
22. If the transect is shorter than the pre-determined desired length, after completing the segment depicted on the map, select "off transect", navigate to nearby equal elevation habitat, select "resume transect", and complete the transect.

23. When the observer is through flying Transects for this flight, the pilot will return to the air strip. When the pilot lands, the Land  button must be clicked to signal to the Mark Animal applet that it should stop tracking the GPS flight path. It is now safe to close ArcPad.

4.1.1.4 Percent Cover Diagrams: Results from previous surveys suggested percent cover near the bear influenced its detectability. Percent vegetation cover is estimated by comparing the cover around a sighted bear with a digitized cover diagram of bears in 10, 20, 30, 40, up to 80% cover. The observer first consults the diagram (Figure A4.2) before classifying the cover to the closest 10% around the bear (or group). Cover percentage was calculated by a pixel count of vegetation in the diagram and all the percentage diagrams are accurate to within 0.5%.

4.1.1.5 Restoring Segment if ArcPad Fails: When the user begins an Off-Transect or On-Transect segment, the GPS points being collected are not only stored in memory but are being backed up in a DBF file called PointLog. In the event ArcPad crashes while a Transect is being surveyed, the segment may be generated from the backup points up to the point when ArcPad crashed.



To restore the segment, simply restart ArcPad and click the Take Off /Load Map  button. The Mark Animal applet will detect backup points in the DBF file and offer to restore them as a segment. Choose 'Yes' to restore the segment or 'No' to clear out the points from the log. To resume flying the Transect, fly to the end of the restored segment, select the Transect, and then click the Start Transect  button. If the crash occurred during an off-Transect segment, clicking the Start Transect  button will automatically open the Animal Mark form.

4.1.2 Important Notes

1. BEFORE you fly the next transect, click on the Select Transect  button to allow the selection of a new transect.
2. Before you take a lunch break or at the end of the day, click the Land  button to end the flight path tracking by the GPS. Shut down ArcPad and turn off the computer and GPS to save battery power.
3. Bears initially detected while off-transect to locate a detected bear or bear group should be recorded but should not be included in the estimation of detection.

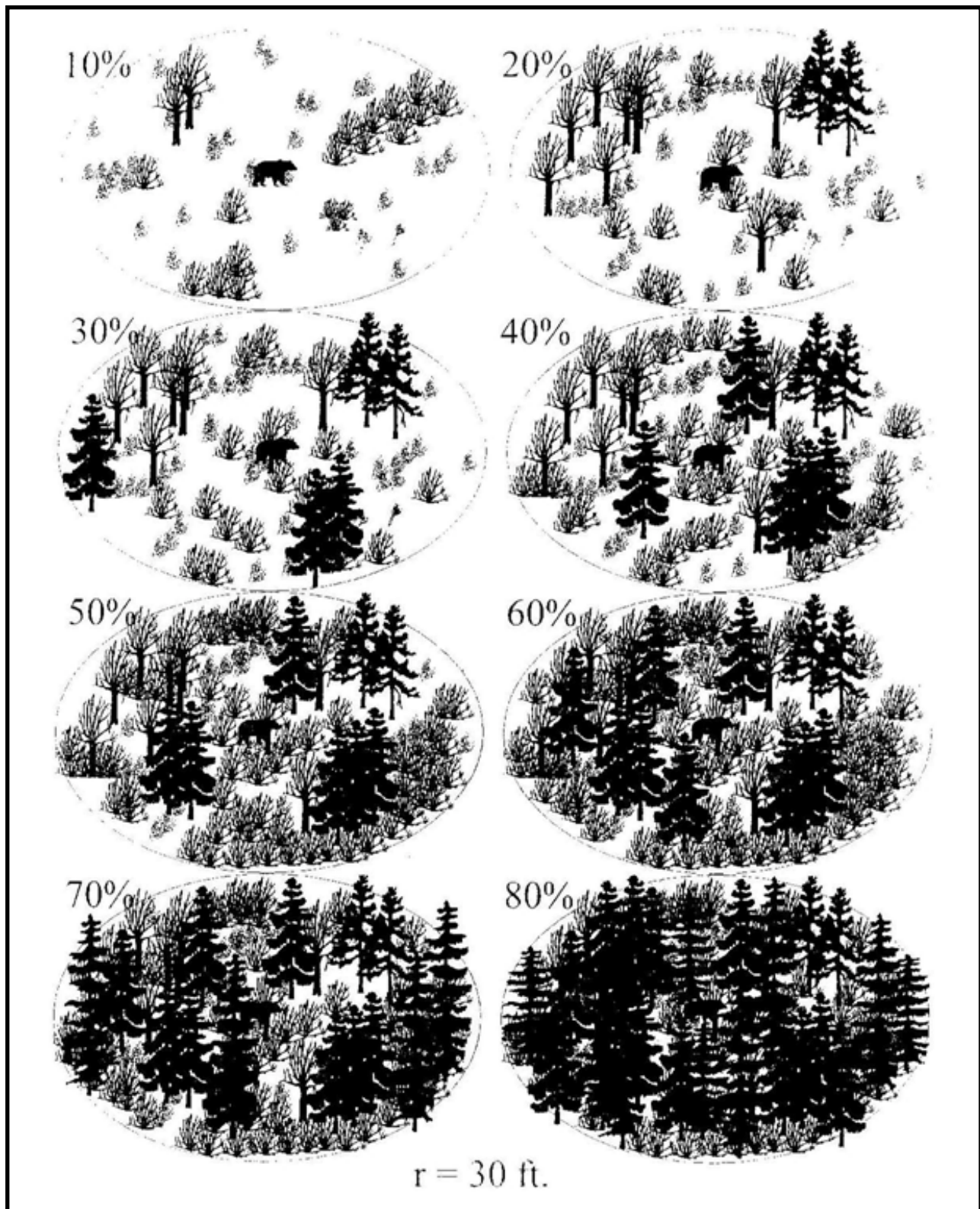


Figure A4.2. Diagram used as a guide to estimate percent cover of vegetation during brown bear aerial surveys (from E. Becker, ADF&G, Unpublished report).

4.1.2.1 Pilot Instructions:

1. Pilots will fly aircraft 91 m (300 ft) AGL. Adjust the plane distance from the mountain slope to obtain a sufficient view of the area represented by the line (contour) on the map (approximately 75 m [246 ft] from the plane on the horizontal axis).
2. Pilots who see a bear or bear group will:
 - a. Toggle their light button ON.
 - b. Wait until the animal is 5 seconds past the trailing edge of the wing.
 - c. Check the observer's light (always before the next step).
 - d. Inform the observer of the bear.
 - e. Avoid inadvertently alerting the observer to a bear sighting.
3. Pilots should not adjust the plane once a bear is sighted - this is a test of the observer.
4. Pilots will inform the observer of upcoming bank turns to provide forewarning that observations will soon occur out the opposite window of the plane.
5. When feasible, pilots will mark the bear location and horizon location with a parallel flight pattern relative to the transect for standardization purposes.

4.1.2.2 Other Things to Remember:

1. Carry extra AA batteries at all times for the GPS as a back-up precaution.
2. Test the GPS battery strength by selecting the PAGE button until the satellite page appears. Battery power is displayed on the left side of the page. Ensure battery power is above one-quarter power.
3. Check the GPS signal strength being received. Refer to the 'status field' in the satellite page. A "3D Nav" reading indicates sufficient signal strength for a three dimensional read from the satellites. The PDOP (Position Dilution of Precision) value can also be checked. PDOP measures the geometrical strength of the GPS satellite configuration. PDOP values less than 4 gives the best accuracy (under 1 meter), between 4 and 8 gives acceptable accuracy and greater than 8 gives poor accuracy.
4. Each time menu buttons are depressed (for transect actions or animal/horizon/markspots events), the GPS location associated with that depression is marked. The mark is placed at the instant the key is depressed.
5. Use the geometric center of a group to mark a bear group.

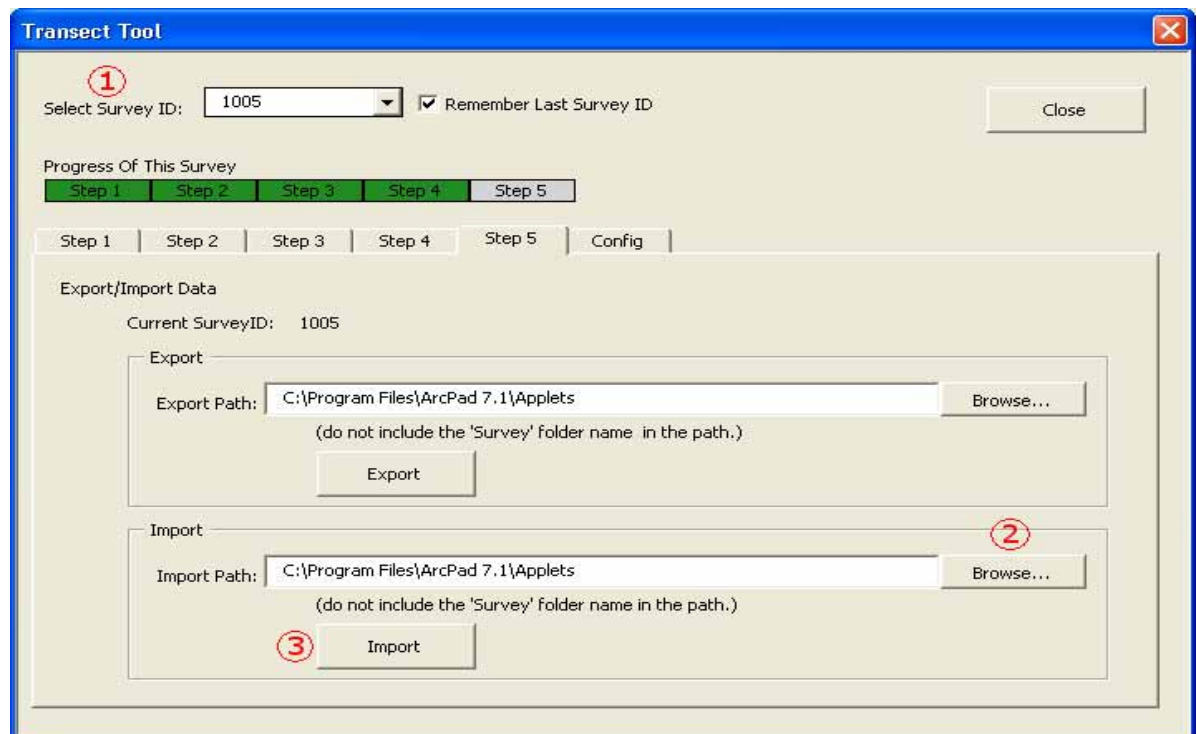
4.2 Daily Survey Data Review and Editing Procedures

Program and User requirements: ArcPad 7.1, ArcGIS 9.3, User should be versed in basic feature editing within the ArcGIS environment.

After Transects have been surveyed, the Shapefiles exported in the Export process should now contain data collected in the field. This import data may include: animal sightings, horizon markers, flight track log, GPS point log and updated records in the Transect Shapefile.

1. First 'Select the SurveyID' of the survey boundary for which you wish to import data.
2. First, click the 'Browse' button next to the 'Import Path' field and navigate to the path of the Survey folder. It's important to note that the Survey folder should not be part of the path – the import path should be the path to the Survey folder not the path to the Survey folder contents.
3. Next, click the 'Import' button to perform the import process. The import process performs the following actions:

- a. The import process will first ensure that all Shapefiles – ‘animals’, ‘Track Log’, ‘Horizon’ and ‘GPSPointsLog’ – are in the Survey folder.
- b. The import process will then determine the TransectID of the Transects that were surveyed and have data to import.



- c. The import process will determine if survey data already exist for any of the Transects and alert the observer. The observer will then have the option to abort the import process or override the existing data. If the observer chooses to override the existing data, then all existing data will be deleted for the Transects with existing data. The import process will then copy all the data from the Shapefiles into their corresponding FeatureClasses – the Shapefiles are named after the FeatureClasses from which they were generated.
4. Make a backup copy of the imported files and store by date and field computer.
5. Complete the initial data verification (cleaning the data) procedures suggested below on a daily basis. Typically, one individual (with GIS expertise) will need to be responsible for performing these tasks, working with the observers to ensure data accuracy:
 - a. Review the data captured in ArcPad (daily) from survey flights.
 - b. Review data entries on data forms daily (if they are used).
 - c. Review the downloaded data in ArcGIS 9.3. ArcPad outputs shapefiles (‘animals’, ‘Track Log’, ‘Horizon’ and ‘GPSPointsLog’) that are directly imported for manipulation. This must be completed for each ArcPad session.
 - d. Check that applicable information on the data forms are in the files. Make these checks using a copy of the original raw data file.

- e. Additional data editing and management tasks listed are from Olson and Putera (2007):
- i. Verify that surveyed transects and bear locations recorded on data forms are listed in the files. If they are not, enter the information.
 - ii. For each transect, select all records from all the survey shapefiles (animals.shp, effsite.shp, and transect.shp), then inspect the records in a view zoomed to the extent of the selected records:
 - Verify that corresponding on-transect segments, sightings, and horizons are numbered correctly (SurveyID, TransectID, and SegmentID are the same) and that this results in a unique combination for identification.
 - Edit survey shapefiles as per any notes written on the survey data forms.
 - Cross-check survey data forms with the shapefiles to verify that all sightings and transects listed on data forms are recorded in the shapefiles, and also to cross-check covariate information.
 - Review effective sighting distance (Horizon) locations relative to sighting locations to evaluate whether they appeared to make sense (an effective sighting distance location should not be closer to a transect line than the corresponding sighting location), and editing was done as needed.
 - Edit transect lines (displayed as DB Tracklog in ArcGIS) to delete off-transect segments as appropriate. This editing is done methodically for each sighting to be sure that editing is done correctly (for example, sometimes the recorder may have forgotten to mark “off transect” until after the plane had already left the transect line. In this case, the segment previous to the off-transect one is edited to delete the length of the segment that is actually off transect rather than on). Also, check off/on transect breaks in the transects for significant overlaps—generally, observers should try to minimize this issue, but sometimes segments overlap some, in which case one should edit the segment continuing along the survey line to eliminate the overlap.
 - Review sighting locations to verify that they were recorded while on transect (occasionally an observer may record a bear observation after passing the designated end length of the transect).
 - It is sometimes helpful to print maps of any sightings in question for the observer to refer to when discussing editing questions. Ideally, an effort should be made to consult observers regarding any editing questions before observer left to fly surveys the following day.
 - iii. Back up the edited survey data once editing work for a particular survey date is completed. This will be by date and field computer.
 - iv. While reviewing and editing survey shapefiles for a particular survey laptop, maintain a list for each transect recorded. Cross-check this list with the table for the Generated Transects shapefile. Resolve any inconsistencies. Once all survey laptop data are checked in, print reports as needed of cumulative transects completed, completed transects for a particular date, and transects remaining. The lists of transects remaining is especially useful for double-checking that transects marked as completed on wall maps are in fact completed, for specifically identifying quickly which transects still need to be

- surveyed, and for determining when new maps depicting remaining are needed.
- v. Prepare new maps that depict remaining transects as needed by working from the ArcGIS project files originally used to produce survey maps.
 6. Check the computer battery level and charge if needed.
 7. Check-off completed transects from wall maps to assist with the survey planning for the following day.

4.3 Exporting Data into ArcPad

After successfully backing up and editing the data collected during survey flights, the shapefiles are exported into ArcPad for data collection the following day. The 'Export/Import Data' tab is where the data generated is exported to Shapefiles.

1. First 'Select the SurveyID' of the survey boundary for which you wish to export data.
2. Click the 'Browse' button next to the 'Export Path' field and navigate to the path of the storage device you wish to export to. Click the folder to select it. The path to the folder should now be set in the 'Export Path' field.

3. Click the 'Export' button to export the data folder to the specified device or location. The data folder is named 'Survey' and includes the following:
 - a. 'TrnOrig' Shapefile-Has all the Transects for the SurveyID that was selected.
 - b. 'animals' Shapefile-An empty Shapefile for storing animal sightings.
 - c. 'Track Log' Shapefile-An empty Shapefile for storing the actual transect flight path.
 - d. 'Horizon' Shapefile-An empty Shapefile for storing horizon marks for animal sightings.
 - e. 'GPSPointsLog' Shapefile-An empty Shapefile for storing all GPS points obtained during the entire flight.

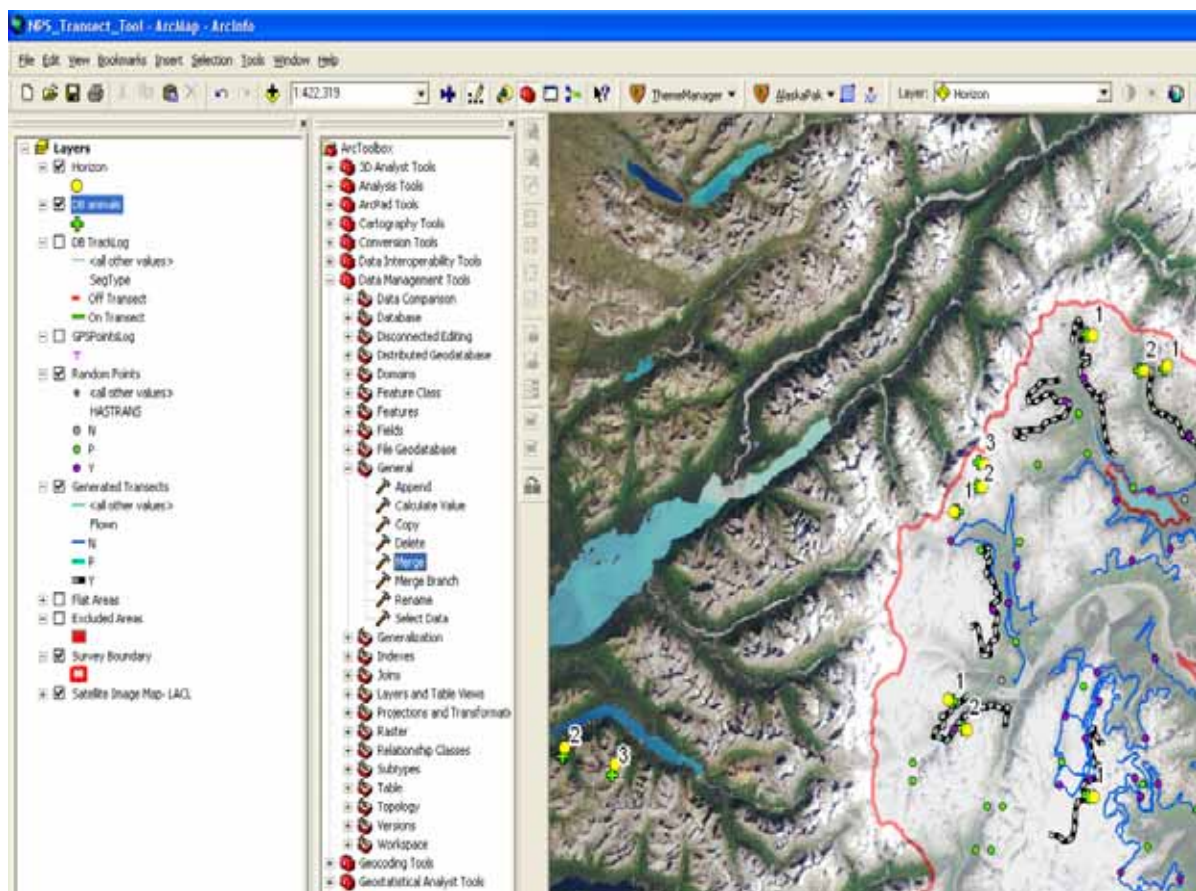
- f. APL files for each of the Shapefiles mentioned above. These APL files contain the symbology for displaying the Shapefile features. This includes not only the colors but the symbols used to represent the shapes.
4. The 'Survey' folder is then placed on the field computer as described in SOP #2 section 2.3, and it will be ready for data collection.

4.4 Post Survey Data Editing and Preparation for Analysis

After all survey flights are completed and data edited as described in section 4.2, data will need to be compiled, reviewed, processed, and exported for analysis.

4.4.1 Post Survey Data Editing

1. The three shapefiles 'Track Log', 'Horizon', and 'animals' from each field computer will need to be merged into one complete file for each feature (ie. 'Complete Track Log', 'Complete Horizon', and 'Complete animals'). The resulting files will contain all completed transects, animal sightings, and horizons collected during the survey.



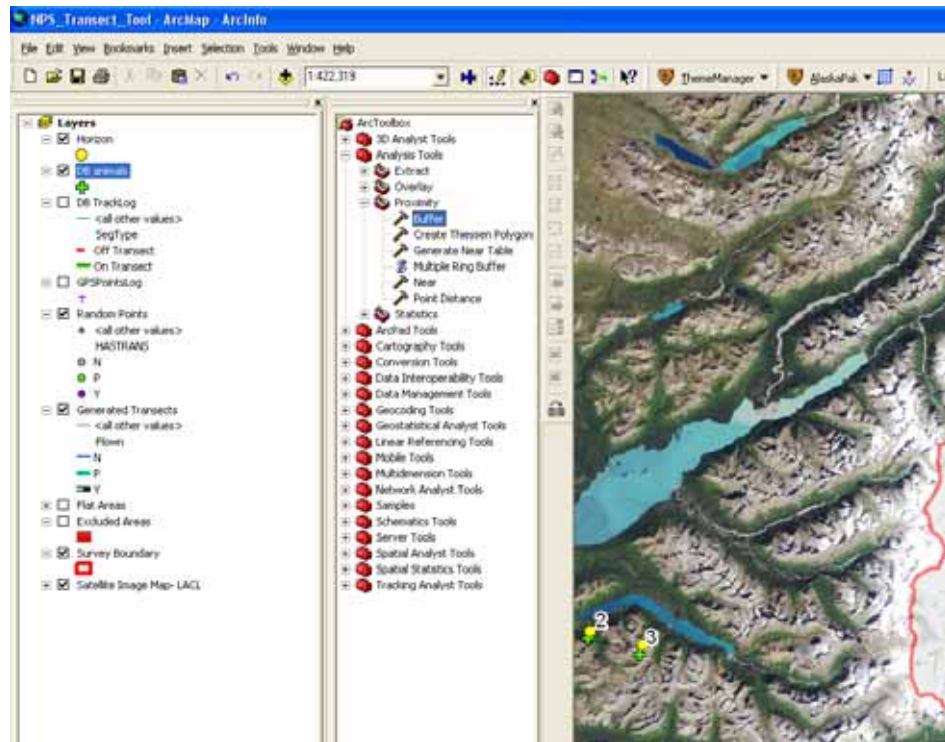
2. Covariate fields are checked for spelling errors and also for any duplicate transect numbers.

3. The merged files of sightings and effective sighting distance records are compared to verify that a corresponding effective sighting distance record existed for each sighting record.
4. The “DIST2TRANS” field in the compiled animals table and the “DistToSeg” field of the compiled Horizon table are examined to look for any unusual distances (such as distances less than the 22-m blind strip and exceptionally far distances; any such records are then reviewed/verified). In addition, the “DIST2TRANS” field value for each sighting record was checked to verify that it was less than or equal to “DistToSeg” value for the corresponding effective sighting distance record. Comparison of corresponding distances is most efficiently done in Microsoft Excel (working from the compiled dbase files from the shapefiles):
 - a. Sort the ‘Horizon’ records by “TransectID”, “SegmentID”, and “HorizonID”. Sort the ‘animal’ records by “TransectID”, “SegmentID”, and “AnimalID” number, then
 - b. Paste the “DistToSeg” and “HorizonID” fields from the ‘Horizon’ table and “DIST2TRANS” and “AnimalID” from the ‘animal’ table into a new worksheet in Microsoft Excel.
 - c. Subtract the “DIST2TRANS” value from the “DistToSeg” value and look for any negative values.

4.4.2 Post-Survey Processing of Final Edited Data

For data analysis, the biometrician or quantitative ecologist uses data records that include sighting records with corresponding effective sighting distance; transect records summarizing length flown for each surveyed transect and including corresponding buffer areas based on buffer distances specified. The following steps produce the data records formatted per the analyst’s specifications.

1. The ‘Complete TrackLog’ is buffered using the Buffer tool in the ArcToolbox of ArcGIS. Specific buffer distances are selected by the analyst (sometimes after initial analysis was performed on an initial data set). Buffering always included a 22-m buffer, which was the approximate blind strip below the aircraft. Additional buffers are generated at 600, 800, and 1,000 m. Buffer coverages follow a standard naming convention of transybnnnn, where yy = last 2 digits of survey year and nnnn = buffer distance in meters.



2. Buffer coverages are used to determine areas surveyed along the transects by following the steps below in ArcGIS:
 - a. Start an edit session for the buffer coverage.
 - b. Right-click the layer and click Open Attribute Table. You can only perform geometric calculations on attribute tables.
 - c. Right-click the field heading for which you want to make a calculation and click Calculate Geometry.
 - d. Click the geometric property you want to calculate. Different properties are available depending on the type of layer you're using.
 - e. Click to use either the coordinate system of the data source or the coordinate system of the data frame.
 - f. Click the units of the output calculations.
3. The tables for the buffer coverages, 'TrackLog', 'Complete Horizon', 'and 'Complete animals' are exported for use in preparing files for the data analysis software. The steps for this process are listed below:
 - a. Click on the Options button on the bottom toolbar of the table and select Export...

Table A4.1. Fields included in dbase files exported for data analysis.

Field name	Field definition
Transect Data	
TransNo	Transect identification number.
Length	Length of surveyed transect (m).
Area	Area surveyed along transect (based on various specified buffers).
Detected Object Data	
GroupID	Unique ID of each group of animals detected (note: group could equal 1).
OBS	Numerical ID of observer who detected the group of animals (i.e., 1 for Pilot, 2 for Passenger, or 3 for both).
DistanceOffTransect	Perpendicular distance (m) from the transect to the detected animal group.
TransNo	Unique ID of transect from which animal group was detected.
GroupSize	Number of animals within the detected group.
OtherCovariates	Additional covariates considered in fitting the detection function.

4. The data files for the exported buffer coverages and ‘TrackLog’ are used to make a file containing a list of transect numbers, along with corresponding lengths, and buffer area. This file represents the ‘Transect Data’ used in the analysis and require specific naming for each variable listed in Table A4.1.
5. The data exported from the ‘animals’ file are used for the ‘Detected Object Data’ file. The variables and their naming convention are listed in Table A4.1.

Literature Cited

Olson, T. L., and J. A. Putera. 2007. Refining monitoring protocols to survey brown bear populations in Katmai National Park and Preserve and Lake Clark National Park and Preserve. Alaska Region Natural Resources Technical Report NPS/AR/NRTR-2007-66, National Park Service, Anchorage, Alaska. Available from (<http://www.arlis.org/docs/vol1/227063700.pdf>). Accessed 9 July 2009.

Data Analysis

Standard Operating Procedure #5 Version 1.0 (7/29/2009)

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Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

5.0 Introduction

This SOP describes how to use the aerial survey data to estimate abundance and density of brown bears, a hierarchical modeling approach to estimate bear distribution and trends, and other analyses that will be used to summarize data. A general overview of the survey procedure is described in section 2 of the protocol narrative and in Becker and Quang (2009). An introduction to the theory and application of line transect sampling is provided by Buckland et al. (2001, 2004).

Required freeware programs and libraries:

- R (R Development Core Team 2009)
- GammaMRDS (Reynolds et al. 2009; Appendix B)
- R2WinBUGS (Sturtz et al. 2005)
- WinBUGS (Lunn et al. 2000).

5.1 Estimating Bear Abundance, Density and Distribution

5.1.1 Abundance and Density

Program GammaMRDS (Reynolds et al. 2009) will be used to convert observations collected during aerial surveys (SOP #4) into estimates of brown bear abundance and density for the areas of interest within SWAN parks. This program is written in R code (R Development Core Team 2009). The user's manual for GammaMRDS in Appendix B provides step-by-step instructions for installing the program and conducting an analysis. A copy of the program can currently be obtained either from Joel Reynolds (USFWS, Anchorage, Alaska; joel_reynolds@fws.gov) or from the SWAN Quantitative Ecologist (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=network_staff).

5.1.2 Distribution

As with abundance and density estimates, a robust estimate of spatial distribution of brown bears will require adequate correction for bears present but undetected along surveyed transects. A common approach to estimating spatial distribution of animals that adjusts for incomplete detectability is occupancy modeling (MacKenzie et al. 2006), but this requires repeated visits to the same sampling units (transects) during the survey period, which is not feasible within the budget constraints of SWAN's brown bear monitoring program. Instead, program GammaMRDS has been converted to a Bayesian hierarchical modeling framework (Royle and Dorazio 2008; Appendix D) and, once the minimum spatial unit for measuring adjacency has been defined, will be used to generate a surface of estimated bear densities covering the sampling universe. The minimum spatial unit will be larger than a transect and based on the average perceived movements of bears during the survey. Thus, spatial distribution will be represented as relative differences in density rather than in estimated occupancy. Note that occupancy is intrinsically linked to abundance and density (Royle and Nichols 2003, Dorazio 2007, Royle and Dorazio 2008). Bayesian hierarchical spatial models offer several advantages over traditional (strictly likelihood-based) models, including decomposition of the sources of variation into process and observational components, trend estimators that are often more precise (due to use of prior data and "shrinkage" induced by borrowing strength across all models [random effects]), and spatially explicit (sub-area) estimates of abundance or density.

Appendix D contains R code that fits the Becker-Quang model within a Bayesian hierarchical modeling framework (Royle and Dorazio 2008) to estimate trends in abundance and density based on the coefficient of a time (year) variable (and associated measure of precision) included in the hierarchical model. This code uses the R2WinBUGS library (Sturtz et al. 2005) so that the Markov Chain Monte Carlo (MCMC; Gilks et al. 1996) method required for this approach can be called from within R to run in the freeware program WinBUGS (Lunn et al. 2000). However, the Becker-Quang model used in GammaMRDS and in the R code in Appendix D is biased due to lack of independence in the double-observer component (e.g., see Buckland et al. 2010). A correction is under development and will be implemented in the next version of this protocol.

Users will continue to follow the analytical steps provided in the GammaMRDS manual (Appendix B), with additional steps describing how to use the Gelman-Rubin statistic (Gelman and Rubin 1992, Brooks and Gelman 1998) and visual inspection to assess proper convergence in MCMC chains, determining the appropriate "burn-in" for MCMC sequences (i.e., how many of the initial iterations to discard before convergence), and assessing goodness of fit of the model (in conjunction with the Bayesian P-value; Gelman et al. 2004). DIC (Spiegelhalter et al. 2002) will replace AIC or AICc (Burnham and Anderson 2002) as the model selection criterion. An option will be added for users to employ a conditional spatial autoregressive model to account for spatial dependence among transects (e.g., Webster et al. 2008, Johnson et al. 2010).

Bear density for each minimum spatial unit will be estimated using the Bayesian hierarchical modeling described previously. The following steps describe how this information will be used in conjunction with landcover data layers from SWAN parks to generate an estimated density surface of bears within the areas of interest.

- Define the minimum spatial unit of interest, which will be larger than a transect and based on the average perceived movements of bears during the survey.
- Use ArcGIS 9.3 (ESRI, Inc., Redlands, CA) to generate the spatial units throughout the area of interest (sampling universe).
- Use ArcGIS 9.3 to link all spatial units to existing landcover maps and associated data layers of SWAN parks. Data layers include landcover (vegetation) class codes, elevation and slope for each point in a grid with points spaced 50 m apart and overlaid onto each park (data are available from the SWAN Data Manager [contact: http://science.nature.nps.gov/im/units/swan/index.cfm?theme=network_staff]).
- In consultation with park and/or ADF&G biologists, develop two-four categories of slope and elevation thought to be correlated with bear distribution.
- Use the landcover data associated with each point falling within a given spatial unit to calculate its average percent landcover class, percent slope category, and percent elevation category.
- Export the resulting percentage data for each spatial unit as a DBF or other file format that can be read into R.
- Develop a set of candidate predictive models comprised of various combinations of percent landcover class, percent slope category, and percent elevation category, which will be used as potential predictors of brown bear distribution.
- Import the data into R and, with the R2WinBUGS library, use DIC (Spiegelhalter et al. 2002) to select the best-fitting model and use it as the final predictive model if it is clearly better supported than others. If no candidate model is clearly better supported than

others, a composite predictive model will be generated by model averaging across all models (Hoeting et al. 1999).

- Use the final predictive model to generate estimated densities of brown bears for unsurveyed spatial units. Categorize bear densities as desired and assign these categories to each spatial unit. Summarize the percentage of each density category (e.g., low, medium, high) across the area of interest.

5.2 Estimating Trends in Bear Abundance, Density and Distribution

Converting program GammaMRDS into a Bayesian hierarchical modeling framework for estimating spatial distribution of bears also makes seamless the estimation of trends in abundance and density. Hierarchical models allow both the estimation of bear abundance or density by survey and, by adding a time (year) covariate, an estimation of trend. The same approach can be applied to estimating trend in spatial distribution of brown bears, but requires the following additional steps.

- Use a time covariate in the Bayesian hierarchical model from section 5.1 to estimate trend in densities for each spatial unit (or, more likely, collection of spatial units).
- Based on the trend estimate and its precision, characterize each spatial unit (or collection of spatial units) as increasing, decreasing, or stable density. Note "stable" could refer to a stable density or to a relatively small change in density that is masked by the imprecision of the trend estimator.
- Tally the number of spatial units (or collections of spatial units) with increasing, decreasing or stable densities to quantify relative percentages across the area of interest.

A minimum of three complete surveys will be required to provide an initial estimate of trend, but more surveys will likely be needed before reasonably precise estimators of trend can be obtained.

5.3 Other Analyses

Other summary analyses include descriptive statistics such as means and standard deviations for particular variables measured during aerial surveys (e.g., bear group size, group composition, elevation ranges of recorded bear locations). An analysis of bear sighting rate per transect per day could indicate changes in timing of den emergence, both within and among years. Example summary tables are included in section 4.5 of the protocol narrative. Graphical analyses could include use of ArcGIS 9.3 to produce color-coded maps of relative densities of bears or of a composite change surface indicating spatially explicit (strip-level) increases, decreases or stable densities to quantify changes in spatial distribution of bear densities across time, much akin to change detection in a time series of vegetation images (e.g., Reed et al. 2006). Finally, estimates of trends in bear density or distribution could be evaluated within the context of visitor use or park management policies.

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Data Management

Standard Operating Procedure #6 Version 1.0 (7/29/2009)

Kellie Peirce
Fairbanks, Alaska

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

6.0 Introduction

This standard operating procedure (SOP) provides instructions for data entry, data validation, and administration of the monitoring data collected by the brown bear monitoring protocol for the Southwest Alaska Network (SWAN). This SOP has been developed following strategies and guidance for data handling and quality assurance/quality control as outlined in the SWAN Data Management Plan (Southwest Alaska Network 2006). Additional procedures for data management may be found in this plan.

Currently, data are managed using a variety of programs including MS Access, MS Excel and ArcGIS 9.3 software (including ArcPad 7.1; ESRI Inc., Redlands, CA). Of these, GIS software is the primary tool used for managing brown bear monitoring data. Some of the current brown bear databases will need to be adjusted to conform to these standards, including the development of an overall working database that incorporates all data output entities. This will be accomplished as part of the brown bear survey in Lake Clark National Park and Preserve (LACL) during 2010.

6.1 Data Stewardship Roles and Responsibilities

The purpose of data stewardship is to ensure information is organized, useful, compliant, available, and secure. Managing brown bear monitoring data appropriately requires a high level of attention to detail for all personnel involved with the monitoring protocol. This includes survey crew members, data entry technicians and project leaders in addition to the data manager. Personnel will perform specific tasks listed in Table A6.1, as well as communicate with and assist others in order to accomplish all required data management activities.

6.2 Database Design and System Architecture

The development of an overall working database that incorporates all data for brown bear monitoring needs to be developed. Programs used for various aspects of brown bear monitoring include: ArcPad 7.1 (data collection), ArcMap/ArcInfo 9.3 (transect development, map creation, data verification, spatial analysis), ArcInfo 9.3 with GRID (data editing, preparing files for statistician, spatial analysis), R (statistical analysis), MS Excel (various survey related files including field data form), MS Word (equipment lists, reporting) and MS Access (transect lists). These are described in more detail below. Suggested database design should follow guidelines outlined in Southwest Alaska Network Data Management Plan (2006).

6.2.1 Data Acquisition, Processing, and Workflow

6.2.1.1 Acquisition: Data are collected according to the SWAN Brown Bear Monitoring Protocol and the specifics described in SOP #4 (Aerial Surveys). Emphasis will be placed on obtaining legible and accurate data during the acquisition phase. This will be accomplished through thorough pre-season training and through data verification and validation processes to be described.

Table A6.1. Specific responsibilities related to data management for the brown bear monitoring program in SWAN parks (revised from Daley 2006).

Role	Primary responsibilities related to brown bear monitoring data management
Project Crew Member This is typically an observer on aerial flights who operates survey equipment, collects and enters data.	• Obtain training in data collection procedures and use of project equipment (on board laptop, GPS unit, etc.), data entry and data documentation. • Record measurements and observations based on monitoring objectives and protocols. • Verify recorded values daily. • Use field notes to document methods, procedures and anomalies. • Enter field data and documentation.
Project Leader/ Wildlife Biologist This is a member of the project crew with the same duties as other crew members as well as leadership responsibilities for field operations.	• Supervise and assist project crew members with training, briefings, data collection, management, verification and documentation. • Coordinate field and office operations including staff training, equipment calibration, data collection, and aspects of analysis and reporting. • Read and follow the SWAN brown bear monitoring protocols, standard operating procedures, and related operational guidelines.
Project Leader/GIS Specialist This is the individual responsible for reviewing, editing, and managing the data collected during the survey and processing the data for analysis post-survey.	• Enact and supervise data quality assurance measures related to data collection, entry, verification, validation, backing up procedures, and deviations from SOPs. • Maintain communication with all cooperating project staff on issues regarding the collection, quality assurance, processing and documentation of monitoring data. • Ensure the production, storage, and availability of data. • Act as the main point of contact for brown bear database content for the park.
Network Data Manager This is the individual who is responsible for data management oversight of the SWAN monitoring programs.	• Ensure that brown bear monitoring data are organized, useful, compliant, available, and secure. • Keeps SOP version information current in data dictionaries and data objects. • Assist crew personnel, project leaders/wildlife biologists, and other network and park staff with data management procedures and assignments to ensure that brown bear data collected by NPS staff and cooperators are entered, quality-checked, analyzed, reported, archived, documented, cataloged, and made available for management decision-making, research, and education and conducts related training. • Assign and oversee data stewardship responsibilities; ensure regular archival of project materials. • Ensure project documentation is complete, complies with metadata requirements, and enhances the interpretability and longevity of the project data.
Network Biometrician/Quantitative Ecologist This individual is responsible for overseeing data analysis and project design phases of SWAN monitoring.	• Review and analyze data resulting from brown bear monitoring. • Assist the project leader/wildlife biologist with information needs, monitoring objectives, and reporting requirements. • Perform data analysis in cooperation with project leader/wildlife biologist if pertinent. • Contribute to the reporting of status and trends for the brown bear vital sign.
SWAN Monitoring Project Leader for Terrestrial Wildlife This individual is responsible for overseeing monitoring of the brown bear vital sign.	• This individual works cooperatively with the project leader/wildlife biologist in cases where both positions exist. • Assist and oversee monitoring activities related to the brown bear vital sign. • Review and analyze data resulting from brown bear monitoring projects for compliance with stated monitoring objectives, information needs, and reporting requirements.

Data from brown bear monitoring efforts will be generated from the following general categories:

- Pre-season preparation
- Aerial surveys
- Post-season analysis
- Reporting.

Data types generated from brown bear monitoring (per survey year) include the following.

- GIS maps and related files for field season preparation (shapefiles)
- paper data from field data forms (MS Excel spreadsheet file)
- digital photos documenting general information related to monitoring efforts (jpeg files)
- data from computers and GPS units collected during aerial surveys (shapefiles)
- edited data files compiled into coverages for data analysis
- results from statistical analyses (post-season analyses including abundance estimation, modeling results, and associated figures and tables) (MS Excel files, MS Access files, R output files, shapefiles)
- data on bear location and distribution (shapefiles)
- reports and summaries (MS Word files, PDF files)

6.2.1.2 Processing: The following steps outline procedures for processing data acquired from brown bear surveys. Unless otherwise stated, the GIS specialist typically performs the following.

1. **Collect all data forms from crew members.** After completing aerial surveys for the day, ensure all crew members have checked their data forms for accuracy, clarity and completeness and then collect data forms.
2. **Review the data forms for clarity while on site.** Resolve any illegible or questionable data forms with the appropriate crew member.
3. **Download data collected during aerial surveys.** The GIS specialist will download the on-board laptop computers (and digital cameras if used) at the end of each survey day. Raw files will be backed up on a desktop computer and external storage devices. Back-up files will be stored in a safe location at base camp and an off site location when feasible. All files will be verified for accuracy and completion after surveys occur. Discrepancies or inaccuracies will be resolved with crew members on site. Data processing using AMLs will compile data, preparing it for final edits and input into files for data analysis.
4. **Photocopy the original data forms.** As soon as possible upon returning from the field, make a copy of the original field data forms. Review each copied data form for clarity and legibility. The copies will be used for data entry.
5. **Archive the original data forms.** Organize the original field data forms by date and survey area. Coordinate with the SWAN data manager for long term storage.
6. **Proof the photocopied data forms.** Review and proofread all the copied data forms as a group to ensure they make sense as a combined unit (e.g., all forms per surveyed transect for the day are present).
7. **Mark corrections on copied data forms with red pen.** Any corrected errors, or changes made by the data “proofer” should be circled and corrected using a red ballpoint pen. Notes, in red ink, should be written on the margins or in the comments section whenever necessary to document the reason for the corrections. Do not fully cross out or erase data on the data forms.

8. **Back-up all files on external media.** Once the proofing process has been completed, save the files onto back-up files on the SWAN “J” and “X” drives. A suggested back-up file name will consist of the project file name with an extra underbar (“_”) and 8 digit date (e.g., “SWAN_bear_YYYYMMDD.mdb”). The backend database file (if/when developed) will be saved onto a CD-ROM along with any additional pertinent files. The CD-ROM should be labeled “SWAN Bear database back-up,” or similar terminology, dated and placed in a secure location.
9. **Inform the data manager that data editing and processing for the current year is complete.**

6.2.2 Quality Assurance and Quality Control

Data verification and data validation are two processes used to ensure data quality assurance and control. *Data verification* checks that data entered into a secondary (e.g., electronic) format match the source data, whereas *data validation* checks that data make sense. Although data entry and verification can be conducted by personnel with a general familiarity of the data, the validation process requires in-depth knowledge about the project and data collected (Southwest Alaska Network Data Management Plan 2006).

6.2.2.1 Data Verification: The project leader is responsible for overseeing data verification of brown bear monitoring data (both physical and electronic sources). The purpose of verifying data is to reduce collection errors thereby enhancing accuracy of data and subsequent analysis and reporting.

Physical data (e.g., paper field data forms and notes) are verified for accuracy, legibility and completeness immediately after collection, first by the particular observer who collected the data, and then by the project leader. Verified physical data are entered, typically by crew members, into the database as soon after collection as possible (as described above). Project leaders then verify these data values entered in the database.

Field data for brown bear monitoring are collected during a short, but intense time period spanning 10-14 days/survey year. These verification requirements are for data generated during this period. Regularly scheduled data verification will occur throughout the year as necessary to ensure data generated from pre-season, post-season and analysis efforts are accurate and complete. The project leader will resolve any errors as soon as possible after these checks are performed following established procedures detailed in SOP #8 (Revising the Protocol or SOPs). These verification processes will facilitate timely database accuracy and annual reporting.

6.2.2.2 Data Validation: Prior to distributing brown bear data for any reason, the project leader/GIS specialist validates the brown bear database in their park’s master brown bear data file. Data validation involves conducting error checks on all data file components to ensure overall order and accuracy. Data validation will occur for each new batch of data to ensure accuracy for NPS internal uses as well as related area-wide projects.

Validation of project data by a project leader/wildlife biologist will be ideally completed by mid-January (or a later scheduled date if workload does not permit this) for data from the previous calendar year. If results are reported from data that have not been validated, a statement and explanation should be included to caution users regarding data quality.

Overall quality control procedures are outlined in Southwest Alaska Network (2006). Specifics related to brown bear monitoring are listed below and also are detailed in SOP #4.

6.2.2.3 Data Modifications; Additional editing of processed survey data will be accomplished by the project leader/GIS specialist. When possible, all changes to data will be documented in the edit log (within the database itself) and accompanied by an explanation that includes pre- and post-edit data descriptions. However, time constraints during the field survey period may preclude the project leader from entering edits in the electronic log. In these cases, edits should be made on hard copy data forms and later transferred to the electronic log. Allowable changes include those that improve or update the data formats while maintaining data integrity.

Computer file organization will be based off of the directory structure implemented in the Katmai National Park and Preserve (KATM) office in King Salmon and in accordance with guidelines in Southwest Alaska Network Data Management Plan (2006). An example of a project directory includes: name of project and year (PROJECTNAMEYR, C:/_laci9a03 where “laci” represents Lake Clark National Park, “9a” represents GMU 9A surveys, and “03” represents the 2003 survey year. Figure A6.1 provides an example image of a file directory structure. Before any major changes are made to brown bear monitoring files or a database, a copy will be stored with the appropriate version number to allow for tracking of changes over time. Versioning of archived data sets is handled by adding an eight digit number to the file name that represents the month (2 digits), day (2 digits) and year (4 digits). Frequent users of the data are notified of the updates, and provided with a copy of the most recent archived version. Changes to a database structure will be recorded within a table of a database itself.

6.2.3 Data Documentation

6.2.3.1 Backup Procedures: A master copy of the brown bear data file will be kept on servers at the participating park(s) and at the SWAN office in Anchorage. The SWAN project leader will coordinate with participating agencies (if relevant) for additional locations. The project leader and network data manager will work with park computer support staff to ensure the data file is secure, accessible to the appropriate group of users, and backed-up regularly.

The Alaska Regional Information Technology staff will manage system backups as detailed in Southwest Alaska Network Data Management Plan (2006). Additional backups of working documents related to brown bear monitoring are performed by the project leader as needed.

6.2.3.2 A Note on Hardcopy Data: The project leader/wildlife biologist will ensure that all hardcopy data and related data documentation items (e.g., log books, field notes, tapes, video, data forms) are gathered upon completion of aerial survey operations. This will occur prior to

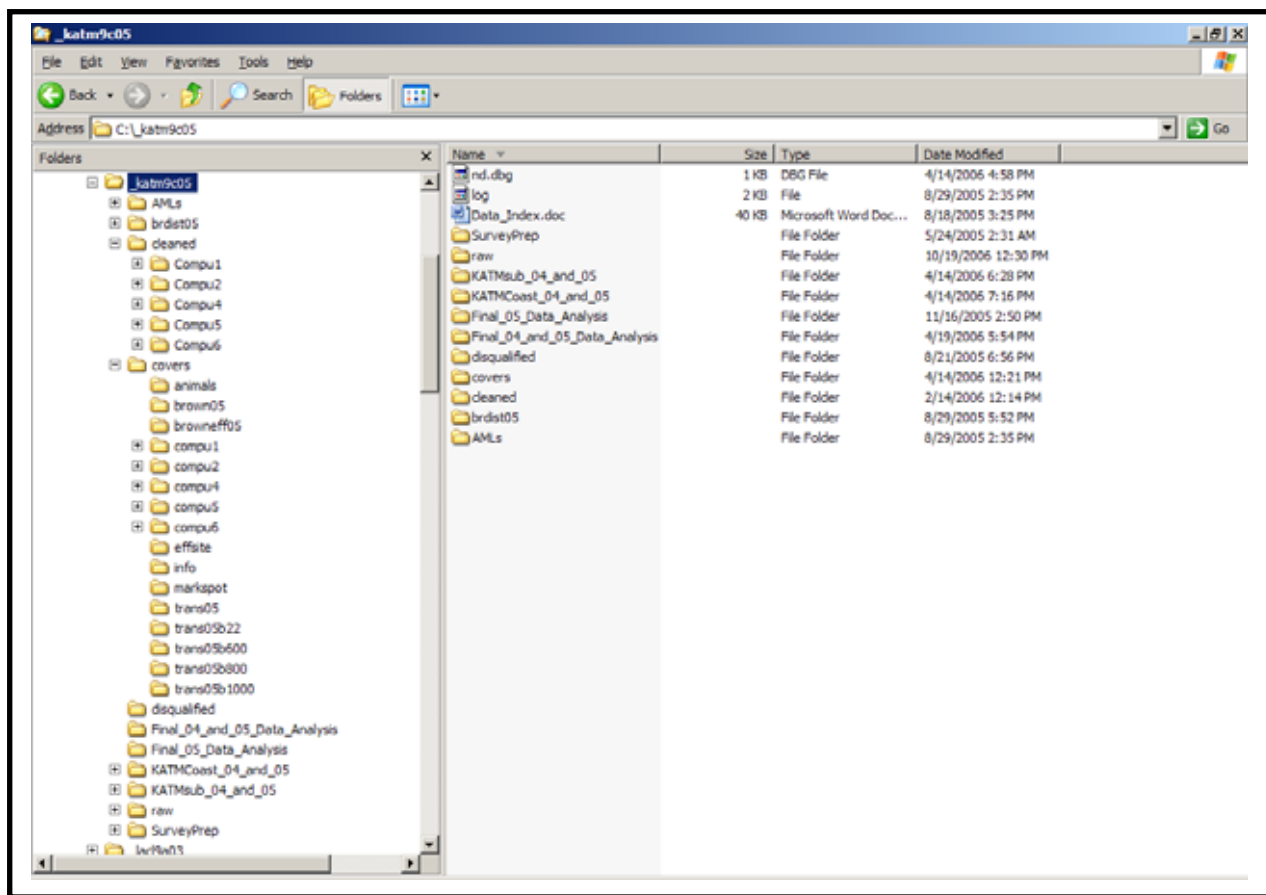


Figure A6.1. Example file directory structure used for brown bear survey data in KATM during 2004-2005.

crew member departure from the survey effort. Review of hardcopy data for the individual's name, date, project title, and numbered pages will be made prior to archiving. These materials are considered "mission critical records" and will be archived permanently. Original materials from the monitoring project may be filed and maintained at each park or with the SWAN data manager for archival in the Alaska Regional Curation Center (ARCC). If originals are kept at individual park locations, copies will be made and archived at the ARCC. Copies of annual reports, summary reports, photographs and maps will also be archived at the ARCC.

6.2.3.3 Data Dissemination and Archiving: The project leader and data manager will work with park staff to establish appropriate user access permission (read-only or read-write) for data dissemination. User permissions will be allocated in order to maintain the integrity of brown bear database files. For example, project staff may have read-write access to the data files, whereas other park staff may be assigned read-only permission to these files and folders.

The SWAN data manager will maintain an archive copy of each park's master brown bear file on the SWAN server. This copy serves as an access point for network staff and as another back-up for data. During periods of data collection via aerial surveys, KATM/LACL will have the most

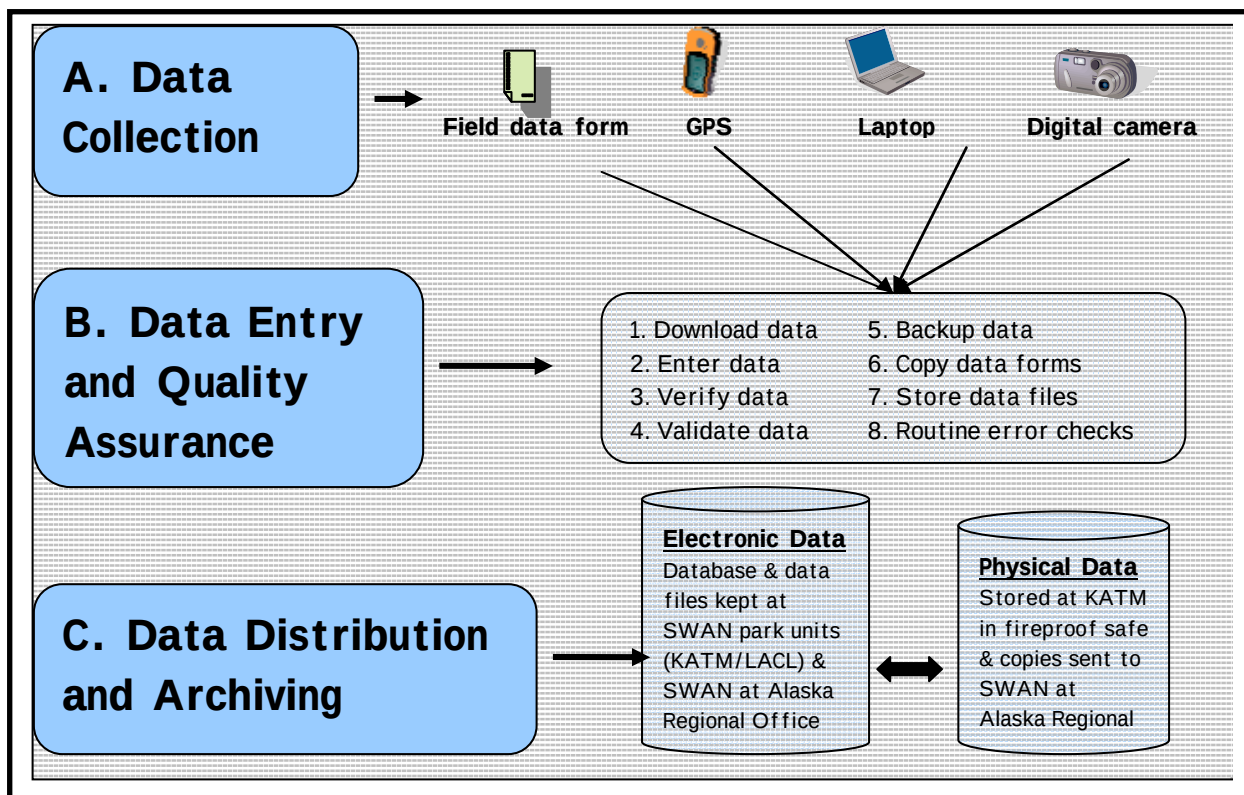


Figure A6.2. Data flow from collection to archiving for SWAN brown bear monitoring data.

current data content, some of which may not meet qualification standards depending on the timing of verification and validation activities. Access to each park's most current brown bear data will be arranged through the project leader who works with the network data manager and park staff to obtain a copy of the master data file and process it to meet the needs of the network staff or other requestor.

Long-term archiving of brown bear data will occur at the ARCC. The project leader will work with the SWAN data manager to determine which data components are sensitive and non sensitive. Non sensitive data may be posted on the SWAN website for public distribution and outreach.

When data requests are made for the most recent brown bear data, the project leader/wildlife biologist will respond to such requests according to the appropriate NPS policy. The network data manager may assist in coordinating the data transfer for such requests. As mentioned above, an annual submission of all data files and types will be made to the SWAN office. Data file types may include the data files, database, images and reference documents. A copy of the submitted master brown bear data file will be archived on the SWAN server at the time of submission. An overview of data flow procedures from data collection through distribution and archiving are detailed in Figure A6.2.

Literature Cited

Daley R. 2006. Standard Operating Procedure #8: Data Management Procedures for Water Quality Monitoring, Version 1.1. Appendix E in: Regulatory water quality monitoring protocol, Version 2.0. National Park Service, Greater Yellowstone Network, Bozeman, Montana.

Southwest Alaska Network. 2006. Data management plan for the Inventory and Monitoring Program, Southwest Alaska Network. National Park Service, Anchorage, Alaska. Available from (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=reports_pub). Accessed 9 July 2009.

Reporting

Standard Operating Procedure #7 Version 1.0 (7/29/2009)

William L. Thompson
NPS—Southwest Alaska Network

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

7.0 Introduction

Written reports on monitoring of brown bears in Southwest Alaska Network (SWAN) parks will primarily be: 1) survey reports, 2) newsletters, field season highlights and mid-winter notes; 3) annual administrative reports, 4) resource briefs, and 5) peer-reviewed articles in scientific journals. These reports may be written by the SWAN Terrestrial Project Leader, SWAN park staff, or a combination of both. Oral reports may consist of presentations to the SWAN technical committee during survey years, either oral or poster presentations at the SWAN Biennial Science Symposium, and either oral or poster presentations at scientific conferences.

7.1 Written Reports

7.1.1 Survey Reports

Survey reports will be generated by the September following the spring survey; these will be final reports for completed surveys and field season highlights (see below) for multiyear partial surveys that have not been completed. Final survey reports will be formatted based on guidelines described on the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). The target audiences for these reports include park staff and natural resource staff and scientists from other state and federal agencies. They will be posted on the SWAN website (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=reports_pub) to ensure their public accessibility.

7.1.2 Annual Newsletters, Field Season Highlights and Mid-Winter Notes

Annual newsletters, field season highlights and mid-winter notes will provide interim summaries of activities and accomplishments associated with the SWAN brown bear monitoring program. The target audiences for these reports will be SWAN park and Alaska Regional Office staffs, collaborators from other state and federal agencies, and the general public. These reports will be publicly available on the SWAN website (http://science.nature.nps.gov/im/units/swan/index.cfm?theme=reports_pub). Examples of each can be viewed on the SWAN webpage: annual newsletter (http://science.nature.nps.gov/im/units/swan/Libraries/Newsletters/swan_newsletter_20080512_1owres.pdf); field season highlights (http://science.nature.nps.gov/im/units/swan/Libraries/Newsletters/SWAN_field_highlights_2008_L_20081002.pdf); and mid-winter notes (http://science.nature.nps.gov/im/units/swan/Libraries/Newsletters/swan_2008midwinter_notes_1owres.pdf).

7.1.3 Annual Administrative Report and Work Plan

The annual administrative report provides a summary of a network's fiscal year activities, accomplishments, and associated budget expenditures to park superintendents, SWAN technical committee members, SWAN staff, Inventory and Monitoring (I&M) regional coordinators, and servicewide program managers. Servicewide program managers use this information in their annual Report to Congress, to respond to inquiries from the budget office, and for other purposes. The format of this report is set by the I&M Washington Office in Fort Collins, CO. Summary information on brown bear monitoring surveys, results and budget expenditures will be included in the annual administrative report during years of partial or complete surveys.

7.1.4 Resource Briefs

Resource briefs provide one-page summaries describing the importance and issues associated with each SWAN vital sign. They will be updated as new survey data are collected and analyzed. The target audiences for these briefs will be SWAN park staffs, scientists from other state and federal agencies, and the general public. The resource brief for brown bears is publicly available on the SWAN website

(http://science.nature.nps.gov/im/units/swan/index.cfm?theme=brown_bear).

7.1.5 Peer-Reviewed Articles

Peer-reviewed journal articles may be published if innovative methods of sampling design or data analysis are developed during the course of the brown bear monitoring program. Peer-reviewed journal articles lend credibility to the SWAN monitoring program, and the I&M Program as a whole, so should be pursued whenever possible. The target audience for these articles will mainly be the scientific community, but they also are an important component of the Annual Administrative Report that is used to inform Congress of the accomplishments of the I&M Program.

7.2 Oral Reports

Oral reports could be in the form of oral presentations or posters. Program updates will be provided to the SWAN Technical Committee during their biannual meetings. Either poster (mainly) or oral presentations may be given at the SWAN Biennial Science Symposium (e.g., see http://science.nature.nps.gov/im/units/swan/index.cfm?theme=science_symposium_2009), which is attended by park staff, cooperating agencies and the general public. Noteworthy results or methodological innovations may be presented at scientific conferences, such as the biennial meeting of the George Wright Society (<http://www.georgewright.org/>). Travel to out-of-state conferences may largely be dictated by availability of travel funds.

Revising the Protocol and SOPs

Standard Operating Procedure #8
Version 1.0 (7/29/2009)

Kellie Peirce
Fairbanks, Alaska

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Add rows as needed for each change or set of changes associated with each version.					

8.0 Introduction

This SOP outlines the process of documentation for changes to the protocol narrative and accompanying SOPs. Personnel editing the protocol narrative or any of the SOPs must follow these procedures (Oakley et al. 2003).

8.1 Revision Procedures

1. Edits to the protocol narrative or SOPs will require review for clarity and technical soundness. Minor changes or additions to brown bear monitoring procedures will be reviewed and approved by the project leader (see number 4 below). If major changes in methods become necessary, an external review will be required. Regional/national NPS staff and outside personnel with expertise in wildlife biology, brown bear research and statistical analyses, will be used as reviewers.
2. Edits to the protocol narrative and SOPs will be tracked in the Revision History Log. The protocol narrative and each SOP is accompanied by a revision history log. The purpose of the log is to track the date, version number, changes and personnel who made the changes to document reason for changes over time. Version numbers assigned to each edited draft should reflect the magnitude of changes. For example, major changes will be designated by whole number increases (e.g., Version 1.0 to Version 2.0, etc.) and minor changes by tenths (e.g., Version 1.1 to Version 1.2, etc.).

The following information will be recorded in the associated Revision History Log for each round of changes to the protocol narrative or SOPs: the previous version number, new version number, date of revision, author of the revision, paragraph(s) and page(s) where changes appear, and the rationale for each change.

3. The data manager will be informed regarding changes to the protocol narrative or SOP so that the new version number can be incorporated in the metadata of the project database. The database may require editing by the data manager to accompany changes in the protocol narrative and SOPs. The data manager will post new versions of the protocol on the internet and, when possible, notify individuals known to have a previous version.
4. Significant changes to data collection procedures must be approved by the project leader, the SWAN monitoring project leader, the network biometrician, the I&M coordinator and the data manager. Upon reviewing the proposed changes, the I&M coordinator will decide on whether additional peer review is required before accepting the changes. If the changes are considered minor they will be approved by the project leader. Any major changes will require a more detailed review as described in number 1 above.

Changes to the protocol narrative and SOPs may occur as a result of regularly scheduled Program reviews. During the review, data may be analyzed to determine if they are satisfying monitoring objectives. If the protocol has not achieved desired results then changes should be recommended..

Literature Cited

Oakley, K., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin* 31:1000-1003.

Appendix B: User's Manual for GammaMRDS

User's Manual for GammaMRDS: An R Package for Fitting Gamma-Shaped Detection Functions to Mark-Recapture Line-Transect Data

Version 1.0.1 (7/7/2009)

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Reynolds, J. H., B. Russell, E. F. Becker, and P. X. Quang. 2009. GammaMRDS: an R package for fitting gamma-shaped detection functions to mark-recapture line-transect data. U.S. Fish and Wildlife Service, Division of Realty and Natural Resources, 1011 E. Tudor Rd, MS 221, Anchorage, AK, 99503.

ACKNOWLEDGEMENTS:

The package evolved from S-Plus code written by Pham X. Quang and Earl F. Becker (earl.becker@alaska.gov) as part of their development of the methodology (Becker and Quang 1999, Becker and Quang 2009). Aaron Christ ported that earlier code ('LT 6.0') to R around 2004. The current package evolved from the version circa 2006, 'LT 7.0'. The software reflects all of their efforts and, hopefully, allows others to benefit from those efforts. The package would not exist in its current form if not for the assistance of Brook Russell and the support of Togiak National Wildlife Refuge, Dillingham, AK, and the Division of Realty and Natural Resources, U.S. Fish & Wildlife Service, Anchorage, AK.

1 Introduction

This manual illustrates the analysis of distance sampling data from a double-observer (‘mark-recapture’) line transect survey collected following the methods outlined in Becker and Quang (2009). These methods allow the detection function to be non-monotonic (peak occurs off transect) and have a maximum detection ≤ 1.0 . The analysis code was developed for the statistical software package R (R Development Core Team 2008).

The methods and software were originally developed for using aerial surveys to estimate brown bear densities in Alaska (Quang and Becker 1999, Becker and Quang 2009). The software is demonstrated estimating the density of brown bears in Togiak National Wildlife Refuge in 2003/2004 (Walsh et al. 2008). The general method, however, is applicable in any double-observer line-transect survey meeting the survey assumptions; there are no inherently *Ursus*-centric assumptions, though there are some *Ursus*-centric options.

This manual assumes that the analyst has a working familiarity with distance sampling estimation, generalized linear models, bootstrap methods, and the R software environment. References to the literature are provided to guide the analyst toward the technical details. As with any tool, familiarity leads to safe use.

2 Analysis Methods Overview

The underlying statistical model and estimation process are detailed in Becker and Quang (2009). A summary follows.

2.1 Data Collection and Preparation

The line transect data are assumed to have been collected by two independent observers sharing a common observation platform, e.g., small fixed-wing aircraft. These observers are generically referred to as ‘Pilot’ and ‘Passenger’. Survey protocols are detailed in Olson and Putera (2007). The main features required are:

- Surveys are conducted on a random sample of line transects over the study region.
- The Pilot and Passenger observe, or search, independently. That is, procedures are used to ensure that detection by one observer does not cue the other observer to search more thoroughly, etc.
- The perpendicular distance of the detected object from the transect, at the time of detection, is measured accurately. Generally, this is achieved by recording the flight line using on-board GPS and ‘going off transect’ and using the GPS to mark the location of the detected group. The perpendicular distance can then be calculated using GIS.
- Covariates describing the detected group and surrounding habitat are accurately recorded.
- Objects can move around within the study region as long as the speed at which the survey transect is traversed is at least two to three times faster than the average object movement speed (Hilby 1986 quoted in Buckland et al. 2001).

2.2 Density Estimation

The density estimate for the study region is obtained by (i) fitting a model describing the probability of detecting an animal as a function of distance from the transect and possibly other covariates, then (ii) using the model-estimated probabilities of detection and observed object group sizes to estimate object density in the searched region. Because the transects were a simple random sample from the study region, this is also an estimate of object density in the study region.

All detections made by ‘the pilot’ are used to estimate the pilot’s detection function; all detections made by ‘the observer’ are used to estimate the observer’s detection function. The combined pilot-observer data are used to estimate the two apex parameters, i.e., maximum $\text{prob}(\text{detection} \mid \text{Pilot})$ and maximum $\text{prob}(\text{detection} \mid \text{Observer})$.

The uncertainty of the resulting density estimate is driven by two components. Foremost is the uncertainty in the fitted detection functions, which is primarily affected by the total number of groups detected and the sources of systematic variation in the detection probability. The total number of groups detected will be affected by the actual density of groups and the sample effort (number of surveyed transects, length of transects, etc.). The other component is variation in group size, which mainly affects density estimation and not in the fitting of the detection model.

Total area searched only affects density estimation. Note that if a particular transect is flown twice in the course of the survey, its search area is counted twice. Thus transects overlapping in space but not time, repeated observations of the same object at different times (on different transects), etc., do not invalidate the method or introduce bias.

2.2.1 Fitting Detection Models

A detection function is modeled as a gamma-density, which has parameters for shape and scale. This allows the detection probability to peak away from the inner edge of the search area; i.e., detection probability does not have to decrease monotonically with distance from the transect.

The scale parameter of the detection function is modeled as a function of covariates, which allows the detection function to stretch or contract (see Figure 1). The two observers can have different general linear models and different detection functions.

Specifically, detection functions are modeled as a gamma distribution:

$$\Pr_{\text{detect}}(\text{dist } y | h_j, r_j, \lambda_j) = \frac{h_j}{\Gamma(r_j)b_j} \left(\frac{y}{\lambda_j b_j} \right)^{r_j-1} \exp\left(\frac{-y}{\lambda_j b_j} \right) \quad (\text{Eqn 1}).$$

y is the perpendicular distance from the transect to the detected object, j distinguishes between the detection parameters of pilot and observer, h is the maximum detection probability at the function's apex, and r is the shape parameter. The scale parameter is set equal to $b \bullet \lambda$, where λ is a general linear model of the observed covariates (Eqn. 2) and b is defined as

$$b = \frac{1}{\Gamma(r_j)} \left(\frac{r_j-1}{e} \right)^{r_j-1},$$

where e is the natural logarithmic base, i.e., $\ln(e)=1$.

Covariates are incorporated via the log-linear model

$$\ln(\lambda_j) = \beta_{j0} + \beta_{j1}x_1 + \dots + \beta_{jk}x_k \quad (\text{Eqn 2}),$$

where the x_i 's are the covariates associated with the i^{th} group detected by observer j , i.e. the pilot or the observer.

Detection functions are fit separately for the pilot and observer positions to allow for varying covariate effects and inherent differences in detection. Detection functions are fitted using maximum likelihood. Estimates of pilot and observer peak detection probabilities $\{h_1, h_2\}$ are obtained from the double-count data via an application of the expectation-maximization, or E-M, algorithm (McLachlan 1997).

2.2.2 Model Selection

After identifying a suite of plausible detection functions for each observer, model selection can proceed using AIC-based methods (Burnham and Anderson 2002).

2.2.3 Model Goodness of Fit

Assuming that a gamma distribution adequately describes an observer's detection function, one can evaluate goodness of fit by assessing whether the estimated detection probabilities of the detected groups differ substantially from a random sample from a gamma distribution. The detection models fit by our methods, though, allow the different groups detected by a specific observer to arise from *different* gamma distributions because the gamma scale parameter can vary with a group's covariate settings. However, the fitted detection function and the probability integral transformation can be used to transform the detections to observations expected to be

from a uniform $[0,1]$ distribution. Either a Chi-square test (after binning observations) or a Kolmogorov test (Conover 1999) can be used to assess the transformed observations for departures from the expected uniform distribution.

2.2.4 Density Estimation

Having fitted a detection model, the number of bears in the searched area then is estimated using a Horvitz-Thompson estimator (Thompson 1992). Bear density is estimated by dividing the estimated number of bears by the total area searched. Each transect's search area is estimated as the area perpendicular to the transect out to the effective strip-width distance, less any blind strip directly alongside the transect and hence underneath the airplane (Becker and Quang 2009). The effective strip width is usually defined as the upper 95th percentile of the observed detection distances (Buckland et al. 2001). For curvilinear transects, area lost or gained due to transect curvature will be calculated using GIS; macros to do so have been written in Arc Info 9.x by R. Strauch (Alaska Department of Fish and Game, Anchorage, Alaska). Total search area is estimated as the sum of the transect search areas. Because of the random transect selection design, the estimated density in the searched area is also the estimated density for the whole study area.

2.2.5 Standard Errors and Confidence Intervals

Although the model fitting function, `FitGMRDSmodel`, provides standard error estimates for the total number of animals and animal groups in the surveyed area (Table B4.1), these are under-estimates because they treat the fitted detection model as known with complete certainty and thus do not account for the uncertainty from estimating the model parameters nor from the model selection process. More accurate standard errors and confidence intervals are obtained by nonparametric bootstrap resampling of the survey transects and repeating the analysis. For a general introduction to bootstrap resampling, see Lunneborg (2000); for a technical introduction see Davison and Hinkley (1997).

3 Software Installation

The GammaMRDS package is a set of R functions for fitting detection models ('Gamma [models for] Mark-Recapture [line-transect] Distance Sampling').

3.1 Required Software

- R version 2.5 or newer.
This is available for free download from the Comprehensive R Archive Network ('CRAN') website, <http://cran.r-project.org/>. Follow the installation directions appropriate for your computer on the R FAQ document.
- R libraries / packages: GammaMRDS, boot, nlme, and trust.
If your computer is connected to the internet, then installing GammaMRDS will automatically install the boot, nlme, and trust R packages required by GammaMRDS if they are not already installed.
If your computer is not connected to the Internet, then you must download these packages on another computer, copy their zip files to the desired computer, and install them from the copied files.
- A text editor for editing the user scripts, such as notepad, emacs, or WinEdt¹.

3.2 Installing R Packages

Packages only need to be installed on your machine once.

3.2.1 Internet-connected Computer

Packages are obtained, after downloading and installing R, by starting R and then using the menu Packages => Set CRAN mirror to select the nearest package repository. Then use Packages => Install package(s) to generate an alphabetical list of all available R packages from which you will select those you want to install on your machine. Select a package by 'right-clicking' on its name with the mouse; select multiple packages by holding down the CTRL- key while you right-click additional package names. Hitting Enter when you are done selecting packages will start the downloading and installation process.

Non-connected Computer

Install packages on an Internet-connected computer as described above, but note where the package zip files are placed (this will be shown in the R command window during the installation process) and do not allow R to delete the zip files after installation. Copy the zip files to the non-connected computer. The R menu Packages => Install from (local) zip file can be used to install packages from a copy of the package zip file.

¹ The R package RWinEdt allows one to link the text editor WinEdt (<http://www.winedt.com/>) to R, providing many useful features for quick copy and pasting of code, etc.

3.3 Loading GammaMRDS into R

The GammaMRDS package has to be loaded during any session in which you want to conduct an analysis.

Load the package via the R command `library(GammaMRDS)`. This will automatically load the other required packages, making available both the user functions (`FitGMRDSmodel`, `GoF.GMRDS`, `BootstrapGMRDSmodel`, `BootSummary`) and the data for the Togiak NWR brown bear example (`TogiakObjectData`, `TogiakTransectData`, `TogiakModel`, `TogiakBootSummary`).

4 Conducting a Simple Analysis

An analysis is conducted by working through the sequence `FitGMRDSmodel => GoF.GMRDS => BootstrapGMRDSmodel => BootSummary`. Type the R commands shown directly into the R command window (followed by Enter key), or copy them from a text editor and paste into the R command window. You can change the data object names, but the functions assume that the required variables within those data objects are named as shown.

4.1 Data Preparation

4.1.1 Required Data and Formatting

The analysis requires two sets of data with the following minimum components and required variable names. The objects can, and likely will, contain additional variables, but these must exist with these names for the analysis functions to work.

- **Transect Data ('TransectData')**
Each row of this object records information on a surveyed transect:
'TransNo' - its unique transect number or ID,
'Length' - surveyed length,
'Area' – the area surveyed along the transect.
Often the area searched will be calculated later, after the initial analysis of detection distances identifies the *strip width* (Buckland et al. 2001).
- **Detected Object Data ('ObjectData')**
Each row of this object records information on a detected group of animals:
'GroupID' - its unique object ID,
'OBS' - who detected the group, numerically coded as 1: Pilot, 2: Passenger or 3: Both,
'DistanceOffTransect' - perpendicular distance from the object to the transect,
'TransNo' - the transect the group was detected from,
'GroupSize' - the number of individuals detected in the group,
and any other covariates for consideration in fitting the detection functions.

Both `TransectData` and `ObjectData` must be data frames.

4.1.2 Importing Data

If you are unfamiliar with how to import data into R, review the 'R Data Import/Export' help file (Help => Manuals (in PDF) => R Data Import/Export). The `read.csv` command is a useful means of importing data from an Excel worksheet (saved as a *.csv file). As described in the Import/Export help file, the functions in the `rodbc` library can be used to import data from most common database formats. Check that the resulting objects are data frames via the `is.data.frame` command² and, if necessary, convert them.

² For information on this command use the **Help** menu on the R toolbar, or at the R command prompt ('>') type `?is.data.frame` and hit Enter.

4.1.3 Data Checking

The analysis assumes that all detection distances are positive. This can be checked using the commands

```
# Check for negative distance & display
# detected objects that have them.
ObjectData[ObjectData$DistanceOffTransect < 0,]
```

Any negative distances must be assessed as to their legitimacy and either deleted from the object data frame or otherwise modified as appropriate into positive distances. Make sure to discuss all negative observations with the person in charge of data collection and pre-processing. Some negative distances may be possible. For example, if flying contour transects in mountains, when the plane banks into a turn the Pilot and Passenger should look out the other side of the plane (the "downhill" side), which could lead to detecting an object with a negative distance. Negative distances that come from detecting an object that is running away across the transect and onto the 'wrong' side, warrant deletion because they violate distance sampling assumptions.

4.1.4 Variables Specifically Required for Bear Survey Analyses

The GammaMRDS functions were developed for analyzing bear survey data (Quang and Becker 1999, Becker and Quang 2009). Portions of the analysis code, therefore, specifically focus on the number of detected cubs, yearlings, and 'Legal'³ bears.

These variables can be automatically created by the following commands if your ObjectData includes a variable named GROUPTYPE.

```
# These commands may have to be modified if your 'Group Type'
# variable is named something else or if your encoding of
# group type differs from that used here.
ObjectData$Ncub <- ifelse(ObjectData$GROUPTYPE == "FemaleWC",
                          (ObjectData$GroupSize -1),0)
ObjectData$Nyrlg <- ifelse(ObjectData$GROUPTYPE == "FemaleWY1",
                          (ObjectData$GroupSize -1),0)
ObjectData$NLegal <- ObjectData$GroupSize - ObjectData$Ncub -
                      ObjectData$Nyrlg
```

If you are not analyzing bear survey data and don't care about these variables, create null values so the calculation scripts still work properly:

```
ObjectData$Ncub <- 0
ObjectData$Nyrlg <- 0
ObjectData$NLegal <- ObjectData$GroupSize
```

4.1.5 Setting the Strip Width

It is common practice in analyzing distance sampling data to eliminate the most extreme detection distances by defining a strip width that excludes the 5% (roughly) of detections with

³ Legally harvestable brown bears under the Alaska Department of Fish and Game regulations, ages 2 years or older.

the largest distances (Buckland et al. 2001). These observations often represent unique conditions, such as objects silhouetted against the horizon, etc., that aid detection even though there is no probability of detecting a closer object in that context (i.e., one further down the slope of the hill, closer to the transect, rather than on the ridgeline). A variety of data displays can help identify the strip width.

```
hist(ObjectData$DistanceOffTransect)
stem(abs(ObjectData$DistanceOffTransect))
quantile(abs(ObjectData$DistanceOffTransect),
          c(.925, .94, .95, .96, .975, .99), na.rm=T)
plot(density(abs(ObjectData$DistanceOffTransect), na.rm=T),
      main="Distances of Observed Groups")
```

The strip width is used to filter the data set and is passed as an argument to the model fitting and bootstrapping functions (below). Note that the example object data frame, `ObjectData`, has already had its upper 5% of detections removed.

4.1.6 Setting the Blind Strip Width

Aerial line transect surveys using a backseat observer have a blind strip underneath the plane that cannot be viewed by that observer. This blind strip stretches from the flight line (the transect line) out to a distance that depends on the type of aircraft, the flight protocol (altitude above ground), the aircraft windows (flat or bubble type), etc. This distance must be determined by conducting a flight study. All objects detected within this distance of the transect must be eliminated since the backseat observer had no chance to detect them (thus they violate the ‘double-observer’ aspect of the study). The blind strip width is passed as an argument to the model fitting and bootstrapping functions (below).

4.1.7 Filter the Observations

Eliminate from the `ObjectData` all observations that were detected within the blind strip or beyond the effective strip width. Before doing so, you should save a copy of the full object data frame under a different name so that it is available for later use. The example object data in `ObjectData` was filtered using the command:

```
ObjectData<- ObjectData[ObjectData$DistanceOffTransect <= 750 &
                        ObjectData$DistanceOffTransect >= 22,]
```

4.1.8 Calculating the Search Area

After the strip width has been determined you will need to calculate the area searched on each transect, which gets stored in `TransectData$Area`. If only linear transects were surveyed this will just be the transect’s length multiplied by the strip width. For contour transects, this will have to be calculated in GIS⁴ to account for the overlap when buffering out to the strip width and removing the blind strip area, then the result must be re-imported into R.

⁴ Refer to Becky Strauch's (ADF&G) AML scripts, "bufftran.aml."

Assuming that the relevant values have already been calculated for each transect and stored in the `TransectData` object, then calculate the total effective search area by summing the transect search areas.

```
area <- sum(TransectData$Area, na.rm=TRUE)
```

4.2 Defining the Detection Model

The `FitGMRDSmodel` function requires the design matrices for each observer's general linear model. For example

```
## Pilot scale model design matrix: log(effective search distance)
## and centered julian calendar date centered
XdesPilot <- model.matrix(DistanceOffTransect ~ log(EFFDIST) +
                          AdjDateCntrd, data=Objectdf)
dimnames(XdesPilot)[[2]] <- c("Intercept", "ln(EFFDIST)", "AdjDateCntrd")

## Passenger's: log(EFFDIST), and survey year as factor.
XdesPassenger <- model.matrix(DistanceOffTransect ~ log(EFFDIST) +
                              I(YR==2004), data=Objectdf)
dimnames(XdesPassenger)[[2]] <- c("Intercept", "ln(EFFDIST)", "YR2004")
```

These commands will have to be modified for each analysis so that the desired covariates are included on the right hand side of the '~' in the `model.matrix` function for the 'Pilot' and 'Passenger' design matrices. The 'Details' section of the online help file⁵ for the R command formula describes the notation and built-in formula functions, such as for automatic creation of interaction terms or indicator variables.

All columns of the design matrices must be named. If a covariate is a categorical variable, the design matrix will include an indicator variable for all but one of the observed categories. Take care in naming each indicator column; you will likely have to review the design matrix and the object data frame to discover which category was selected as the baseline. Alternatively, you could control the process by creating the indicator variables directly in the object data frame and then simply including all but the baseline category indicator as covariates in the `model.matrix` call.

4.3 Setting the Starting Values for Model Fitting

Observer-specific detection functions are fitted using the trust numerical optimization program to maximize the model likelihood (Geyer 2005). The optimization problem can be rather complicated, therefore for best performance you need to provide the optimization routine reasonable starting values so it can begin its search in a feasible section of the parameter space.

Each design matrix has an associated starting value vector that is passed as arguments to the model fitting function. The starting value vector must have one more element than the number of columns in the design matrix. The components of the starting value vector must be in the same

⁵ Use the Help menu on the R toolbar, or at the R command prompt ('>') type `?formula` and hit Enter.

order as the columns of the design matrix: e.g., the first element of the Pilot's starting value vector must be the starting guess for the intercept coefficient (the intercept is the first column of the Pilot's design matrix), the second must be the starting guess for the coefficient of the covariate in the second column of the Pilot's design matrix, etc.

The last element in the starting value vector is the starting guess for the shape parameter of the fitted gamma density ('r' in Eqn 1). This parameter is constrained to be ≥ 1 . When it is 1, peak detection occurs on the inner edge of the transect search area and the detection function is monotonically decreasing. This is highly unlikely for aerial surveys and thus should be seen as a potential warning flag of poor starting values resulting in poor convergence. For Alaskan bear surveys using this method, 3 has been a reasonable shape parameter starting value.

```
## Assign starting values (Intercept and shape param set to 3)
startbPilot <- c(3, rep(1, dim(XdesPilot)[2]-1), 3)
startbPassenger <- c(3, rep(1, dim(XdesPassenger)[2]-1), 3)
```

4.3.1 Efficient Starting Values

The optimization uses a trust region algorithm that rescales the parameter space during the search using information on the relative scale of the coefficients being estimated (Geyer 2005). The analysis estimates the relative scale of the coefficients from the starting values, thus care should be taken to use starting values of appropriate relative scale. The default starting values are Intercept = 3, gamma shape parameter (r) = 3, and all covariate coefficients = 1. Having the same order of magnitude for the covariate coefficient starting values works for the example because all of the covariates take values on roughly the same order of magnitude (from 1 – 10): ln(EFFDIST) varies from 4 to 7.5, AdjDateCntrd varies from -8 to 6, and YR2004 varies from 0 to 1.

Where the covariates vary over different orders of magnitude, their coefficients will likely differ in their orders of magnitude. Good starting values should reflect this difference. For example, consider two covariates in the design matrix, with the first varying over a range from 1 to 4 and the second varying over a range from 1 to 100, thus differing by a factor of 25 in their range of variation. If both covariates are expected to have roughly similar magnitude effect on the response, then the starting value guesses for their respective coefficients should be scaled on the order of roughly 25 to 1 (or 1 and 0.04).

Alternatively, when faced with a number of potential covariates, one could fit a set of models for each observer, each model containing only a single covariate, then use the resulting parameter estimates as the starting values. These should both reflect the appropriate relative scales and provide a good starting point for the optimization.

4.4 Fitting the Detection Model

```
## Fit the detection model.
DetectionModel <- FitGMRDSmodel(ObjectData=Objectdf,
  XdesPilot=XdesPilot, XdesPassenger=XdesPassenger,
  startbPilot=startbPilot, startbPassenger=startbPassenger,
  wMax=750, wb=22, modeltitle="Togiak Example")
```

4.4.1 ‘Bear Survey’-specific Options

Cubs can be very difficult to detect, thus it is reasonable to expect that some are missed, resulting in some groups that are actually sows with cubs being recorded as single adult bears. If you are analyzing bear survey data and wish to use an *ad hoc* adjustment to account for undercounting cub groups, set the `UseCubFix` argument to `TRUE` in the model fitting function call (the default is `FALSE`).

After fitting the detection model, this adjustment calculates a correction factor when the estimated total number of bear groups with cubs is less than the estimated total number of bear groups with yearlings, as this is counter to general biological expectations under an assumption of relatively constant productivity and first year survival (Earl Becker, Alaska Department of Fish and Game, Anchorage, personal communication). The adjustment factor is then used as a multiplicative expansion factor to ‘correct’ the estimates of total number of cubs, total number of bear groups, and total number of adults (since a cub group is assumed to include a sow). Both the unadjusted and adjusted estimates are returned.

4.4.2 Fitted Model Object, Checking Convergence

If the numerical optimization of either the Pilot or Passenger general linear models fails to converge, a warning will be printed in the command window stating the source of the failure (Pilot or Passenger model) and the `DetectionModel` object will be assigned a value of `NULL`. If this occurs, try different starting values (and double check that all columns of the design matrix are named, that all required variables have their required names, etc.).

If both numerical optimizations converge, the model fitting function will print summary details of the model fit in the command window and pass all the results to the `DetectionModel` object. The `DetectionModel` object is a list with the components described in Table B4.1.

Even if the model appears to have converged, check the estimates to make sure they are sensible: specifically, the last two components of `hvec`, `b1`, `b2`, `Ng` and `Na` of the fitted model object (Table B4.1). You should also rerun the analysis with a variety of starting value vectors, saving each resulting model and checking that they are converging to the same parameter estimates (approximately).

Standard errors and confidence intervals for all quantities of interest are calculated using bootstrap resampling (see section 4.9 ‘Assessing Uncertainty’).

4.5 Model Selection

Although not illustrated in the example analysis, the model fitting function `FitGMRDSmodel` returns the maximum likelihood, AIC, and AICc values of each observer’s scale model (Table B4.1), allowing one to conduct AIC-based model selection on the covariate models and/or multi-model inference (Burnham and Anderson 2002). AICc is recommended when the number of observations is small relative to the number of parameters, e.g. sample size < 40 * number of parameters (ibid). The parameters include the coefficients in the scale model + the gamma shape parameter; the sample size for fitting an observer’s model is the number of bear groups detected by that observer (recorded in the fitted model object’s `hvec` component, Table B4.1).

Table B4.1. Components of the fitted detection model object.

Component Name	Content
Ydata	Matrix with columns GroupID, OBS, DistanceOffTransect
XdatPilotF	The Pilot design matrix with an additional last column containing the fitted detection probability for each detected object (named π_i for the detection probability vector Π_i)
XdatPassengerF	The Passenger design matrix additional last column containing the fitted detection probability for each detected object (named π_i for the detection probability vector Π_i)
hvec	A 5-element vector recording the total number of groups detected just by the Pilot, the total number detected just by the Passenger, the total number detected by both observers, and the resulting maximum likelihood estimates of the Pilot's and Passenger's maximum probabilities of detection (the estimates of h_j in Eqn 1)
Ng	Horvitz-Thompson estimate of the total number of animal groups within the surveyed area
Na	Horvitz-Thompson estimate of the total number of animals within the surveyed area
seNgHT	Estimated Horvitz-Thompson standard error for the Ng estimate
seNaHT	Estimated Horvitz-Thompson standard error for the Na estimate
NaLegal	Horvitz-Thompson estimate of the total number of 'Legal' bears (aged 2 and above) within the surveyed area
CubCF	Estimated 'cub' correction factor (if UseCubFix = TRUE was used)
Ng_adj	Adjusted estimate of total number of groups in surveyed area (from using the cub correction factor)
Na_adj	Adjusted estimate of total number of adults in surveyed area (from using the cub correction factor)
b1	Vector of Pilot's detection function parameter estimates
b2	Vector of Passenger's detection function parameter estimates
wMax	Effective strip width used in the analysis
wb	Blind strip width used in the analysis
modeltitle	Descriptive title of the detection model.
maxlik1	Maximum likelihood from the Pilot's scale model
maxlik2	Maximum likelihood from the Passenger's scale model
AIC1	Akaike's Information Criterion for the Pilot's scale model
AIC2	Akaike's Information Criterion for the Passenger's scale model
AICc1	Corrected Akaike's Information Criterion for the Pilot's scale model
AICc2	Corrected Akaike's Information Criterion for the Passenger's scale

4.6 Model Goodness of Fit

The function `GOF.GMRDS` provides two tests of the consistency between the transformed observations and the Uniform $[0,1]$ distribution. Setting the function's argument `USE.KS = TRUE` conducts a two-sided one-sample Kolmogorov test with an exact p-value calculated for sample sizes < 100 . This test will be somewhat conservative since the transformed values are based on the fitted parameters of the observer's scale model (Tadikamalla 1990). Setting `USE.KS = FALSE` only bins the transformed values into 15 equal-sized bins and calculates a Chi-square goodness of fit test. This test ignores information in the ordering of the bins and can be very unstable and heavily dependent upon the chosen number of bins.

4.7 Calculating Final Density Point Estimates

```
## Calculate surveyed area
area <- sum(TransectData$Area, na.rm=TRUE)
## [1] 16544.42
```

```
# Estimate density of objects (e.g., brown bears) in study area
  cat("Overall Animal Density = ", 1000*DetectionModel$Na/area," per 1000
km^2\n")
## Overall Animal Density = 40.35072 per 1000 km^2
```

4.8 Visualizing the Fitted Detection Model

The script `FinalModelPlots` (section 5) illustrates using the `lattice` commands to effectively present the detection model and how its shape changes under different covariate values. In the Togiak example, the Pilot's scale parameter varied with the natural logarithm of the effective search distance⁶, 'ESD', and the search day relative to the full survey season. Because each combination of specific covariate values (potentially) results in a different detection function, there must be judicious choice of settings for display (Figure B4.1). The example script calculates three values for each covariate –the three quartiles (25th, 50th, and 75th percentiles) for ESD and equally spaced survey dates, then uses the multi-panel and group/superpose features of the `lattice` package to display the representative detection functions.

4.9 Assessing Uncertainty

The function `BootstrapGMRDSmodel` conducts the nonparametric bootstrap resampling of transects and fitting of the detection function. The default is to conduct 2,000 bootstrap replicates as recommended by Lunneborg (2000); this may require a long time to compute for complicated models, in which case we recommend you let it run overnight.

4.9.1 Accounting for Survey Stratification

For valid estimates, the bootstrap resampling must mimic the original survey sampling structure. If the original survey included stratification on a factor, then the bootstrap resampling must be stratified on that factor. For example, the Togiak brown bear study sampled transects over the course of two years and thus was stratified by year, so the bootstrap must also stratify the resampling of transects by year. This is accounted for by setting the `Strata` argument in the `BootstrapGMRDSmodel` function equal to a vector recording the year each transect was sampled. The default is to assume all observations are from the same strata (= unstratified).

```
## using Togiak NWR example data, but just 100 replicates to illustrate
## USE MORE REPLICATES IN REAL LIFE
boot.out <- BootstrapGMRDSmodel(TogiakTransectdf, TogiakObjectdf,
  FittedModel=TogiakModel, Strata=TogiakTransectdf$YR,
  UseCubFix=FALSE)
```

⁶ Effective search distance is the furthest distance being actively searched at the time of the observation. It records the instantaneous width of a person's active search area. It is expected to change with both terrain and habitat; it is expected to be shorter on contour transects in high gradient terrain due to visual blocking by the wings, and shorter in thicker vegetation due to slower search rates hence narrower search area for a fixed flight speed. Effective search distance was recorded for the person who detected the bear group; when both parties detected the group, an agreed upon common ESD was recorded (Walsh et al. 2008).

4.9.2 Convergence Problems during Bootstrapping

The Pilot and Passenger detection models are fitted to each bootstrap replicate, i.e., 2000 model estimations under the default settings. If the numerical optimization routine fails to converge for any of those replicates, a warning will be printed to the R command window identifying whether the problem was in the Pilot or Passenger models. The bootstrap replication will continue with all of the parameter estimates for the failing replicate set to NA. Consider rerunning the bootstrap command to see if the failure was just an extreme resample or sign of some more serious numerical problem in fitting the models.

4.9.3 Bootstrap Output

Bootstrapping creates a ‘bootstrap object’, here named `boot.out`, with a number of components. The component of main interest is `boot.out$t`, the matrix containing the parameter and density estimates from each of the bootstrap resamples (each row is a resample). The distribution of the

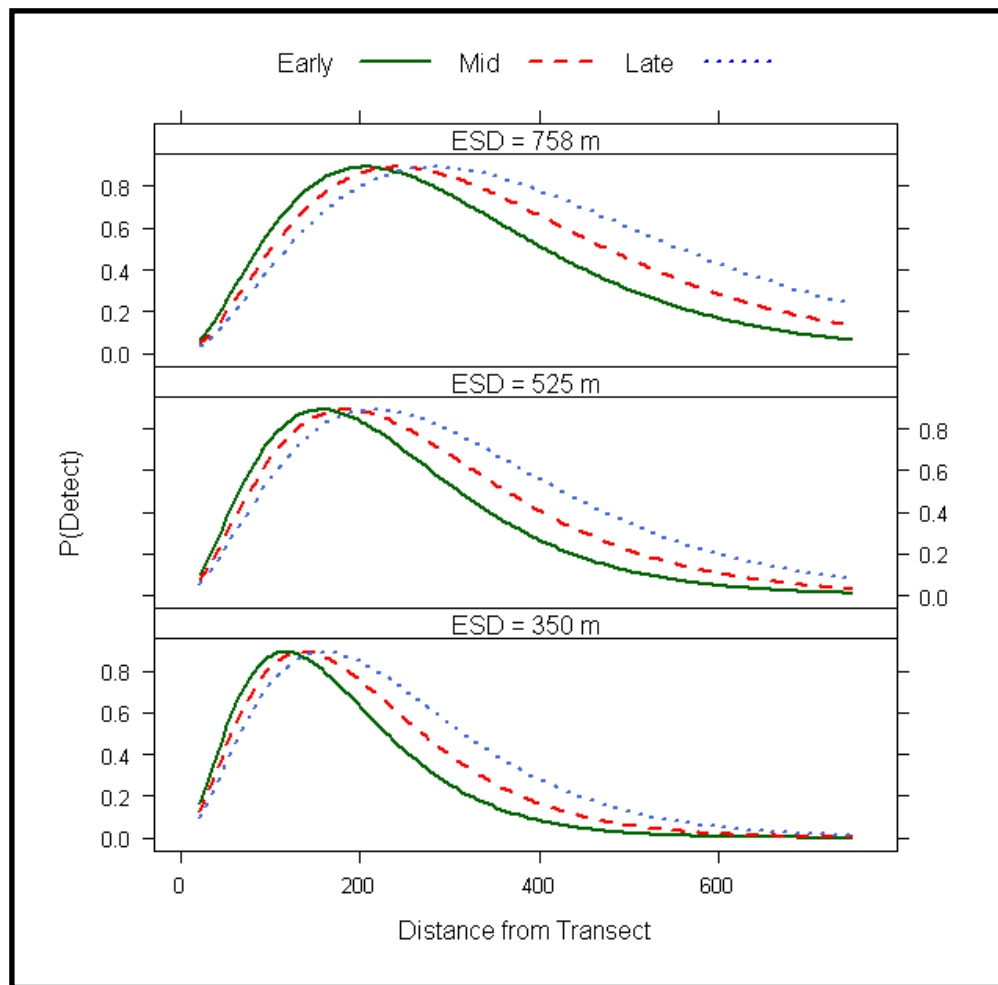


Figure B4.2. Pilot's detection function model from the Togiak example data set. The Pilot's scale parameter model varies with the natural logarithm of the effective search distance (ESD) and the survey date relative to the full survey period. So detection functions are plotted for early, middle, and late survey dates (curves in each panel) at the three quartiles of the ESD (panels). In later surveys there was a noticeable tendency to search further out from the transect, perhaps due to increasing experience with the survey protocol and survey region.

bootstrap replicate estimates for a given parameter is an estimate of the parameter's sampling distribution, and provides a basis for estimating bias, standard errors, coefficients of variation and confidence intervals.

4.9.4 Bootstrap Summaries

The `BootSummary` function calculates a number of summaries for each parameter or statistic in the estimation output (Table B4.2). There are many types of bootstrap confidence intervals, the summary function calculates bias-corrected accelerated ('BCa') and percentile intervals (Lunneborg 2000). A bootstrap percentile 95% confidence intervals is estimated as the 2.5% and 97.5% quantiles of the distribution of bootstrap replicate estimates and can always be calculated. BCa intervals are more difficult to calculate but are more accurate⁷ (Davison and Hinkley 1997). The summary function attempts to calculate both types of intervals – if successful, we recommend using the BCa intervals. If the BCa interval calculations fail, you should reset the `CType='perc'` in the command. You can also modify the desired confidence level and rounding of results. The function will stop if there are any NAs in the `boot.out$t`.

```
ExampleBootSummary <- BootSummary(bootObject=boot.out,
                                   CType=c('perc'), CONF=0.95)
```

ExampleBootSummary

```
## Parameter      Est      Bias RelativeBias StdError  CV  LowerPercentile UpperPercentile
##      Ng      378.1178  4.5536      0.0120  44.3266  0.1172    301.2090      472.7558
##      Na      666.2586  8.5613      0.0128  85.2152  0.1279    524.2119      848.4671
##      ...
```

Table B4.2. Summary characteristics of each parameter's sampling distribution estimated from bootstrapping. See Lunneborg (2000) for details.

Summary	Formula	Comments
Bias	$\bar{\theta}_{bootstrap} - \theta_{estimate}$	The average of the bootstrap replicate estimates for a parameter θ minus the parameter's estimate from the original model fitting
Relative Bias	$(\bar{\theta}_{bootstrap} - \theta_{estimate}) / \theta_{estimate}$	
Standard Error	$SE_{boot}(\theta) = \sqrt{\sum_{i=1}^B (\theta_{bootstrap i} - \bar{\theta}_{bootstrap})^2 / (B-1)}$	$\theta_{bootstrap i}$ is the i th bootstrap replicate estimate and B is the number of bootstrap replicate samples
Coef. Of Variation	$SE_{boot}(\theta) / \theta_{estimate}$	

⁷ BCa intervals attempt to "...correct the percentile interval estimates both for any bias in the sampling distribution and for any tendency [of] the sampling distribution spread to [change] ... as the value of θ changes," Lunneborg (2000).

4.9.5 Bootstrap Diagnostics

`plot(boot.out)` creates three diagnostic plots of the bootstrap replicate estimates for each parameter or statistic, allowing visual assessment of ‘extreme’ observations (here, transects) and their impact on the estimates (Figure B4.2). Generally, the sample sizes required by the survey method should be sufficiently large to ameliorate the influence of any extreme observations. The plots are a useful means of confirming this assumption.

A histogram of replicate estimates allows one to visually assess the skewness of the bootstrap resampling distribution; it also includes a vertical dashed line marking the estimate from the original model fitting, allowing visual assessment of bias (if the ‘center’ of the histogram differs widely from the actual estimate).

A quantile-quantile plot of the replicate estimates against a standard normal distribution allows visual assessment of whether the estimates are approximately normally distributed (do they fall along a diagonal line?) (see Cleveland 1993).

A jackknife-after-bootstrap plot (Canty et al. 2006) displays, for each observation, both its ‘extreme-ness’ (along the horizontal axis) and its impact on the bootstrap distribution (vertically). Consider, for example, the jackknife-after-bootstrap plot of the ‘animal density per 1000 km²’ statistic from the example data set (Figure B4.2, lower figure).

‘Extreme-ness’ of an observation, more properly denoted *influence*, is calculated as the difference between the mean of all replicate density estimates and the mean of the just those estimates from bootstrap samples that did not include the observation. This value is then divided by the bootstrap standard error to get the ‘standardized jackknife value’ plotted on the horizontal axis (Figure B4.2). In the example, the 742nd observation is shown to have a standardized jackknife value of 11 or so (see the small ‘742’ in the lower right corner of the plot), meaning that the density estimate is about 11 standard errors smaller in the bootstrap samples that don’t include this transect. The 742nd row of the `TransectData` is transect number 890. There were three bear groups with a total of 5 bears detected on this one transect!

```
> ObsYdatboot[ObjectTranboot==890,]  
      [,1] [,2]      [,3] [,4] [,5] [,6] [,7]  
[1,] 3004    3  51.189    1    1    1    1  
[2,] 3005    1 660.595    1    1    1    1  
[3,] 3006    2  52.629    3    3    3    3
```

A group (row 1) with 1 animal (column 4) was detected by both observers (column 2) 51 m off the transect (column 3); a group (row 2) with 1 animal detected by the Pilot 660 m off the transect; and a group with 3 animals detected by the Passenger 53 m off the transect.

As a result of the large number of animals detected on this one transect, the distribution of the bootstrap replicate estimates for just those replicates without this transect differs somewhat from that constructed from all of the replicate estimates. This is displayed in the graph’s main area where the solid lines (denoting, according to the y-axis label, the 5%, 10%, 16%, 50% (median), 84%, 90%, and 95% quantiles of the sampling distribution) of the outer tail quantiles shrink slightly toward the median relative to their values from the full set of replicate estimates

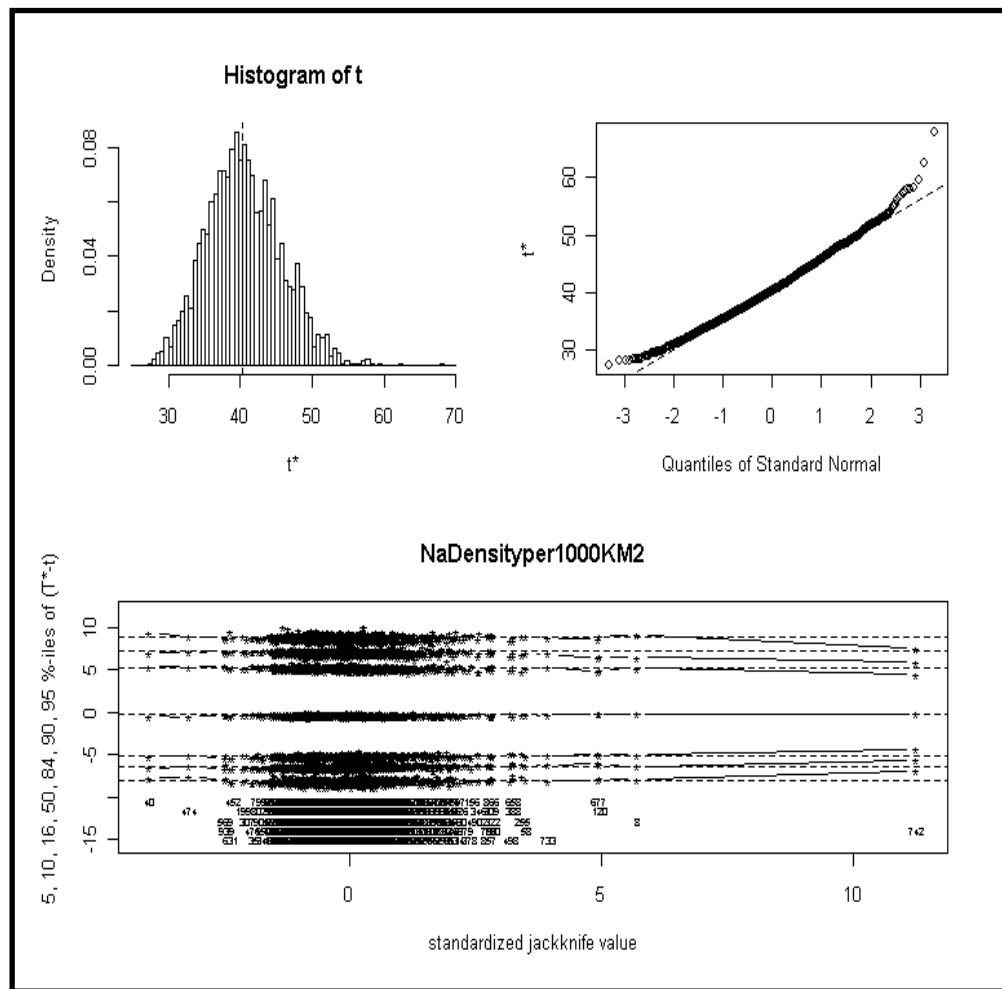


Figure B4.3. Bootstrap diagnostic plots for the density of brown bears per 1000 km² from the Togiak NWR survey (Walsh et al. 2008).

(denoted by the dashed lines). For example, without this transect the 95% quantile shrinks from about 9 animals/1000 km² above the median value to about 7.5 animals above the median.

Setting the argument `jack=FALSE` in the plot command will eliminate calculation of the jackknife-after-bootstrap plot for each.

5 Example Lattice Script

```
##### Plots to illustrate final combined model
## Pilot: log(ESD) + AdjDate
## Passenger: log(ESD) + Year
#####
### Example Script for Plotting Final Detection Model #####
#####
# PURPOSE: Commands to generate plots depicting a fitted
# detection function at some strategically chosen covariate
# combinations.
#
# Specifically, these commands depict the detection function
# models fit to the 2004/2005 brown bear survey data from
# Togiak National Wildlife Refuge (Walsh et al. 2008).
#####
# authors: Joel_Reynolds@fws.gov
# last edit: 3 Oct 2008
#####
# References:
# Walsh, P., J. Reynolds, G. Collins, B. Russell, M. Winfree,
# and J. Denton. 2008. Brown bear population density on
# Togiak National Wildlife Refuge and BLM Goodnews Block,
# southwest Alaska. U. S. Fish and Wildlife Service,
# Dillingham, Alaska.
#
#####
library(lattice)
# set the color theme to color with a white background
lattice.options(default.theme = "col.whitebg")

#####
# Pilot Detection Functions
#####
# /* Percentiles for Search Distance */
# Pilot Covariates:
# log(ESD) log of effective search distance
# AdjDate centered version of Julian date of survey
#####

# Estimates
TrashOut<-TogiakModel

#####
#### Selecting Representative Covariate Combinations ####
#####
# log(Effective Search Distance)
# get quartile values of observed distribution of
# this continuous covariate. Each quartile value will
# be used in single panel of the plot.
logESD<-quantile(TrashOut$XdatPilotF[,2],probs=c(.25,.50,.75),
                na.rm = FALSE)

# AdjDate
# a centered version of Julian date ranging from -7 to 6.
# Select three equally spaced values for depiction.
# Each value will be used in a single curve per panel.
AdjDate<-c(-3.5,0,3.5)
```

```

# y - distance of detected object from transect
# main covariate; will form x-axis of scatterplot.
trashPredictorDistance<-seq(22,750,5)

#####
#### Get Parameter Estimates #####
#####
# shape parameter - last component of parameter vector
r1 <- TrashOut$b1[4]
# calculate b component of scale
bscale <- (1/gamma(r1))*(((r1-1)/exp(1))^(r1-1))
# covariate coefficients (& intercept)
betas <- TrashOut$b1[-4]

# create data frame
trashlength<-length(trashPredictorDistance)
trashPredict<-data.frame(Distance=rep(trashPredictorDistance,9),
  Inter=rep(1,trashlength*9),
  LogESD=rep(rep(logESD,rep(trashlength,3)),3),
  AdjDate=rep(AdjDate,rep(trashlength*3,3)))

# calculate detection densities
lambda <- exp(as.matrix(trashPredict[, -1])%betas)

blah<-trashPredict$Distance/(lambda*bscale)
trashPredict$detect<-TrashOut$hvec[4]*(1/(gamma(r1)*bscale))*
  (blah^(r1-1))*exp(-1*blah)
Apex <- bscale*(r1-1)*lambda
#####
# Display Pilot detection functions
#####
xyplot(detect~Distance|as.factor(LogESD),data=trashPredict,
  # 'groups' argument automatically overlays the different curves for the
  # different 'AdjDate' values (treating AdjDate like a grouping
  factor)
  groups=AdjDate,type="l",lwd=2,
  layout=c(1,3),xlab="Distance from Transect",ylab="P(Detect)",
  #main="Pilot Detection Function",
  # add legend at top of plot
  key=list(space="top",
    text=list("Early"),lines=list(lty=1,col="darkgreen"),
    text=list("Mid"),lines=list(lty=2,col="red"),
    text=list("Late"),lines=list(lty=3,col="blue"),lwd=2),
  # create specific labels for each panel's strip
  strip=strip.custom(style=1,factor.levels=c("ESD = 350 m",
    "ESD = 525 m", "ESD = 758 m"), bg="white"))

#####
# Passenger Detection Functions
#####
# /* Percentiles for Search Distance */
# Passenger Covariates:
# log(ESD) log of effective search distance
# Year Factor: 2004 coded as 0, 2005 as 1
#####

```

```
#####
#### Selecting Representative Covariate Combinations #####
#####
# log(Effective Search Distance)- use same as for Pilot
logESD<-quantile(TrashOut$XdatPilotF[,2],probs=c(.25,.50,.75),
                na.rm = FALSE)
# Year runs from 0, 1
Year<-c(0,1)

# y - distance from transect
trashPredictorDistance<-seq(22,750,5)

# shape
r1 <- TrashOut$b2[4]
# b component of scale
bscale <- (1/gamma(r1))*(((r1-1)/exp(1))^(r1-1))
# covariate coefficients (& intercept)
betas <- TrashOut$b2[-4]

# make into data frame
trashlength<-length(trashPredictorDistance)
trashPredict<-data.frame(Distance=rep(trashPredictorDistance,6),
                        Inter=rep(1,trashlength*6),
                        LogESD=rep(rep(logESD,rep(trashlength,3)),2),
                        Year=rep(Year,rep(trashlength*3,2)))

# calculate detection densities
lambda <- exp(as.matrix(trashPredict[, -1])%*%betas)

blah<-trashPredict$Distance/(lambda*bscale)
trashPredict$detect<-TrashOut$hvec[4]*(1/(gamma(r1)*bscale))*
  (blah^(r1-1))*exp(-1*blah)
Apex <- bscale*(r1-1)*lambda

#####
# Display fitted detection function for Passenger
#####
xyplot(detect~Distance|as.factor(LogESD),data=trashPredict,
      # 'groups' argument automatically overlays each year's function in each
      panel
      groups=Year,type="l",lwd=2,
      layout=c(1,3),xlab="Distance from Transect",ylab="P(Detect)",
      #main="Passenger Detection Function",
      # add legend at top of plot
      key=list(space="top",
              text=list("2003"),lines=list(lty=1,col="darkgreen"),
              text=list("2004"),lines=list(lty=2,col="red"),lwd=2),
      # create specific labels for each panel's strip
      strip=strip.custom(style=1,factor.levels=c("ESD = 350 m",
          "ESD = 525 m", "ESD = 758 m"),bg="white"))
```


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Appendix C: Using Simulation to Determine Sampling Frequencies Required to Detect a Specified Trend in Brown Bear Abundance Estimates in Katmai and Lake Clark National Parks and Preserves

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NPS- Southwest Alaska Network

1 Introduction and Methods

Simulations were run to evaluate the ability of different sampling frequencies to detect specified trends in abundances of brown bears in Katmai (KATM) and Lake Clark (LACL) National Parks and Preserves. Bennett et al. (2006) suggested a sampling frequency of 5-10 years for monitoring brown bears in parks within the Southwest Alaska Network, so these simulations evaluated sampling frequencies of 5, 7, and 10 years, with a 1-year (annual) interval added as a benchmark. The simulation approach is adapted from Lukacs (In prep.) and is detailed below, with results presented in the next section.

- 1. Obtain estimates of abundance ($\hat{N}$), standard error ($\hat{SE}[\hat{N}]$), and coefficient of variation ($\hat{CV}[\hat{N}]$) of brown bears for KATM and LACL from Olson and Putera (2007).
-
- KATM: $2,183 \pm 379$ ($\hat{SE}[\hat{N}]$); $\hat{CV}(\hat{N}) = 0.17$
- LACL: 466 ± 232 ($\hat{SE}[\hat{N}]$); $\hat{CV}(\hat{N}) = 0.50$
-
- where $\hat{CV}(\hat{N}) = \frac{\hat{SE}(\hat{N})}{\hat{N}}$
-
- 2. Randomly generate 1000, 22-year time series of true abundances (N) under a specified finite rate of population growth ($\lambda = 0.99-0.95$, which is a decrease of 1% to 5% per year) for each park. The true abundance for a given year i (N_i) in a time series is calculated as $N_i = N_0 \lambda^i$ (Eberhardt 1987), where N_0 is the initial true abundance from each park in Step 1.
-
- a) Randomly choose the observed finite rate of decline value for a given year i (i.e., λ_i , $i = 1$ to 22) within each simulation run from a Normal distribution with mean $\lambda = 0.99$ to 0.95 (true rate) and $SE(\lambda) = 0.026$ (from a 15-year data set of brown bears in MT and BC; Hovey and McLellan 1996). This step imposes temporal (process) variation into the true abundances within each simulated time series.
-
- b) Borchers et al. (2002) referred to the results of this step as the state model, which basically describes the dynamics of a population.
-
- 3. Randomly generate an estimated abundance ($\hat{N}_i$) and its estimated standard error ($\hat{SE}[\hat{N}]$) for each year i of each simulated time series produced in Step 2.
-
- a) Randomly select an estimated abundance from a Normal distribution with mean based on the true abundance for year i (i.e., N_i) of each simulated time series produced in Step 2 and standard error $\hat{SE}(\hat{N})$ from each park in Step 1.

- b) Randomly select the estimated standard error of the estimated abundance in year i , $\hat{SE}[\hat{N}_i]$, by multiplying the true abundance for a given year i (N_i) by the randomly chosen estimated coefficient of variation for that year, $\hat{CV}(\hat{N}_i)$. The estimated coefficient of variation for a given year i , $\hat{CV}(\hat{N}_i)$, was randomly chosen from a Normal distribution with a mean $\hat{CV}(\hat{N})$ of the relevant park from Step 1 and standard error ($SE[\hat{CV}]$) = 0.009 (from McClintock et al. 2006 for 3 brown bear populations in Alaska; original data from Miller et al. 1997).
-
- c) Availability bias is assumed to be relatively constant over time.
-
- d) This step applies sampling variation to the true abundances generated in Step 2 thereby producing abundance estimates for each year in each simulated time series. This sampling variation includes variation due to sampling design (among-unit variation; Thompson et al. 1998) and due to incomplete counts within sampling units (enumeration variation in Thompson et al. 1998 or the observation model in Borchers et al. 2002)
-
- 4. Estimate the trend for each simulated time series and summarize how often the upper 90% confidence limit of each trend estimate either is equal to and/or below different values of annual rates of change.
-
- a) Log-transform the estimates of abundance within each simulated time series from Step 3 and use them as response variables in the trend models by park (Earnst et al 2005).
-
- b) Fit a weighted loglinear model to each change rate/time series combination (e.g., Kissling et al. 2007) from Step 3 and record how often in the 1000 simulated time series, by park, that a trend of a specified rate of change is detected based on sampling every year, once every 5 years, once every 7 years, and once every 10 years. Estimates of trend are the estimate coefficients of the year (predictor) variable in the weighted loglinear model, where annual rate of change = (EXP[estimated coefficient of year variable from loglinear model] - 1) (or multiply this value by 100% to get percent annual change; Earnst et al. 2005). If the specified percent annual change (0%, -0.5%, -1%, etc.) is equal to and/or below the upper 90% confidence limit for the estimated coefficient of the year variable, then a trend of that magnitude has been detected (Figure C1.1). Note that typical statistical power analysis compares the upper confidence limit to 0 (or lower limit, if positive change), which only tells you that there was a trend but not its magnitude (or its detectable magnitude) unless you assume the cited true change value (model) is correct, i.e., a statistically significant trend equals the true trend value used in power calculations.
-

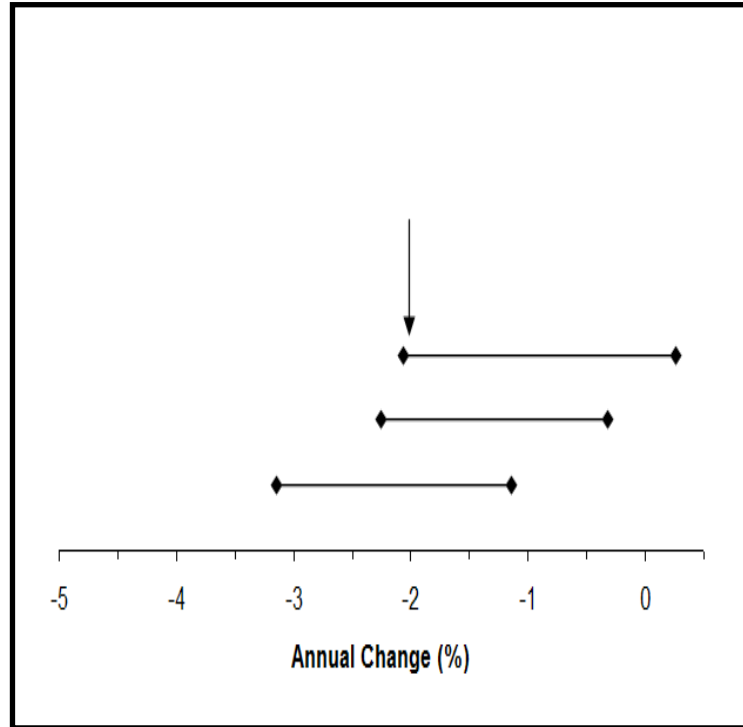


Figure C1.1. An illustration of how the probability of detecting an annual change is calculated for different levels of true change and sampling frequencies. In this example, 90% confidence intervals (CIs) of the trend (change) estimate are generated from three different simulation runs from a 20-22 year time series of abundance estimates upon which a true annual change of 2% (black arrow) was applied. Note that these CIs could have been produced under any one of the sampling frequencies, which dictate length of the time series and the number of observations used in these calculations (see footnote in Table C1.1). The upper limit of the top 90% CI is greater than 0 so a change was not detected, but the upper limits of the other 2 CIs were lower than 0 so they did detect a non-zero change. Consequently, there is a 67% (2/3) chance of detecting a <0% annual change ("Estimated annual change" in Table C1.1) when the true annual change is 2%. The upper limits of both the middle and the top CIs exceed -0.5%, whereas the upper limit of the bottom CI does not, so there is a 33% (1/3) chance of detecting a -0.5% annual change when the true annual change is 2%. Similarly, there is a 33% chance of detecting a -1% annual change because the upper limit of the bottom CI is less than -1%. The upper limits of all 3 CIs exceed -1.5% annual change so there is a 0% chance of detecting an annual change with 90% confidence at this level and lower.

- 5. Repeat Steps 1-4 with other values of $\hat{CV}[\hat{N}]$ and $\hat{SE}[\hat{N}]$, as necessary. For instance, a $\hat{CV}[\hat{N}] = 0.10$ would be derived by adjusting the observed $\hat{SE}[\hat{N}]$ in Step 1 so that it was 10% of the observed $\hat{N}$ for a particular park (i.e., $\hat{SE}[\hat{N}] = 218$ for an $\hat{N} = 2,183$ in KATM).

2 Results and Discussion

An estimated coefficient of variation of 50% (i.e., $C\hat{V}(\hat{N}) = 0.50$), which was based on the abundance estimate for LACL, was inadequate to detect even a trivially small change under a true 5% annual decline when sampling every year over a 20-year period. The chance of detecting a non-zero change under this maximum-change scenario in these simulations was only 38%; in most cases, there was less than a 20% chance of detecting a change (decline) of any magnitude included in simulations based on $C\hat{V}(\hat{N}) = 0.50$ (results not shown). The ability to detect trends in abundance greatly improved with the lower $C\hat{V}(\hat{N})$ from KATM (17%), but even this value was largely inadequate except for sampling at 1-year intervals (Table C1.1). However, simulations based on a $C\hat{V}(\hat{N}) = 0.135$ and sampling every five years indicated this effort was sufficient for detecting a non-zero annual decline when the true rate of annual decline was 2%, which translates into about an 80% chance of detecting a declining trend (greater than 0% reduction) in a population when the true population was reduced by about 35% over 21 years ($1 - 0.98^{21} = 0.35$). In this same scenario, simulation results indicated a 75% chance of detecting at least a 1% annual decline when the true annual decline was 3% during a 21-22 year period, which is equivalent to detecting a 19% ($1 - 0.99^{21} = 0.19$) population reduction when the true population was reduced by 47% ($1 - 0.97^{21} = 0.47$) over 21 years. There were essentially no situations in which a 10-year sampling interval was adequate for detecting trends in abundances, even for a $C\hat{V}(\hat{N}) = 0.10$ (results not shown).

Table C1.1. Percentage of 1000 simulation runs in which the upper 90% confidence limit (CL) of the estimated population trend in brown bear abundance was equal to and/or below a specified annual change rate for true rates of population change (λ) of 0.99 to 0.95 (or 1% to 5% decline per year) during a 20-22 year period. The simulated time series of bear abundances were based on observed estimated coefficients of variation ($\hat{CV}[\hat{N}]$) of 0.17 (17%) for Katmai National Park and Preserve and of 0.135 (13.5%) for Game Management Unit 9C, which contains Katmai National Park and Preserve (Figure 2.3; Olson and Putera 2007). Values in bold font indicate at least an 80% chance of detecting an annual rate of change of the listed magnitude given the true annual rate of change, sampling frequency, and $\hat{CV}[\hat{N}]$ during a 20-22 year period (i.e., analogous to statistical power = 0.8).

			Percentage of 1000 simulation runs in which the upper 90% CL was equal to and/or below the listed estimated annual change (i.e., minimum detectable annual rate of change)					
$\hat{CV}[\hat{N}]$	Sampling interval (year) ^a	True annual change	Estimated annual change					
			<0% ^b	≤-0.5%	≤-1%	≤-1.5%	≤-2%	≤-2.5%
0.17 (17%)	1	-1%	41%	18%	6%	2%	<1%	<1%
		-2%	79%	59%	36%	16%	6%	2%
		-3%	94%	87%	73%	54%	35%	18%
		-4%	99%	96%	92%	82%	68%	48%
		-5%	100%	99%	97%	93%	84%	72%
	5	-1%	25%	13%	5%	2%	1%	0%
		-2%	51%	38%	23%	14%	7%	4%
		-3%	67%	58%	46%	35%	24%	15%
		-4%	75%	67%	58%	49%	39%	30%
		-5%	81%	74%	67%	60%	48%	40%
	7	-1%	25%	14%	6%	3%	1%	<1%
		-2%	46%	33%	22%	13%	7%	3%
		-3%	61%	50%	40%	28%	18%	13%
		-4%	73%	64%	57%	46%	37%	26%
		-5%	75%	69%	63%	56%	48%	40%
	10	-1%	17%	11%	6%	3%	1%	<1%
		-2%	30%	24%	16%	10%	6%	4%
		-3%	37%	32%	25%	19%	14%	10%
		-4%	45%	41%	36%	31%	25%	20%
		-5%	49%	45%	40%	35%	30%	25%
0.135 (13.5%)	1	-1%	76%	35%	6%	<1%	<1%	<1%
		-2%	99%	93%	67%	30%	6%	1%
		-3%	99%	99%	99%	91%	63%	27%
		-4%	100%	100%	99%	99%	96%	83%
		-5%	100%	100%	100%	100%	99%	99%
	5	-1%	49%	22%	7%	1%	<1%	<1%
		-2%	80%	61%	40%	18%	6%	2%
		-3%	93%	86%	75%	58%	37%	19%
		-4%	98%	95%	89%	79%	67%	51%
		-5%	98%	96%	93%	87%	80%	70%
	7	-1%	44%	18%	6%	1%	<1%	<1%
		-2%	75%	59%	40%	19%	7%	1%
		-3%	86%	77%	67%	50%	36%	16%

Table C1.1. Percentage of 1000 simulation runs in which the upper 90% confidence limit (CL) of the estimated population trend in brown bear abundance was equal to and/or below a specified annual change rate for true rates of population change (λ) of 0.99 to 0.95 (or 1% to 5% decline per year) during a 20-22 year period. The simulated time series of bear abundances were based on observed estimated coefficients of variation ($\hat{CV}[\hat{N}]$) of 0.17 (17%) for Katmai National Park and Preserve and of 0.135 (13.5%) for Game Management Unit 9C, which contains Katmai National Park and Preserve (Figure 2.3; Olson and Putera 2007). Values in bold font indicate at least an 80% chance of detecting an annual rate of change of the listed magnitude given the true annual rate of change, sampling frequency, and $\hat{CV}[\hat{N}]$ during a 20-22 year period (i.e., analogous to statistical power = 0.8) (continued).

			Percentage of 1000 simulation runs in which the upper 90% CL was equal to and/or below the listed estimated annual change (i.e., minimum detectable annual rate of change)					
$\hat{CV}[\hat{N}]$	Sampling interval (year) ^a	True annual change	Estimated annual change					
			<0% ^b	≤-0.5%	≤-1%	≤-1.5%	≤-2%	≤-2.5%
0.135 (13.5%)	7	-4%	95%	89%	83%	74%	62%	47%
		-5%	94%	90%	87%	82%	76%	67%
	10	-1%	28%	16%	7%	2%	<1%	<1%
		-2%	47%	36%	24%	15%	6%	2%
		-3%	62%	54%	44%	34%	23%	12%
		-4%	69%	63%	56%	48%	39%	29%
		-5%	73%	68%	62%	55%	49%	42%

^a A 1-year sampling interval yields 20 observations (year 1 - 20) , a 5-year interval produces five observations (year 1, 6, 11, 16, and 21) , a 7-year interval generates 4 observations (year 1, 8, 15, and 22), and a 10-year interval produces three observations (year 1, 11, and 21).

^b The <0% change category represents the traditional definition of statistical power, i.e., the probability of detecting a non-zero change regardless of its magnitude.

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Appendix D: Beta Version of R2WinBUGS Code


```

# This is a BETA version of code that fits the Becker-Quang (2009) Gamma
# Mark-Recapture Distance Sampling model to bear groups detected during
# aerial surveys along randomly selected contour transects. Analysis
# proceeds using data augmentation in WinBUGS. The individual covariate(s)
# thought to affect the scale parameter (reparameterized as  $b \times \lambda$ ) of
# the Gamma detection function for each observer are included in a loglinear
# model.
#
# NOTE: This code requires more Beta testing before being put into use.

# Set the working directory on your computer.

setwd('C:/Bill/BrBear/Bayesian_Distance_Model')

# List the R libraries needed for this analysis.

library(RODBC)
library(doBy)
library(xts)
library("R2WinBUGS")
library(abind)

# Import the csv files containing the data for each covariate/variable
# (separately) and convert each to a matrix. Data are imported with rows
# corresponding to transects (n = 639), and columns corresponding to actual
# observations within each transect *plus* data augmented observations
# (total = 25 observations [columns]).

# area (m2) surveyed along transect from 22m to 800m as per Quang's
# original analysis

area800<-read.csv("area800.csv",header=TRUE)
area800<-as.vector(as.matrix(area800))
length<-area800/800
length<-length/1000

# perpendicular distance (m) from the transect to the detected group
# (object)

x<-read.csv("distofftran.csv",header=TRUE)
x<-as.matrix(x)

# number of individuals per detected group (assumes complete count of group)

groupsz<-read.csv("groupsz.csv",header=TRUE)
groupsz<-as.matrix(groupsz)
clust<-groupsz

# estimate of distance (m) to sighting horizon for each detected group (the #
# logarithm of effective distance was the only covariate shown to have an
# important influence during Quang's original analysis)

effdist<-read.csv("effectdist.csv",header=TRUE)
effdist<-as.matrix(effdist)

# double-observer portion of the input data

```

```

# multinomial representation of detections made by the pilot only
# (e.g., 10 in encounter history format).

one0<-read.csv("one0.csv",header=TRUE)
one0<-as.matrix(one0)

# multinomial representation of detections made by both the pilot
# and the rear-seat observer (e.g., 11 in encounter history format).

one1<-read.csv("one1.csv",header=TRUE)
one1<-as.matrix(one1)

# multinomial representation of detections made by the rear-seat
# observer only (e.g., 01 in encounter history format).

zero1<-read.csv("zero1.csv",header=TRUE)
zero1<-as.matrix(zero1)

# multinomial representation of groups missed by both the pilot and
# the rear-seat observer (e.g., 00 in encounter history format).

zero0<-read.csv("zero0.csv",header=TRUE)
zero0<-as.matrix(zero0)

# generate 3-dimensional array of multinomial
# representations of detections (e.g., 639 by 25 by 4 array)
# that is used to compute the "capture" probabilities
# for each observer later in the program

ncap<-abind(one0,one1,zero1,zero0,along=3)

# Specify the total number of MCMC samples (ni), the burn-in (nb), the
# thinning rate (nthin), the number of MCMC chains (nc), the number of
# detections plus augmented observations for each transect (M), and
# number of surveyed transects (ntr). The actual MCMC samples selected
# = (ni-nb)/nthin.

BQdens.fn=function(ni=100000,nb=20000,nthin=20,nc=2,M=25,ntr=639){

# divide perpendicular distances by 1000 to rescale

x<-x/1000

# divide effective sighting distances by 1000 to rescale

effdist<-effdist/1000
leffdist<-log(effdist)

sink("model.txt")
cat("
model {

# Assign prior distributions to the various model parameters

```

```

# prior for coefficient of cluster (group) size for relating to distance
#(correcting for bias)

betaclust~dnorm(0,0.01)

cInt~dnorm(0,0.01)      # prior for intercept of model relating cluster
                        # size to distance

#betaeffd~dunif(-10,10)  # prior for coefficient of effective sighting
                        # distance

mu1.p~dunif(-6,6)       # avg sightability (p) for pilot
mu2.p~dunif(-6,6)       # avg sightability (p) for observer

psi~dnorm(0,0.01)       # prior for psi, zero-inflation parameter

rPilot~dunif(1,10)      # set prior for Pilot's gamma shape parameter
rObserver~dunif(1,10)   # set prior for Observer's gamma shape
                        # parameter
hPilot~dunif(0,1)       # set prior for Pilot's max (prob(detect))
hObserver~dunif(0,1)    # set prior for Observer's max (prob(detect))
interceptP~dnorm(0,0.01) # set prior for Pilot's intercept of the
                        # log-linear model embedded in the gamma
                        # distn's lambda parameter (scale).
intercept0~dnorm(0,0.01) # prior for Observer's intercept of the
                        # log-linear model embedded in the gamma
                        # distn's lambda parameter (scale).
ESDslopeP~dnorm(0,0.01) # prior for Pilot's ESD coeff of the log-linear
                        # model embedded in the gamma dist's lambda
                        # parameter (scale).
ESDslope0~dnorm(0,0.01) # set prior for Observer's ESD coeff of the
                        # log-linear model embedded in the gamma
                        # distn's lambda parameter (scale).

bPP<-loggam(rPilot)
bOP<-loggam(rObserver)
bP<-1/exp(bPP)*pow((rPilot - 1)/2.717,rPilot-1)  #calculate pilot's b
b0<-1/exp(bOP)*pow((rObserver - 1)/2.717,rObserver-1) #calculate observer's
                                                    # b
lambdaP<-exp(interceptP)                        #calculate pilot
                                                    # lambda vector
lambda0<-exp(intercept0) )                      #calculate observer's
                                                    # lambda vector

tau.e<-1/(sigma.e*sigma.e) # precision in random effects model for psi
sigma.e~dunif(0,100)      # prior for precision in random effects model
for psi

# for each transect
for(i in 1:ntr){

#   e[i]~dnorm(0,tau.e)I(-10,10)  # if desired, prior for normal random
                                # effect on psi (habitat/transect
                                # adjustment so don't assume all

```

```

# transects the same)

# these two lines use the logit transformation for adding the normal random
# effect to psi, i.e., constrain values to be between 0 and 1

lpsi1[i]<-(psi)#+e[i])
psi1[i]<-1/(1+exp(-lpsi1[i]))

# for each object on the transect
# includes many NAs (i.e., data augmentation)

for(j in 1:M){
  w[i,j]~dbern(psi1[i])          # prior for presence on a transect
  x[i,j]~dunif(0, 2.907)         # prior for observed perpendicular
                                # distances (max observed distance
                                # (scaled) = 2907/1000=2.907)

  groupsz[i,j]~dpois(cmean[i,j]) # prior for cluster size
  log(cmean[i,j])<-cInt+betaclust*x[i,j] # model for cluster size related to
                                # distance (same approach used in
                                # Program DISTANCE)

# pilot and observer detection functions

#   effdist[i,j]<-x[i,j]+stuff[i,j] # prior for effective sighting
#                                   # distance
#   stuff[i,j]~dgamma(0.01,0.01)

# calculate the thresholds to decide whether pilot, observer, both, or
# neither saw the group

#first, extract the following from hvec, b1, and b2 (from the ESD model
#fitted to the Togiak data):

#create vectors of probabilities for pilot/observer to see groups

p1[i,j]<-(hPilot/(exp(bPP)*bP))*pow(x[i,j]/(lambdaP*bP),rPilot-1)*
  exp(-1*x[i,j]/(lambdaP*bP))
p2[i,j]<-(hObserver/(exp(bOP)*bO))*pow(x[i,j]/(lambdaO*bO),rObserver-1)*
  exp(-1*x[i,j]/(lambdaO*bO))

# compute capture probabilities for observers

cp1[i,j]<- (1-p1[i,j])*p2[i,j]
cp2[i,j]<- p1[i,j]*(1-p2[i,j])
cp3[i,j]<- p1[i,j]*p2[i,j]
cp4[i,j]<- (1-p1[i,j])*(1-p2[i,j])

mu[i,j,1]<-w[i,j]*cp1[i,j]          #w is binary indicator
mu[i,j,2]<-w[i,j]*cp2[i,j]
mu[i,j,3]<-w[i,j]*cp3[i,j]
mu[i,j,4]<-w[i,j]*cp4[i,j] + (1-w[i,j])

ncap[i,j,1:4]~dmulti(mu[i,j,1:4],1)
}

```

```

N[i]<-(sum(w[i,1:M]))*(exp(cInt))      # calculating abundance per
                                         # transect, cInt=corrected mean
                                         # cluster size

D[i]<-N[i]/(length[i]*0.8)
Dint[i]<-D[i]*length[i]
}

D1<-sum(Dint[1:ntr])/sum(length[1:ntr]) # density calculation
TotN<-D1*14031.38

}

}
", fill=TRUE)
sink()

data <- list ("x","groupsz","ncap","M","ntr","length")
e<-rep(0,ntr)
inits <- function(){
  list (psi=0,cInt=1,betaclust=0.1,rPilot=3,rObserver=3.1,hPilot=0.8,
        hObserver=0.8, interceptP=1.2,intercept0=0.15,ESDslopeP=0.74,
        ESDslope0=0.89)
  list (psi=0,cInt=1,betaclust=0.1,rPilot=3,rObserver=3.1,hPilot=0.8,
        hObserver=0.8,
        interceptP=1.2,intercept0=0.15,ESDslopeP=0.74,ESDslope0=0.89)
#sigma.e=2.5
}
parameters <-
c("D1","TotN","bP","b0","cInt","betaclust","psi","lambdaP","lambda0","rPilot"
,"rObserver",
"hPilot","hObserver","interceptP","intercept0") #"sigma.e"

out <- bugs(data, inits, parameters, "model.txt",
n.thin=nthin,n.chains=nc,n.burnin=nb,n.iter=ni,
          bugs.directory="/Program Files (x86)/WinBUGS14",debug=TRUE)

print(out, digits.summary=5)

}

BQdens.fn()

```

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.

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