Susitna–Watana Hydroelectric Project
(FERC No. 14241)

Big Game Movement and Habitat Use Study

2012 Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	**Definition**
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AEA	Alaska Energy Authority
APA	Alaska Power Authority
APA Project	Alaska Power Authority Susitna Hydroelectric Project
DCH	Delta Caribou Herd
FERC	Federal Energy Regulatory Commission
GIS	geographical information system
GMU	Game Management Unit
GPS	Global Positioning System
ILP	Integrated Licensing Process
km^2	square kilometer
m	meter
mi^2	square mile
NCH	Nelchina Caribou Herd
NEPA	National Environmental Policy Act
Project	Susitna-Watana Hydroelectric Project
RM	River mile based on 1980s project
SD	standard deviation
UD	Utilization Distribution
VHF	Very High Frequency

SUMMARY

Extensive research on wildlife populations was conducted in the Susitna River basin during the 1980s after the Alaska Power Authority (APA) first proposed the Susitna Hydroelectric Project (APA Project). That research included radio telemetry studies and population surveys of moose, caribou, Dall’s sheep, bears, and wolves. The goal of the 2012 study was to acquire and analyze existing data on big game populations in the region in which the Project area is located, including reanalysis of historical data using newer analytical methods, to determine whether additional information on distribution or movement patterns needs to be collected during the 2013–2014 study program for the Federal Energy Regulatory Commission (FERC) licensing process.

The 2012 study had three objectives: (1) identify all relevant data available from the Alaska Department of Fish and Game (ADF&G); (2) synthesize that information with regard to the seasonal abundance, distribution, movements, and habitat use of moose, caribou, Dall’s sheep, brown bears, black bears, and wolves in the Project area; and (3) evaluate the adequacy of that information for assessing potential Project-related effects on these wildlife resources in the middle and upper Susitna River basin.

Data-sharing agreements were developed among ADF&G, the Alaska Energy Authority (AEA), and the Alaska Department of Natural Resources (ADNR), as well as between ADF&G and ABR, allowing ADF&G survey and telemetry data to be obtained by ABR for analysis. This study is the initiation of a multi-year data-synthesis effort beginning in 2012 and continuing in 2013–2014. In addition, ADF&G began Project-specific moose and caribou telemetry studies in 2012, which will continue in 2013–2014 (AEA 2012).

The study area varies somewhat by species, depending on the extent of data collection (refer to accompanying map figures), but is centered on Game Management Unit (GMU) Subunit 13E. When applicable, analyses will include data collected in adjacent subunits such as 13A, 13B, 14B, 16A, and 20A. The study area includes all areas that may be altered or disturbed by the proposed dam, reservoir inundation zone, and associated Project facilities such as access road and transmission line corridors, as well as adjacent seasonal ranges in the upper and middle Susitna River basin. It is important to note that the areas analyzed for historical telemetry data were limited by the extent of the 1980s studies, whereas current studies will focus on the entire Project area.

The availability of telemetry and population survey data varied among different periods. The historical telemetry data from the original APA studies (primarily Very High Frequency [VHF] collar locations) were provided by ADF&G for caribou (1980–1985), moose (1976–1984), brown bears (1978–1985), and black bears (1980–1985). No historical telemetry data were available for Dall’s sheep or wolves. Previous studies conducted in the 1980s primarily used minimum convex polygons to delineate home ranges, so a more advanced geospatial analytical technique (fixed-kernel density analysis) was applied to the historical APA data for the 2012 study. Further consultation and coordination with ADF&G will be necessary to obtain and analyze other, more recent telemetry and population survey data in 2013 and 2014, including studies involving currently deployed animals, such as the moose and caribou studies using new radio collars deployed specifically for the Project (see RSP Sections 10.5 and 10.6 in AEA 2012). The results of the 2012 analyses will be used to inform the analyses of recent and current telemetry and population survey data that will be conducted in 2013 and 2014, in preparation for

the License Application in 2015 (see RSP Sections 10.5.1, 10.5.7, 10.6.1, and 10.6.7 in AEA 2012).

The proposed Susitna–Watana Hydroelectric Project (Project) has the potential to result in direct and indirect impacts on big game populations, habitat use, movements, and distribution. The reservoir inundation zone and proposed access corridor could remove big game habitat and create potential impediments to movements. Disturbance associated with construction and vehicle noise and changes in hunting patterns, recreation, and other human activity has the potential to indirectly affect the numbers and distribution of animals in the region.

The following sections summarize the findings of the 2012 analyses of historical telemetry data:

Moose—The 2012 analysis examined 5,400 telemetry locations of 211 different moose (160 females, 48 males, and 3 of unknown sex) obtained during the historical APA upstream study period from October 21, 1976, to September 10, 1984. Results demonstrate that moose used the proposed reservoir inundation zone and the area near the proposed camp facilities at a high level, especially in winter.

Caribou—The 2012 analysis examined 2,651 telemetry locations of 92 different caribou (74 females, 17 males, and 1 of unknown sex) from the Nelchina Herd, obtained during the historical APA study period from April 14, 1980, to July 9, 1985. The highest seasonal densities of caribou in the Project area occurred during autumn, when the peak estimated seasonal density (based on a herd size of 20,000 animals) was ~1 caribou/km^2 in the reservoir inundation zone.

Brown Bear—The 2012 analysis examined 3,799 telemetry locations of 90 brown bears (52 females, 38 males) obtained during the historical APA study period from April 9, 1978, to September 30, 1985. Although the extent of movements was broad, the home ranges of most collared bears (82%) overlapped with the Project area to some degree. Home ranges calculated using the fixed-kernel density estimator were substantially larger than the original estimates from the 1980s, which were calculated using minimum convex polygons.

Black Bear—The 2012 analysis examined 3,457 telemetry locations of 74 black bears (40 females, 34 males) obtained during the historical APA study period from May 1, 1980, to September 30, 1985. Black bears tended to use lower elevations in river valleys, with most collared bears using the Susitna River valley and its major tributaries. The reservoir inundation zone was used by a large proportion (67%) of the collared bears. The original APA study concluded that such areas were important for black bears, especially in the spring when newly emerging plants, overwintered berries, and moose calves were available there.

Taken together, the analyses begun in 2012 provide additional details to support the original conclusions of the initial Project studies, but with application of more rigorous geospatial analytical techniques. The Project area encompasses historical high-density areas of seasonal use and movements for the Nelchina caribou herd, important winter habitat for moose, and high-use areas of seasonal use for both brown bears and black bears.

Most of the data analyzed thus far date from three decades ago. Although basic patterns of seasonal movements are unlikely to have changed in the intervening period, the populations and distribution of some big game species have changed. Analyses of more recent data from ADF&G will provide crucial information for the eventual analysis of Project impacts to be conducted for the FERC License Application. Those analyses will provide context to understand long-term population and distribution patterns of big game species in the study area.

1. INTRODUCTION

This report provides the results of the 2012 Big Game Movements – Habitat Use Study, based on the work outlined in the 2012 Wildlife Habitat Use and Movement Study plan (AEA 2012).

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, an approximately 300-mile-long river in Southcentral Alaska. The Project's dam site would be located at river mile (RM) 184 (Figure 1).

This study provided information to inform the 2013–2014 licensing study program, Exhibit E of the License Application, and FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

The Susitna River basin is an important region for subsistence and sport hunting and trapping because much of it is easily accessible by road from Anchorage and Fairbanks and has sizable game populations, including moose (*Alces americanus*), caribou (*Rangifer tarandus*), Dall's sheep (*Ovis dalli*), brown (grizzly) bear (*Ursus arctos*), black bear (*U. americanus*), and wolf (*Canis lupus*).

Construction and operation of the Project, as described in the Pre-Application Document (AEA 2011) may result in wildlife habitat loss and alteration, interference with animal movements, disturbance, and changes in human activity. The Project may result in loss of, or displacement from, seasonally used sensitive habitats in the middle and upper Susitna River basin, such as caribou calving areas, bear foraging habitats, and Dall's sheep lambing areas and mineral licks. This study was intended to help characterize and further define data gaps regarding wildlife abundance, distribution, movements, and sensitive habitats and inform subsequent studies developed under the ILP. This study began a multi-year effort to synthesize existing information and collect new data, which will continue in 2013–2014.

Extensive research on wildlife populations was conducted in the region during the early 1980s for the original Alaska Power Authority Susitna Hydroelectric Project (APA Project). That research included radio-telemetry studies of moose, caribou, brown bear, black bear, and wolf populations (e.g., Ballard et al. 1984, Miller 1987, Pitcher 1987, Ballard and Whitman 1988). Since those studies concluded, the Alaska Department of Fish and Game (ADF&G) continued to conduct research and monitoring of big game species in Southcentral Alaska, although not necessarily in the same areas studies for the APA Project. Integration of the historical data with data collected more recently will provide valuable information to inform Project design, mitigation, and impacts analysis, as well elucidating data gaps to inform decisions on research needs and study design.

The study effort will continue in 2013–2014, as part of the analyses for Sections 10.5–10.8 of the Revised Study Plan for the Project, as filed with FERC on December 14, 2012 (AEA 2012).

2. STUDY OBJECTIVES

The objectives of this study were to acquire and analyze relevant data from ADF&G on the abundance, distribution, movements, and habitat use of moose, caribou, brown bear, black bear, Dall's sheep, and wolf in the upper and middle Susitna River basins, and to evaluate the adequacy of that information for assessing potential Project-related effects on these species. This information was intended to help identify any remaining data gaps for use in developing 2013–2014 study plans. An important part of the analytical effort was to apply newer techniques for conducting spatial analyses with a geographic information system (GIS), which were not available at the time the original APA Project studies were conducted.

More detailed, species-specific objectives were listed in the 2012 study plan for moose, caribou, Dall's sheep, bears, and wolves, which will be carried forward under the Study Plan for the formal studies in 2013–2014 as more data become available from current ADF&G studies, including deployment of radio collars on moose and caribou and other population surveys of big game.

3. STUDY AREA

The study area was defined broadly to include all areas that may be affected directly or indirectly by Project activities and facilities, the reservoir inundation zone, access roads, and transmission corridors. The study area included seasonal ranges adjacent to the Project area in the middle and upper Susitna River basin and was centered on Game Management Unit (GMU) Subunit 13E, extending as needed into adjacent areas such as Subunits 13A, 14B, and 16A (Figure 1). Caribou data analyses will incorporate information for both the Nelchina and Delta caribou herds (NCH and DCH, respectively) in the 2013–2014 studies, although only historical data were available for the NCH in the 2012 analysis. The study area for bears includes salmon spawning areas downstream from the Watana Dam site that may be affected by changes in stream flows, temperatures, and ice conditions.

The APA Project studies in the 1980s examined a large area that differed somewhat from the current Project area. The analyses reported here focus on the results of radio-telemetry studies conducted mainly upstream from Devils Canyon, although some data are included farther downstream when radio-collared animals moved. The historical study areas varied among species. Because these analyses focused on telemetry data, the areas where animals were captured and outfitted with telemetry collars were well-defined, but animal movements after collaring were variable. Thus, the outer extent of all the relocations of collared individuals for each species defined their respective study areas.

4. METHODS

Data-sharing agreements were established among ADF&G, the Alaska Energy Authority (AEA), and the Alaska Department of Natural Resources, as well as between ADF&G, AEA, and the study lead (ABR), allowing ADF&G survey and telemetry data to be obtained for analysis by ABR and incorporation into the Project geodatabase, while still adhering to state restrictions regarding access to telemetry locations and harvest data. Although ADF&G began Project-specific moose and caribou telemetry studies in 2012, no data were available yet from those efforts to include in this analysis.

ADF&G provided historical telemetry datasets collected during the original APA Project studies to examine animal distribution and movements in and adjacent to the Project area. Historical telemetry data for caribou, moose, black bear, and brown bear were reanalyzed, using geospatial techniques not available in the 1980s, for comparison with the current Project area components (reservoir inundation zone, associated facility locations, and access and transmission corridors).

Fixed-kernel density analysis was used to delineate range use by the NCH and by individual moose and bears. Seasonal herd ranges and home ranges were compared with the current Project area and statistics were compiled regarding the proportion of animals using various portions of the Project area. Previous studies conducted in the 1980s used the minimum convex polygon method (Mohr 1947) to delineate animal ranges. That technique simply draws a polygon around some or all of the outermost animal locations recorded during occasional radio-tracking surveys. The resulting minimum convex polygon can vary with sample size, is very sensitive to outliers, can encompass large areas of home range that are not used, and does not differentiate between areas of high and low use (Burgman and Fox 2003; Franzreb 2006). In contrast, fixed-kernel density analysis is less sensitive to small sample sizes or outliers (Seaman et al. 1999), is less likely to include unused areas, and produces a utilization distribution (UD) that estimates the relative amount of use of each pixel by an animal within the area of analysis (Seaman and Powell 1996). The UD is a three-dimensional surface that can be used to create contour maps identifying proportional use of the area. For instance, the 50%, 75%, and 95% UD contours used in this report represent estimates of the areas that encompass the corresponding percentages of range use by a collared animal. When fixed-kernel density analysis is conducted using the locations of randomly selected individual caribou from a single herd during a particular season, the UD estimates the relative proportion of the herd found in each pixel during that season.

4.1. Deviations from the Study Plan

Only historical telemetry data from previous research conducted in the late 1970s and 1980s for the original APA Project were available for the analyses reported here. Data collected subsequently to that research for other ADF&G studies have not yet been acquired, but are planned for inclusion in analyses to be conducted for the 2013–2014 studies. Incorporation of data from other studies is not necessarily straightforward because of differences in objectives, study areas, and methods. In addition, the telemetry locations and associated data from the APA Project wolf and wolverine studies could not be located (R. Strauch, ADF&G, personal communication), so the reports and publications describing those studies (summarized in ABR 2011) remain as the only sources of Project-specific information on those species. No telemetry data were collected for Dall’s sheep in the APA Project studies and other population survey data are scant for the Project area (ABR 2011; also see the separate Technical Memorandum on the 2012 Wildlife Harvest Analysis), so that species will be the focus of a new population survey in 2013 (see RSP Section 10.7 of AEA 2012). Hence, the work reported herein focused on reanalyzing historical telemetry data for caribou (1980–1985), moose (1976–1984), brown bears (1978–1985), and black bears (1980–1985).

The historical telemetry datasets consisted entirely of locations of animals that were equipped with standard Very High Frequency (VHF) radio collars. VHF collars require an observer to detect the collar's radio signal and then follow the signal to the animal. These locations often are imprecise, have long and variable periods of time between locations, and have a limited number of locations for each individual. The low spatial and temporal resolution of these older datasets limited the number of analyses that could be conducted in 2012; for example, the sample sizes of telemetry locations were too small to generate seasonal kernel-density estimates for moose and bears. Due to the extensive analyses already completed for these data in the APA Project study reports referenced in the Results below, this reanalysis focused on describing animal distribution in relation to the current Project area, to illustrate the extent of past use, demonstrate the applicability of the techniques planned for use in the 2013–2014 studies, and help identify potential data gaps.

4.2. Caribou

A total of 2,651 telemetry locations of 92 NCH animals (74 females, 17 males, 1 of unknown sex) were analyzed for the period from 14 April 1980 to 9 July 1985. The mean number of locations per animal was 28.8 (standard deviation [SD] = 19.7, range = 3–75). The mean length of time that individual caribou were collared was 2.3 years (SD = 1.4 years, range = 65 days–5.2 years).

Following Pitcher (1987), the year was divided into six different seasons for analysis: spring (1 April–14 May), calving (15 May–10 June), summer (11 June–31 July), autumn (1 August–30 September), the rut (breeding season; 1–31 October), and winter (1 November–31 March). Fixed-kernel densities were calculated for each combination of year and season and for all data from each season. A plug-in bandwidth estimator (Gitzen et al. 2006) was used for this analysis and density kernels were calculated using Geospatial Modelling Environment software (Beyer 2012). Overlaying the seasonal UD contours on the Project area components produced estimates of the proportions of the herd that were within different portions of the Project area during each combination of year and season. Those proportions were multiplied by the size of the NCH (approximately 20,000 animals at the time the data were collected) to estimate caribou density within different parts of the Project area for each combination of season and year.

4.3. Moose

A total of 5,400 telemetry locations of 211 moose (160 females, 48 males, 3 of unknown sex) were analyzed from the APA Project upstream study area for the period from October 21, 1976, to September 10, 1984. The mean number of locations per animal was 25.6 (SD = 24.5, range = 1–105). The mean length of time that individual moose were collared was 2.2 years (SD = 1.6 years, range = 1 week–7.9 years).

Fixed-kernel densities were calculated for each collared moose that was located at least 30 times. A minimum of 30 independent locations should be used when conducting fixed-kernel analysis (Seaman et al. 1999). Given the long time periods between relocation flights, the locations were likely to be spatially independent, but they may have oversampled certain seasons in which multiple tracking flights were conducted.

A plug-in bandwidth estimator (Gitzen et al. 2006) was used for this analysis and kernels were calculated using Geospatial Modelling Environment software (Beyer 2012). Overlaying the UD on the Project area components produced estimates of the proportion of time that each collared individual was within the different portions of the Project area. The 95% UDs of all 69 moose

(62 females and 7 males) with at least 30 locations were mapped and the Count Overlapping Polygons tool for ArcGIS 10.1 (Environmental Research Systems Institute, Redlands, CA) was used to quantify how many of those UDs overlapped with each portion of the Project area.

4.4. Brown Bear

A total of 3,799 telemetry locations of 90 different brown bears (52 females, 38 males) were analyzed for the period from April 9, 1978, to September 30, 1985. The mean number of locations per animal was 38.2 (SD = 38.2, range = 1–163). The mean length of time individual brown bears were collared was 1.7 years (SD = 1.6 years, range = 1 day–5.4 years).

Fixed-kernel densities were calculated for each bear with at least 30 relocations, as described above for moose. The 95% UD contours of all 39 brown bears (29 females and 10 males) with at least 30 relocations were mapped to quantify how many of those home ranges overlapped each portion of the Project area, using the Count Overlapping Polygons tool for ArcGIS.

4.5. Black Bear

A total of 3,457 telemetry locations for 74 black bears (40 females, 34 males) were analyzed for the period from May 1, 1980, to September 30, 1985. The mean number of locations per animal was 41.3 locations (SD = 32.2, range = 1–142). The mean length of time individual black bears were collared was 2.0 years (SD = 1.6 years, range = 1 day–5.4 years).

Fixed-kernel densities were calculated for each bear with at least 30 relocations, as described above for moose. The 95% UD contours of all 42 black bears (26 females and 16 males) with at least 30 relocations were mapped to quantify how many of those home ranges overlapped each portion of the Project area, using the Count Overlapping Polygons tool for ArcGIS.

5. RESULTS

For each of the four species for which historical telemetry data were available, a synopsis of information from previous research is provided, based largely on the wildlife data-gap analysis report (ABR 2011). That background information is then followed by a summary of the results of the reanalysis conducted using fixed-kernel density techniques.

5.1. Caribou

5.1.1. Previous Research

Caribou herds in Alaska generally are delineated on the basis of their fidelity to calving grounds, following the herd concept proposed by Skoog (1968). Caribou occurring in the upper Susitna River basin belong primarily to the NCH. Pitcher (1982) described annual and seasonal distribution information among various geographic areas of the herd range that originally were delineated by Skoog (1968).

Since herd size was first estimated in the late 1940s, the NCH peaked at approximately 70,000 caribou in the early 1960s, then declined precipitously to 7,000–10,000 by the early 1970s. At the time of the original APA Project studies, the herd had increased to 18,713 by 1980 (Pitcher

1982) and 27,528 by 1985 (Pitcher 1987). It grew steadily to about 50,000 animals by 1995, then declined and has remained fairly stable, in the range of 30,000–35,000 caribou, since the mid-1990s. Based on the most recent population census in June 2012, ADF&G estimates that the NCH currently numbers approximately 46,500 animals (ADF&G press release, July 31, 2012).

The caribou study conducted by ADF&G for the APA Project began in April 1980 and ended in October 1985 (Pitcher 1987). The study objectives were to determine the population status of the NCH, delineate subherds, and investigate range use, movement patterns, migration routes, and timing, and to predict Project impacts and recommend mitigation strategies. Using VHF telemetry, researchers tracked 85 collared caribou (including 60 females monitored for two or more calving seasons) for various periods of time (1–63 months) for a total of 2,651 relocations (Pitcher 1987). Telemetry data were supplemented with photocensuses and population composition counts.

In addition to the main NCH, three resident subherds were identified in specific portions of the herd range, based on radio-tracking. About 400 caribou were estimated to reside year-round in the headwaters of the Talkeetna River south of the APA Project impoundment zones. Nearer the Susitna River, the Chunilna Hills had a resident group of about 250 caribou, and about 1,500 caribou used the upper Susitna, Nenana, and Chulitna river drainages year-round. Two additional subherds were suspected to occur in the western Talkeetna Mountains and in the Clearwater Mountains along the southern slope of the Alaska Range, northeast of the Project area.

The APA Project area was located at the western end of the NCH annual range. Winter distribution was highly variable, encompassing a large area east of the Talkeetna Mountains extending across the Lake Louise flats to the Wrangell Mountains, but did not include areas of historical winter use in the Talkeetna Mountains and north of that project's Watana impoundment zone. The core calving area included the drainages of the Oshetna and Black rivers and Kosina Creek. Primary summer range for females was on the northern and eastern slopes of the Talkeetna Mountains. Males tended to lag far behind the females, remaining longer on winter range and spending most of the summer in low shrublands. During the rut (breeding season) in October, caribou were spread from the Talkeetna Mountains east to the foothills of the Wrangell Mountains.

Spruce forests were used primarily during rut, winter, and spring by both sexes. During calving and summer, males tended to use lower elevation shrubland and tundra–herbaceous sites, while females used highland tundra–herbaceous habitats. Deciduous or mixed forest types were used very little.

Spring migration to calving grounds in the eastern Talkeetna Mountains sometimes crossed the upper portion of the APA Project Watana impoundment zone. Historical records indicated that reservoir would have intersected a major migratory route used by pregnant females moving to calving grounds during late April and May, and by females and calves moving from calving grounds to summer range during late June and July (Pitcher 1982). Crossings generally were infrequent but, during spring migration in 1984, 50% of the collared female caribou in the NCH crossed the Susitna River from north to south within the APA Project Watana impoundment zone (LGL 1985). Skoog (1968) considered the geographic area in which the Watana impoundment zone would have been located to be among the most important year-round areas for the herd. Habitat loss was not considered to be an important concern, however, because only a relatively small area of apparently low-quality habitat would be inundated by the two reservoirs proposed for the APA Project (Pitcher 1982). Instead, the principal concern was the need to cross the impoundment zone.

5.1.2. Reanalysis of Historical Telemetry Data

In the first half of 1980s, NCH animals were distributed near the current Project area during all seasons, but the highest densities of caribou generally occurred south or east of the Project area (Figure 2, Appendices 1–6). During calving and summer, the highest densities occurred just south of the inundation zone, but lower densities extended across the Project area to the Parks and Denali highways (Appendices 2–3). During autumn, the area of highest density use included much of the eastern portion of the inundation zone and large portions of the Project area were within the 75% UD contour (Appendix 4). During rut and winter, the herd shifted its range farther east, extending across the Richardson Highway (Appendices 5–6). During spring, the herd moved back toward the west, with a portion of the area of highest density use overlapping the eastern end of the inundation zone (Figure 2, Appendix 1).

Overall, the highest estimated densities of NCH animals in the 1980s in the Project area occurred during calving and autumn and the lowest densities occurred during winter (Figure 3). The reservoir inundation zone had the highest densities among the different Project components, with the Denali corridor having the second highest densities, and the Chulitna corridor having the lowest densities (Figure 3). The density patterns among different Project components generally were similar throughout the year, but the Denali corridor had the highest densities of caribou during the rut and winter seasons.

5.2. Moose

5.2.1. Previous Research

Baseline studies of moose in the Susitna River basin by ADF&G began several years before the formal APA Project study program commenced in 1980. The moose studies for the APA Project were divided into upstream and downstream (above and below Devils Canyon) components, with different investigators and objectives. The upstream study began with radio-collaring in 1976 and ended in January 1986 (Taylor and Ballard 1979; Ballard and Whitman 1988; Ballard et al. 1991). The downstream study began in 1980 and continued through 1986 (Modafferi 1987), with monitoring of population dynamics continuing through 1991, using some of the animals collared for the APA Project studies (Modafferi and Becker 1997).

Between 1976 and 1985 in the upstream study area (upper Susitna River basin), 394 moose were equipped with VHF radio collars and 69 adults were fitted only with numbered canvas collars (Ballard and Whitman 1988). Sixty-one animals originally captured as calves (not including 218 neonates) and 115 adults were located 5,421 times from October 1976 through January 1986. The APA Project upstream study area was reduced in 1983, based on the home ranges of radio-collared moose, to focus more closely on the two APA Project reservoir zones (Devils Canyon and Watana).

All moose exhibited seasonal movements within their home ranges, but the magnitude varied substantially. Home range values were calculated as minimum convex polygons (Mohr 1947), with some modifications to account for steep terrain and heterogeneous habitats (Ballard and Whitman 1988). Moose were classified as resident if seasonal ranges overlapped between summer and winter, or as migratory if they did not. Ballard et al. (1991) reported that home-range sizes averaged 290 km² (112 mi²) for resident moose and 505 km² (195 mi²) for migratory moose. Distances between the summer and winter ranges of migratory animals ranged from 1 to 93 km (0.6–58 miles) (Ballard and Whitman 1988); the moose that moved the farthest were those that summered in the Clearwater Mountains north of the Denali Highway and wintered along the Susitna or Maclaren rivers. Three periods of major movements were identified: autumn and spring migrations and movements during the rut (breeding season). During rut in late September and early October, some moose made distinctive movements to upland areas not used at other times of the year. Most movements of radio-collared sedentary moose occurred from higher elevations in the summer to lower elevations in winter (Ballard and Taylor 1980). Fall migration began between late October and November and appeared to be correlated with the first heavy snowfall (>0.3 meter [m], or 1 foot). Spring migration occurred more gradually, from mid-April through mid-July.

Ballard and Whitman (1988) documented 170 crossings of the Susitna River by 59 (52%) of 113 radio-collared moose, in the two SHP impoundment zones. Several areas near the currently proposed reservoir inundation zone were used extensively, including the mouth of Tsusena Creek, the area midway between Watana Creek and Jay Creek, and areas near the mouths of Jay Creek and Kosina Creek (Ballard and Whitman 1988). Crossings occurred in all months of the year but were common during late winter, peaking in April, when moose occupied winter ranges at lower elevations. [Note: These numbers were minimal and crossing locations were approximate because of the nature of VHF telemetry, which requires tracking from aircraft, unlike the more frequent monitoring that is now possible using satellite or Global Positioning System (GPS) telemetry.]

Vegetation types dominated by spruce and willow were used preferentially by moose. Taylor and Ballard (1979) recorded 70% of moose observations (n = 376) in spruce-dominated habitats and reported that most locations where calves were first seen (n = 20) were in spruce-dominated habitats. Areas with relatively low browse biomass were used heavily by moose during winter, because more browse was available due to shallower snow cover (Ballard et al. 1991). Moose used lower elevations more often during severe winters and moose survival declined during severe winters (Ballard and Whitman 1988; Ballard et al. 1991). The number and density of moose using the SHP Watana impoundment zone varied widely among winters of moderate severity, ranging from 42 to 580 (0.2 to 2.3 moose/km², or 0.4–6.0 moose/mi²) (Ballard and Whitman 1988). Based on the carrying-capacity model developed for the APA Project, Becker (1987) estimated that construction of the two APA Project impoundments would reduce the carrying capacity of the study area by 405 moose during a moderate winter and 674 moose during a severe winter.

5.2.2. Reanalysis of Historical Telemetry Data

A total of 69 radio-collared moose (62 females and 7 males) had 30 or more locations in the historical dataset. The mean home range size, based on the 95% UD contour (i.e., the animal would be expected to be within that area 95% of the time) was 449.0 km² for females (SD = 528.9 km²) and 884.7 km² for males (SD = 532.5) (Table 1). Of the 69 collared moose, the home ranges of 51 animals (73.9%) overlapped with the current Project area (Figure 4, Table 2) and those 51 moose were located in the Project area an average of 11.9% of the time. The reservoir inundation zone had the highest use, with 66.7% of the 69 collared moose using the area for an average of 8.0% of the time (Table 2). The Denali corridor had the lowest use among all portions of the Project area, with 13.0% of collared moose using it for an average of 0.5% of the time, but much of that corridor is outside the area in which moose were collared. The number of overlapping home ranges showed that the highest use by collared moose occurred near the reservoir inundation zone and the dam and camp facility area (Figure 4).

5.3. Brown Bear

5.3.1. Previous Research

The APA Project study of brown bears was conducted upstream of Devils Canyon from 1980 to 1985, during which time 97 individual bears were captured and 53 were equipped with VHF radio collars. The initial capture and release sites were within an area of 2,170 km^2 centered approximately at the confluence of the Susitna River and Watana Creek (Miller 1987). The movements of these bears (including some dispersals and long movements to den sites) encompassed an area of 13,912 km^2, based on 2,901 telemetry relocations. Home range sizes were calculated as minimum convex polygons (Mohr 1947) and were pooled across individuals and years, producing mean values of 1,941 km^2 for males and 501 km^2 for females. Radio-tracking also provided data on population size and density, seasonal movements, dispersal, demography (litter size, age at first reproduction, reproductive interval, cub survival), den locations, and rates of predation on moose calves. Key findings were summarized and potential impacts were discussed in the final report by Miller (1987), which was the primary source of the following information.

The APA Project bear study area (also referred to as the “impoundment impact zone,” which was larger than the area that would have been inundated) was defined empirically as the area in which brown bears would be affected by the proposed reservoirs and was estimated by delineating the home ranges of 53 radio-collared bears. The mean home-range size (males and females combined) corresponded to a circular area 37.5 km (23.3 miles) in diameter. Hence, it was assumed that brown bears would be affected by the APA Project within a corridor extending 37.5 km on each side of the Susitna River, from Devils Canyon upstream to the confluence with the Oshetna River.

Brown bear density was estimated in a portion of the study area using radio-telemetry and a capture–mark–resighting technique (Miller 1987; Miller et al. 1997). Density was estimated at 27.9 brown bears/1,000 km^2 (386 mi^2), resulting in an extrapolated estimate of approximately 327 bears using the APA Project impoundment impact zone (including both of the reservoirs planned for that previous project).

The most significant impact of the APA Project on brown bears was predicted to be loss of habitat due to flooding of the Watana Reservoir. Approximately 12% of the relocations (n = 1,720) of radio-collared brown bears were in the APA Project Watana Reservoir zone; brown bears used that area twice as frequently as expected, both in spring and for all months combined. That pattern of use was evident for males and most females, but not for females accompanied by cubs of the year. Bears spent the highest proportion of time in the APA Project Watana impoundment zone during June, foraging on south-facing slopes for roots, new vegetation, and overwintered berries, and preying on moose calves. Females with young cubs tended to use higher elevations, probably to reduce the risk of predation by male brown bears.

Important sources of food for brown bears in the APA Project study area were ungulates, salmon, and berries. Brown bears preyed on moose calves from late May to early June, with predation rates declining substantially by mid-July (Ballard et al. 1990). Bears, especially males, moved to the Prairie Creek drainage, southwest of Stephan Lake (between the Devils Canyon and Watana dam sites), during July and early August to feed on spawning Chinook salmon (LGL 1985). Despite the availability of protein-rich animal foods, berry production appeared to be the major factor limiting brown bear productivity in the APA Project study area (LGL 1985). Crowberries were most abundant in the impoundment zones, whereas blueberries and lowbush cranberries were distributed more evenly across the entire study area (Miller 1987). Horsetails, an important spring food, were more abundant outside the impoundment zones (Helm and Mayer 1985).

Brown bears frequently crossed rivers. Of 658 locations for males, 14.9% were on the opposite side of the Susitna River from the preceding location, as were 9.1% of 1,668 locations for females. Home ranges of male bears were larger than those of females, and therefore were more likely to span the river.

5.3.2. Reanalysis of Historical Telemetry Data

A total of 39 brown bears (29 females and 10 males) were relocated 30 or more times. The mean home range size, based on the 95% UD contour, was 759.7 km² for females (SD = 637.2 km²) and 3,118.2 km² for males (SD = 2,969) (Table 3). Of the 39 collared brown bears, the home ranges of 32 animals (82.1%) overlapped with the current Project area (Figure 5, Table 4) and those animals used the Project area an average of 7.9% of the time. The reservoir inundation zone had the highest use, with 71.8% of brown bears using the area for an average of 4.0% of the time (Table 4). The Gold Creek corridor had the lowest use among the Project area components, with 51.3% of brown bears using it for an average of 1.7% of the time. Overlap among home ranges showed that the highest use among collared brown bears occurred near the center of the Project area (Figure 5), reflecting an effect of capture location as well as selection by bears of areas within the reservoir inundation zone, as was reported by Ballard and Whitman (1988).

5.4. Black Bear

5.4.1. Previous Research

Previous research on black bears for the APA Project was conducted upstream from Devils Canyon, with the exception of a dietary study in the downstream area. Black bears were studied between 1980 and 1985; 110 individual bears were captured and 32 were equipped with VHF radio collars during that period. The initial capture locations (available in Miller 1987) of the 32 radio-collared bears encompassed an area of 1,120 km^2 with the subsequent relocations (n = 2,195) encompassing an area of 2,950 km^2 (excluding dispersals). Collared bears were tracked to provide data on population size and density, seasonal movements, dispersal, demography (litter size, age at first reproduction, reproductive interval, cub survival), den locations, and rates of predation on moose calves. Key findings, as well as discussion of possible impacts, were summarized in the final report (Miller 1987).

The upstream study area ("impoundment impact zone") was defined as the area in which bears would be directly affected by the two reservoirs proposed for the APA Project. That area was estimated by plotting the locations of all unmarked bears observed (*n* = 282 locations) and of 32 radio-collared bears (*n* = 2,273 locations) during 1980–1984 and then drawing a line around all points, excluding those considered to represent erratic movements (Miller 1987). The mean home-range size, calculated as minimum convex polygons (Mohr 1947) for both sexes combined, was 134.6 km^2 (males = 251.5 km^2; females = 67.1 km^2). Suitable habitat in the upstream study area was restricted primarily to the immediate vicinity of the Susitna River and its major tributaries. The downstream study area below Devils Canyon was based on home-range estimates for 22 radio-collared bears. In contrast to the upstream area, black bear habitat occurred over most of the downstream study area (Miller 1987). The black bear study area differed from the brown bear study area because of differences in habitat preferences and home-range sizes.

Population density was estimated in a portion of the study area using a combination of radio telemetry and a capture–mark–resighting technique (Miller 1987, Miller et al. 1997). Density was estimated at 89.7 black bears/1,000 km^2 (386 mi^2), producing an extrapolated estimate of 107 bears using the two APA Project impoundment zones.

The most significant impact of the APA Project on black bears was predicted to be loss of habitat, including den sites, due to flooding of the APA Project Watana Reservoir, in which 42% of the relocations (*n* = 1,305) of radio-collared black bears occurred (Miller 1987). Bears were particularly abundant in the Watana impoundment zone during May and June, presumably foraging for overwintered berries and newly emerged plants such as horsetails, and preying on moose calves (the same spring food resources used by brown bears). Of 54 dens found in the vicinity of the proposed Watana Reservoir, 30 (55%) were in the area that would have been inundated. The rate of reuse of individual dens in the upstream area was high, suggesting that availability of den sites was limited. Miller (1987) concluded that, although transient black bears likely would continue to use the area, a resident population would not survive in the vicinity of the Watana Reservoir.

Although black bears occasionally ate moose calves, berries seemed to be their most important food source (LGL 1985). Bears spent most of their time in forested areas along creek bottoms, moving out into adjacent shrublands during late summer as they foraged for berries, particularly in the area between Tsusena and Deadman creeks (Miller 1987). The potential for human–bear conflicts was higher in those areas because the shrublands were favored sites for camps, borrow areas, and permanent residences (Miller 1987).

Black bears made extensive seasonal movements up and down the Susitna River, remaining within the forested habitats along the river. Effects of the APA Project on movements were difficult to predict, but crossings may have been inhibited, particularly by the large bay that would have been created near the mouth of Watana Creek (Miller 1987).

5.4.2. Reanalysis of Historical Telemetry Data

A total of 42 black bears (26 females and 16 males) had at least 30 telemetry relocations. The mean home range size, based on the 95% UD contour, was 122.8 km^2 for females (SD = 140.0 km^2) and 583.7 km^2 for males (SD = 477.0) (Table 5). Of those 42 bears, the home ranges of 31 animals (73.8%) overlapped to some degree with the current Project area (Figure 6, Table 6) and those bears used the Project area an average of 22.6 % of the time. The reservoir inundation zone had the highest proportional use, with 66.7% of black bears using the area for an average of

14.2% of the time (Table 6). The Denali corridor had the lowest use among all portions of the Project area, with 28.6% of black bears using it for an average of 0.4% of the time. These figures were affected by the locations where bears were captured but also reflect the fact that most black bear habitat occurs in riverine areas at low elevations. Overlap among home ranges showed that black bears concentrated at lower elevations along the Susitna River, with the heaviest concentration in the western portion of the reservoir zone and near the proposed camp facility area (Figure 6).

6. DISCUSSION AND CONCLUSIONS

Not surprisingly, the reanalysis of telemetry data described above produced results that generally were consistent with those of previous analyses for the APA Project studies, although the analytical technique used provided more robust estimates of range sizes and proportional use of the Project area among species. Because these datasets were analyzed thoroughly in the past for the APA Project studies, we focused on providing additional description and quantification of the distribution of caribou, moose, and bears in the current Project area, as summarized in the sections below for individual species.

Reanalysis of decades-old data can be challenging. Much of the context for understanding movements can be lost and documentation and metadata often are incomplete. Given their age, these data were in remarkably good condition, with a large amount of documentation having been preserved by ADF&G (see Acknowledgments), but some codes were difficult to understand or interpret. Missing values or inconsistencies in the data were difficult to rectify. Given those uncertainties and because the previous APA Project analyses were extensive, we focused our reanalysis on broad patterns of distribution and on evaluating analytical approaches for application to the more intensive telemetry datasets currently being collected by ADF&G for the 2013–2014 moose and caribou studies.

Our results provide additional details to support the original conclusions of these studies. The current Project area is located in or near high-density seasonal use areas for caribou, it contains important wintering habitat for moose, and it is used extensively by both brown and black bears. Whereas brown bears roam widely over large areas that include the Project area, black bears are much more constrained to habitats at lower elevation in the Susitna River valley and adjacent tributaries. Some data gaps in spatial coverage of the current Project area were noted in the historical telemetry datasets (see Figures 4–6), mainly in the western and northern ends of the access corridors, due in part to the fact that much of the APA study emphasis in the 1980s was focused on the two APA Project reservoir impoundment zones, but also because the current corridors differ somewhat from proposed in the 1980s. Collaring animals over a broader study area, as is being done for the current Project studies, will provide data to address those gaps for moose and caribou. Intensive collection of location data from GPS collars will provide much larger sample sizes for use in evaluating seasonal movements and range use in relation to Project components.

The historical telemetry data reanalyzed in this report are about three decades old. Although basic patterns of distribution, movements, and habitat use are unlikely to have changed significantly, the populations of different species undoubtedly have changed over the intervening years, resulting in indirect effects on other species. Analyzing other recent data and collecting current data will provide important findings and additional context for understand long-term population and distribution patterns of big game species in the area, thereby providing a basis for predicting the effects of the current Project during the licensing process.

6.1. Caribou

The current Project area is located in seasonal ranges that generally received medium- and low-density use by the NCH during 1980–1985. Caribou densities in those years were greater in the current reservoir inundation zone and the Denali corridor than in the Chulitna or Gold Creek corridors.

The highest estimated seasonal densities of caribou in the current Project area occurred during autumn, with high-density use occurring in the eastern end of the reservoir zone. The peak estimated seasonal caribou density (based on a herd size of 20,000) was 0.97 caribou/km^2 in the reservoir inundation zone during autumn (Figure 3). The density would be higher at larger herd sizes, assuming the herd distribution remains similar to the distribution observed in the early 1980s. For example, at the current (2012) herd size of 46,500 caribou, all estimated densities in Figure 3 would be 2.3 times higher. Whether these density patterns persist with the current distribution of the NCH will be elucidated by future analyses of telemetry data currently being gathered for GPS and VHF radio collars, which will continue through 2014 (see RSP Section 10.6 in AEA 2012).

In addition, portions of the nearby DCH have begun using some areas near the Project area seasonally (ABR 2011). During 2006–2008, radio-tracking revealed that some DCH animals moved from the north into the upper Susitna River drainage and crossed the Denali Highway, moving as far south as far as Butte Lake (Seaton 2009). The results of the current telemetry study begun for the Project in 2012 and continuing through 2014 will produce a substantial volume of new data for use in delineating the seasonal ranges and movements of caribou in both herds (see RSP Section 10.6 in AEA 2012).

6.2. Moose

Reanalysis of the moose data confirmed the results of previous analyses showing that moose used the Watana Reservoir inundation zone and the vicinity of the proposed camp facilities at a high level. Although the locations at which moose are captured has a large effect on the results in a distributional study, the distribution of home ranges was more concentrated in the Watana Reservoir zone than was the distribution of the initial collar locations (Figure 4), which is consistent with high use of the reservoir for winter habitat. These findings were corroborated by population censuses conducted in 1980 and 1983, which found that the highest moose density occurred upstream from the Watana Dam site, between Watana Creek and Jay Creek (Taylor and Ballard 1979). The results of the late-winter population survey conducted by ADF&G for this Project in March 2012, during a winter of unusually heavy snowfall, will provide further insight into the current importance of the reservoir zone for the regional moose population, producing a preliminary density estimate (uncorrected for sightability) of 1.59 moose/mi^2 (0.61 moose/km^2) in the reservoir inundation zone and immediately adjacent area (K. King, ADF&G, personal communication). The Watana Reservoir zone was used by both resident and migratory moose in the 1980s (Ballard and Whitman 1988) and migratory patterns had strong effects on the size of the home ranges. In general, bull moose had larger home ranges than did cows.

6.3. Brown Bear

Brown bears have large home ranges, with those of males being much larger than those of females. Given the broad extent of the movements by this species, the home ranges of most (82.1%) radio-collared brown bears in the late 1970s and early 1980s overlapped the current Project area to some degree. The home ranges estimated using the fixed-kernel density technique were substantially larger than the original estimates derived using minimum convex polygons (Miller 1987). These differences are thought to have resulted from a combination of using a different home range estimator and the fact that the reanalysis included only those bears for which at least 30 locations were obtained. Minimum convex polygon estimates are highly sensitive to sample size, resulting in lower estimates for animals with few locations.

6.4. Black Bear

Black bears were found at lower elevations in the Susitna River valley and associated tributaries. The reservoir inundation zone was used by a large proportion (66.7%) of the black bears that were collared in the 1980s. Telemetry reanalysis confirmed the finding that black bear range use in the reservoir inundation zone is largely confined to a fairly narrow area centered along the Susitna River. The reservoir zone was important for black bears, especially in the spring when newly emergent plants, overwintered berries, and moose calves were available. Miller (1987) concluded that a resident population would not be likely to persist in the Watana Reservoir zone, but that transient bears would continue to use the area.

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8. TABLES

Table 1. Home range size of radio-collared moose during 1976–1984, based on fixed-kernel density analysis for animals with at least 30 relocations.

Sex	*n*	UD Contour (%)	Mean Size (km^2)	SD (km^2)
Female	62	50	85.0	96.6
		75	193.9	230.2
		95	449.0	528.9
Male	7	50	181.6	134.4
		75	396.2	273.9
		95	884.7	532.5

Table 2. Use of the current Project area by 69 radio-collared moose during 1976–1984, based on fixed-kernel density analysis for animals with at least 30 relocations.

Area	% Moose in Area[1]	Mean % Use[2]	SD[3]
Reservoir Inundation Zone	66.7	8.0	8.7
Dam and Camp Facility Area	27.5	7.1	12.1
Gold Creek Corridor	23.2	3.6	5.0
Denali Corridor	13.0	0.5	0.9
Chulitna Corridor	14.5	4.0	5.3
Total	73.9	11.9	12.7

Notes:

1 Individuals that had >0.01% of use of the area, based on the utilization distribution.
2 Mean percentage of time spent in the area by individual moose, for those moose that used the area.
3 Standard deviation of mean percentage of time spent in the area by individual moose, for those moose that used the area.

Table 3. Home range size of radio-collared brown bears during 1978–1985, based on fixed-kernel density analysis for animals with at least 30 relocations.

Sex	*n*	UD Contour (%)	Mean Size (km²)	SD (km²)
Female	29	50	159.5	109.6
		75	344.1	261.4
		95	759.7	637.2
Male	10	50	690.8	808.6
		75	1,471.7	1,563.1
		95	3,118.2	2,969.0

Table 4. Use of the current Project area by 39 radio-collared brown bears during 1978–1985, based on fixed-kernel density analysis for animals with at least 30 relocations.

Area	% Bears in Area[1]	Mean % Use[2]	SD[3]
Reservoir Inundation Zone	71.8	4.0	4.5
Dam and Camp Facility Area	53.8	2.4	3.0
Gold Creek Corridor	46.2	1.7	2.2
Denali Corridor	51.3	1.4	1.8
Chulitna Corridor	53.8	1.6	2.1
Total	82.1	7.9	5.9

Notes:

1 Individuals that had >0.01% of use of the area, based on the utilization distribution.

2 Mean percentage of time spent in the area by individual bears, for those bears that used the area.

3 Standard deviation of mean percentage of time spent in the area by individual bears, for those bears that used the area.

Table 5. Home range size of radio-collared black bears during 1980–1985, based on fixed-kernel density analysis for animals with at least 30 relocations.

Sex	*n*	UD Contour (%)	Mean Size (km²)	SD (km²)
Female	26	50	23.9	20.7
		75	51.8	48.0
		95	122.8	140.0
Male	16	50	124.5	107.3
		75	271.1	227.7
		95	583.7	477.0

Table 6. Use of the current Project area by 42 radio-collared black bears during 1980–1985, based on fixed-kernel density analysis for animals with at least 30 relocations.

Area	% Bears in Area[1]	Mean % Use[2]	SD[3]
Reservoir Inundation Zone	66.7	14.2	13.8
Dam and Camp Facility Area	45.2	11.5	9.5
Gold Creek Corridor	40.5	2.9	4.7
Denali Corridor	28.6	0.4	0.4
Chulitna Corridor	33.3	2.3	2.6
Total	73.8	22.6	15.9

Notes:

1 Individuals that had >0.01% of use of the area, based on the utilization distribution.

2 Mean percentage of time spent in the area by individual bears, for those bears that used the area.

3 Standard deviation of mean percentage of time spent in the area by individual bears, for those bears that used the area.

9. FIGURES

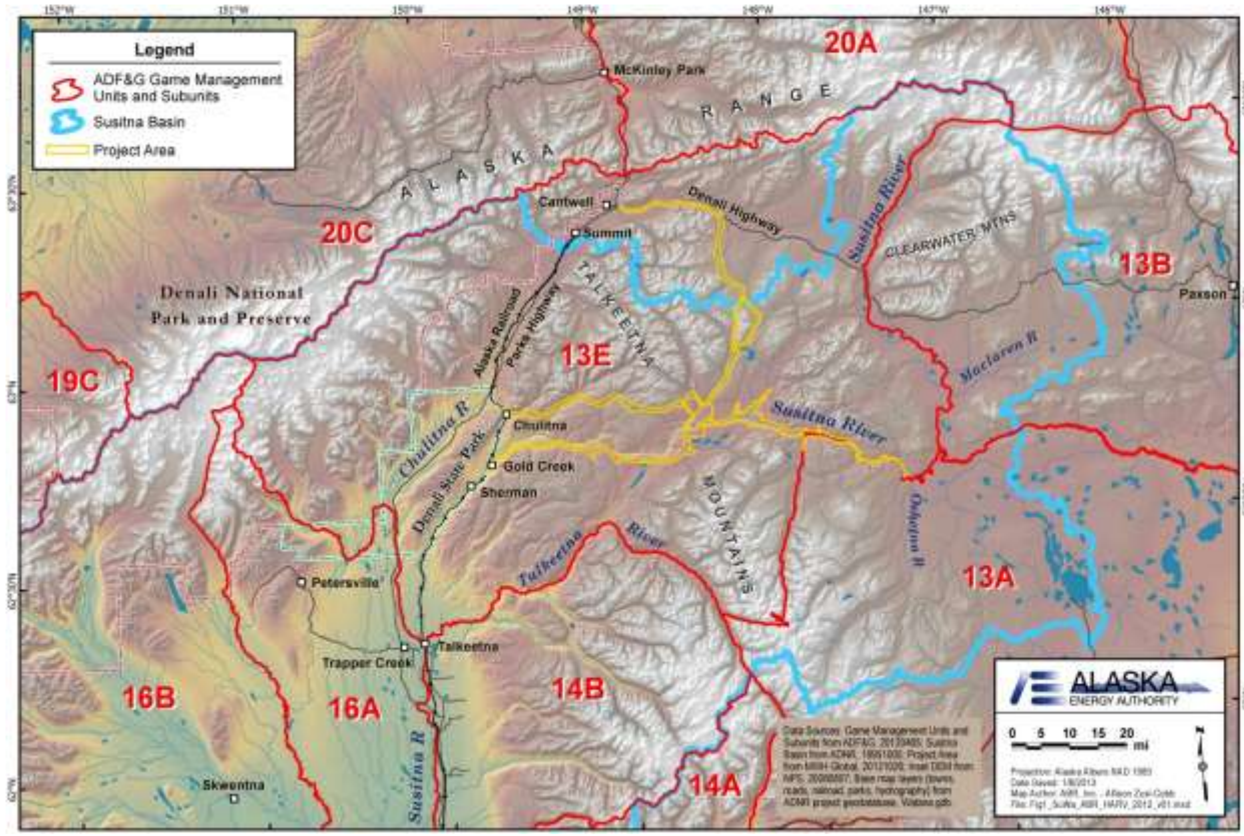


Figure 1. Location of the Project area in relation to state Game Management Units and the Susitna River basin.

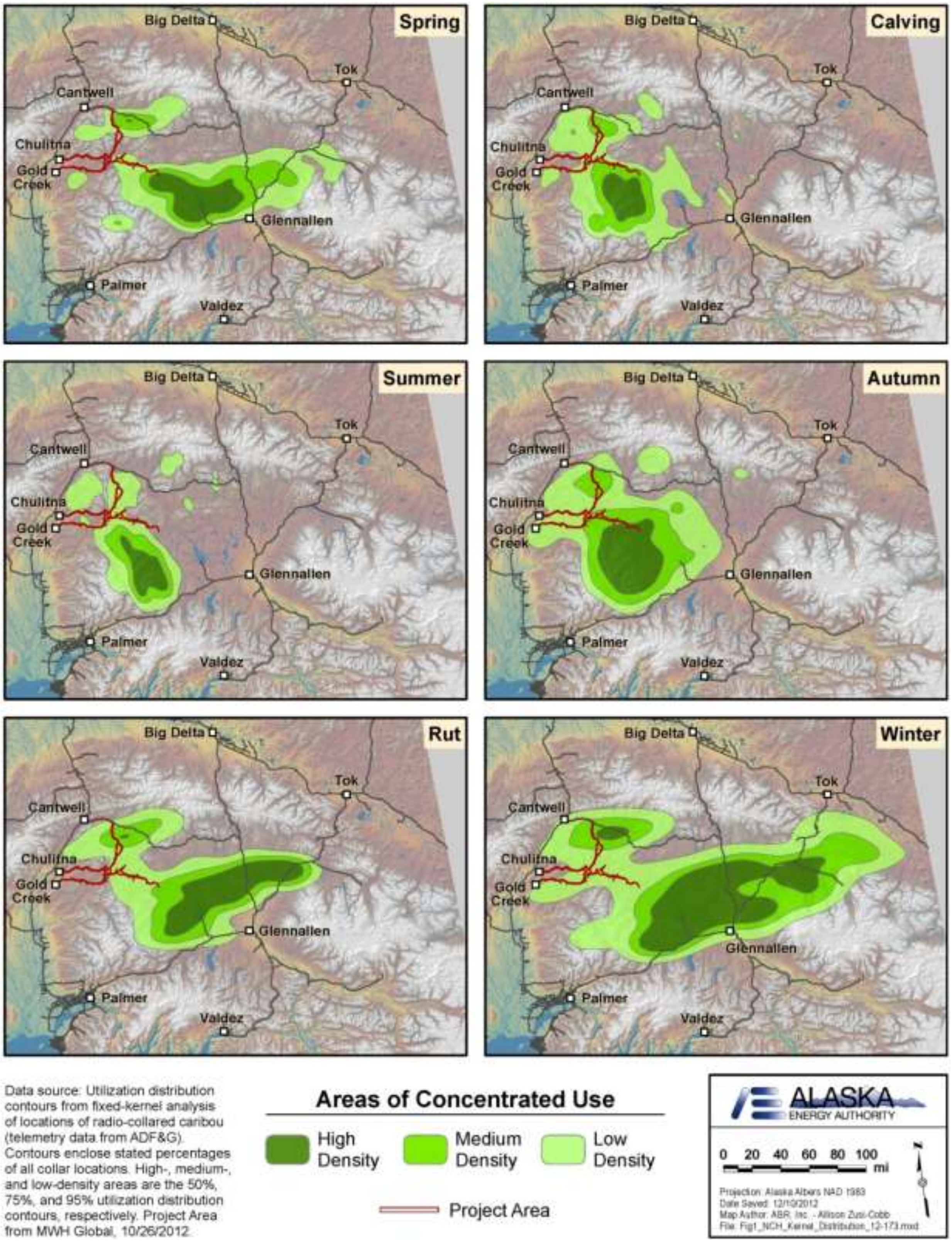


Figure 2. Seasonal distribution of radio-collared caribou during 1980–1985, based on fixed-kernel density analysis of telemetry locations.

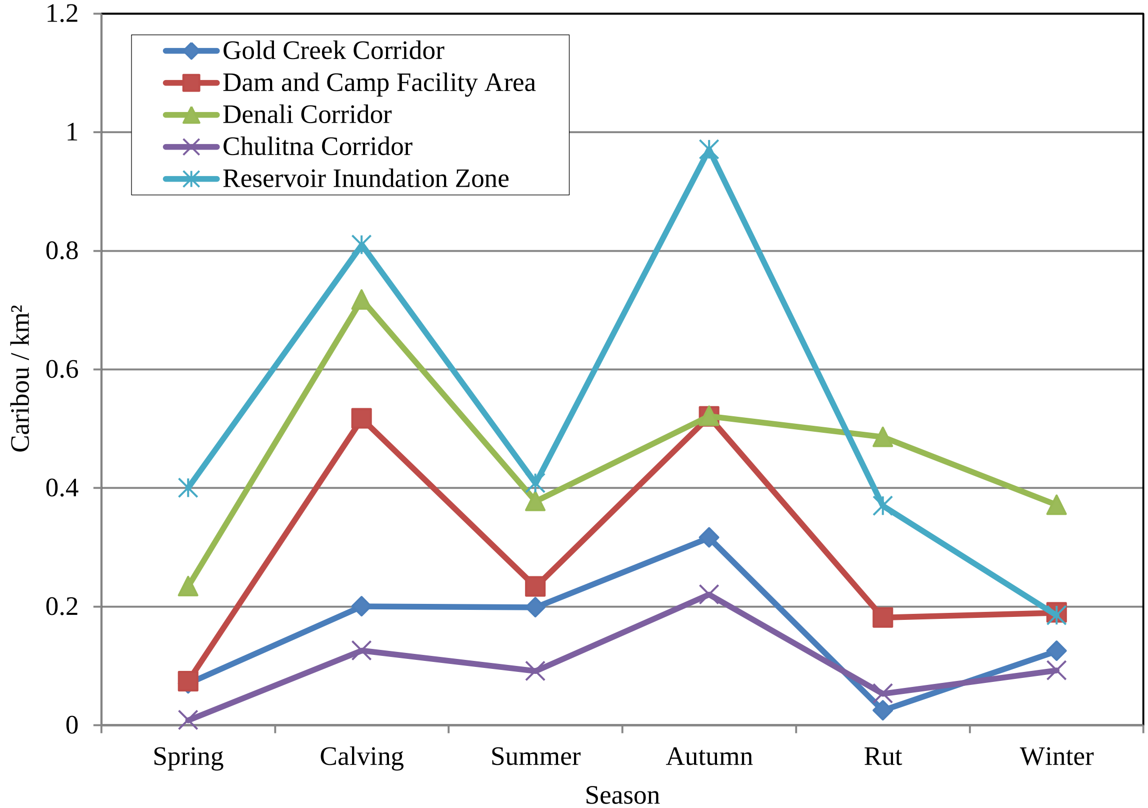


Figure 3. Estimated seasonal density of the Nelchina Caribou Herd (based on herd size of 20,000) that used different portions of the current Project area, based on fixed-kernel density analysis of telemetry data collected during 1980–1985.

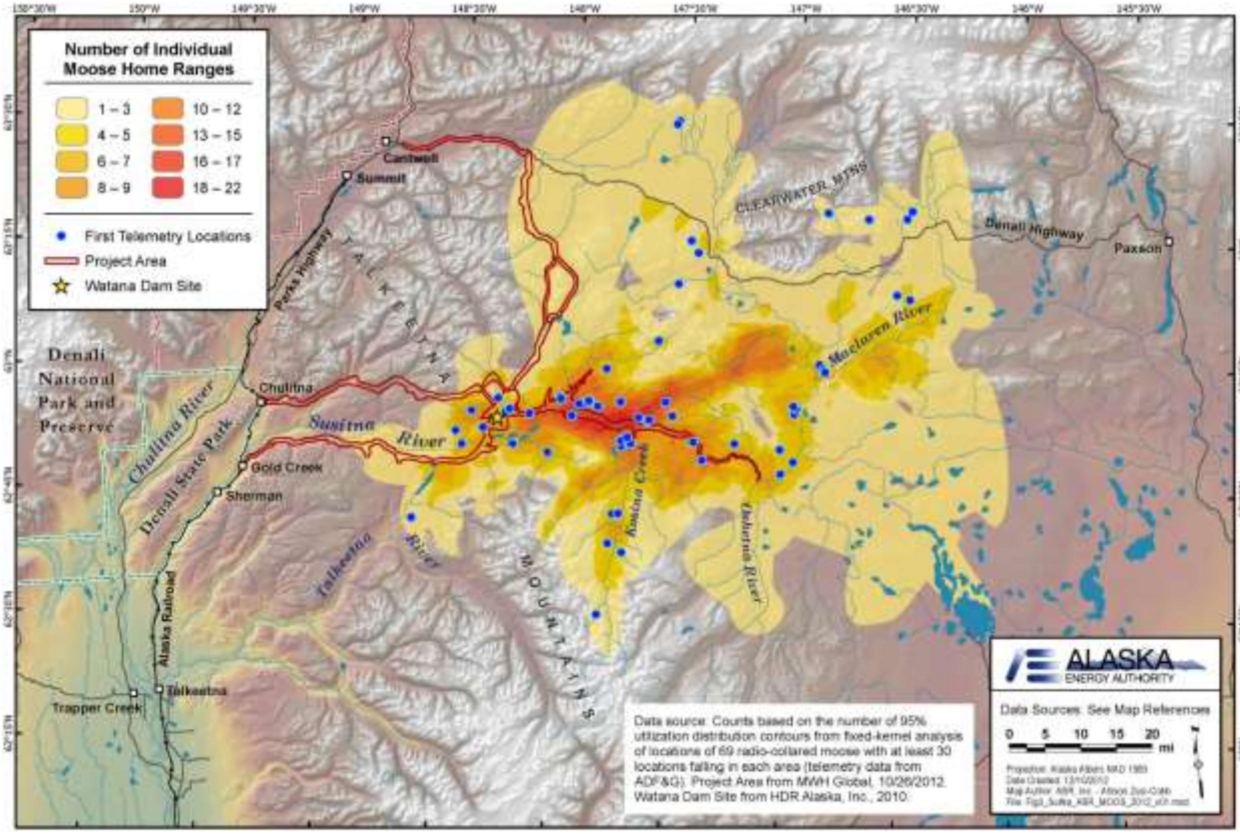


Figure 4. Spatial distribution of the home ranges (95% UD contour) of 69 radio-collared moose during 1976–1984 in relation to the current Project area, based on fixed-kernel density analysis of telelmetry locations.

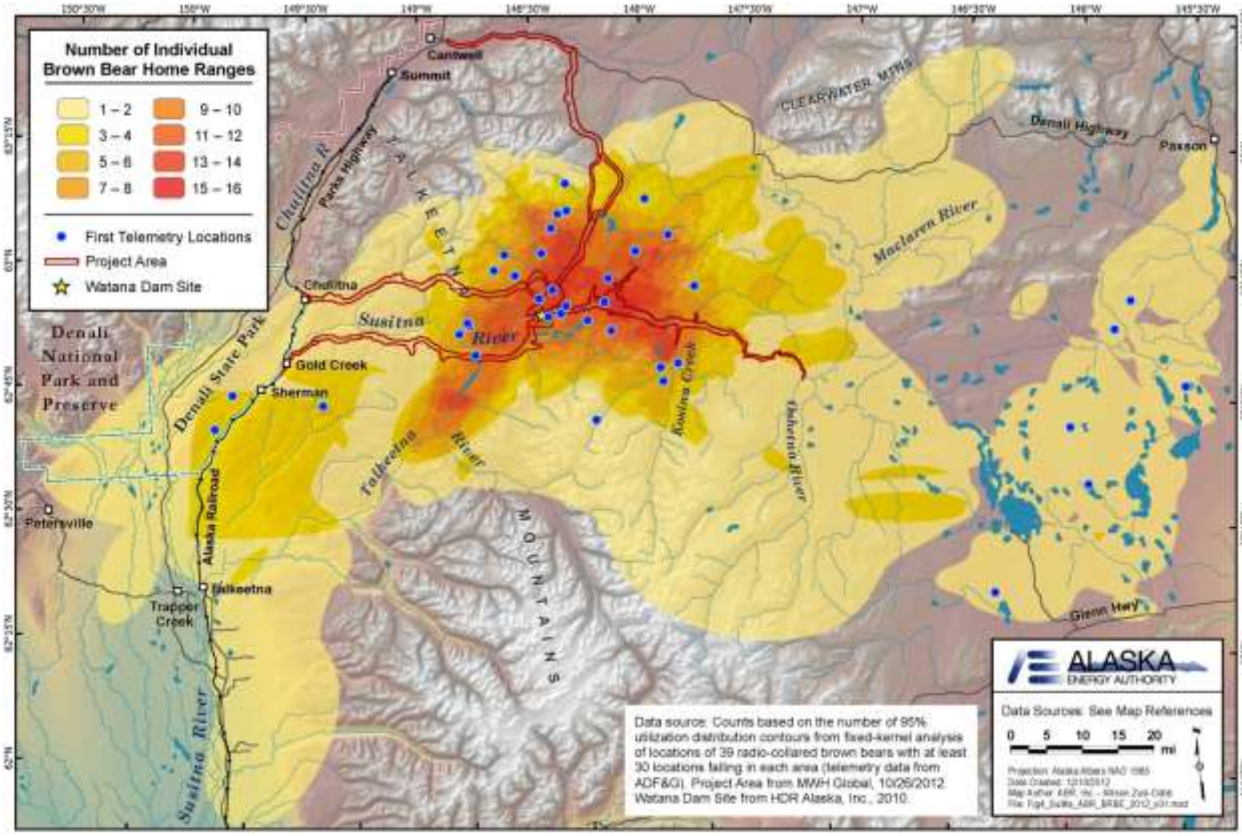


Figure 5. Spatial distribution of the home ranges (95% UD contour) of 39 radio-collared brown bears during 1978–1985 in relation to the current Project area, based on fixed-kernel density analysis of telemetry locations.

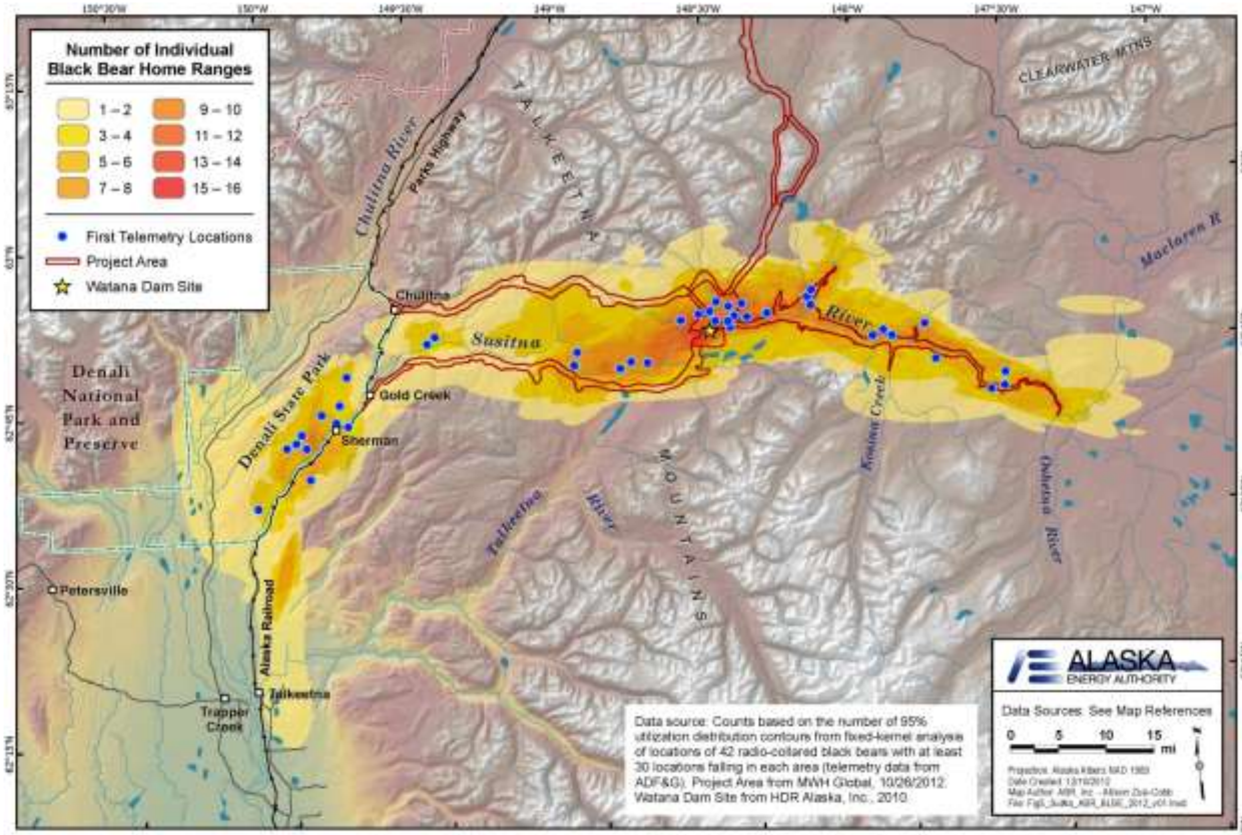
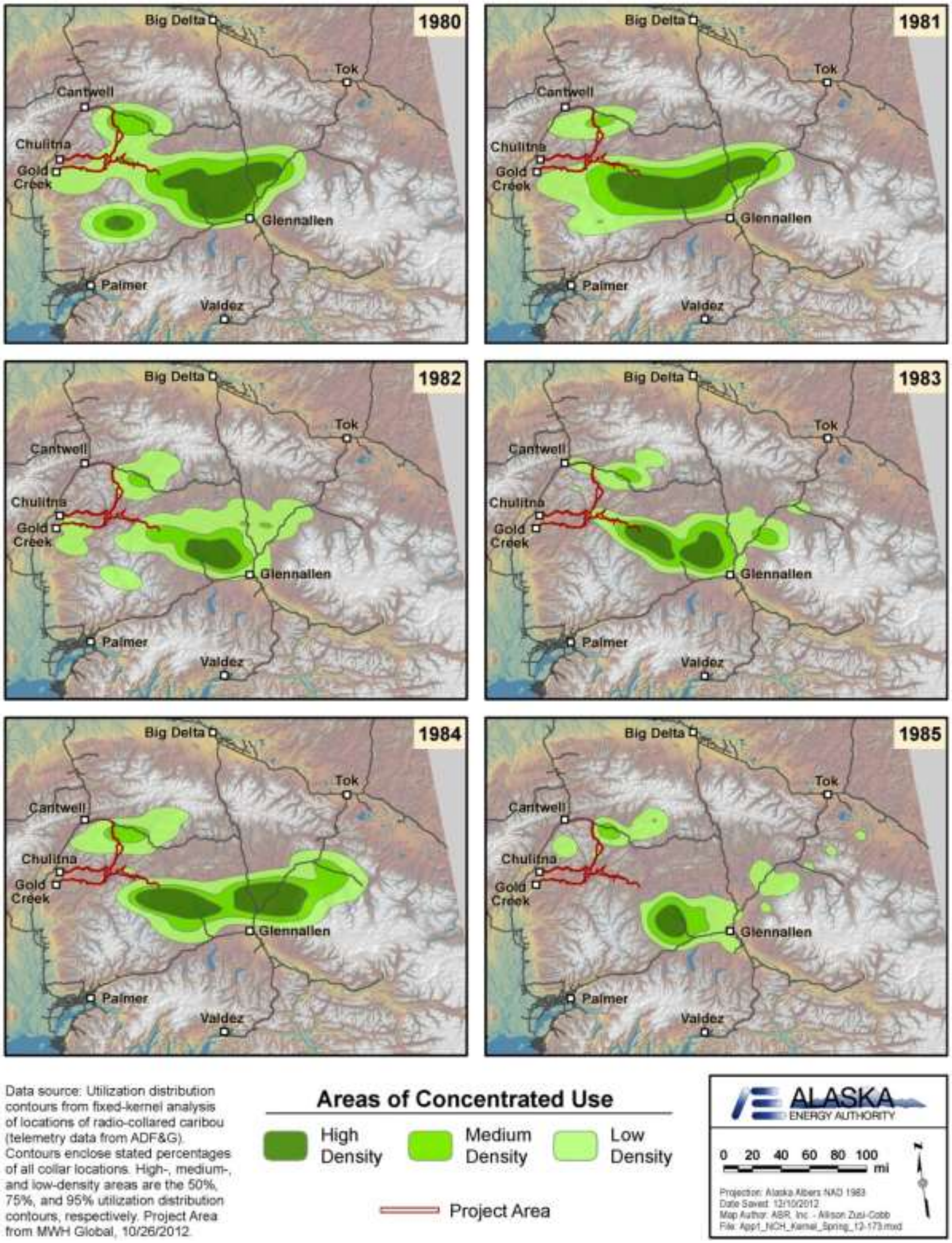


Figure 6. Spatial distribution of the home ranges (95% UD contour) of 42 radio-collared black bears during 1980–1985 in relation to the current Project area, based on fixed-kernel density analysis of telemetry locations.

10. APPENDICES

Appendix 1:

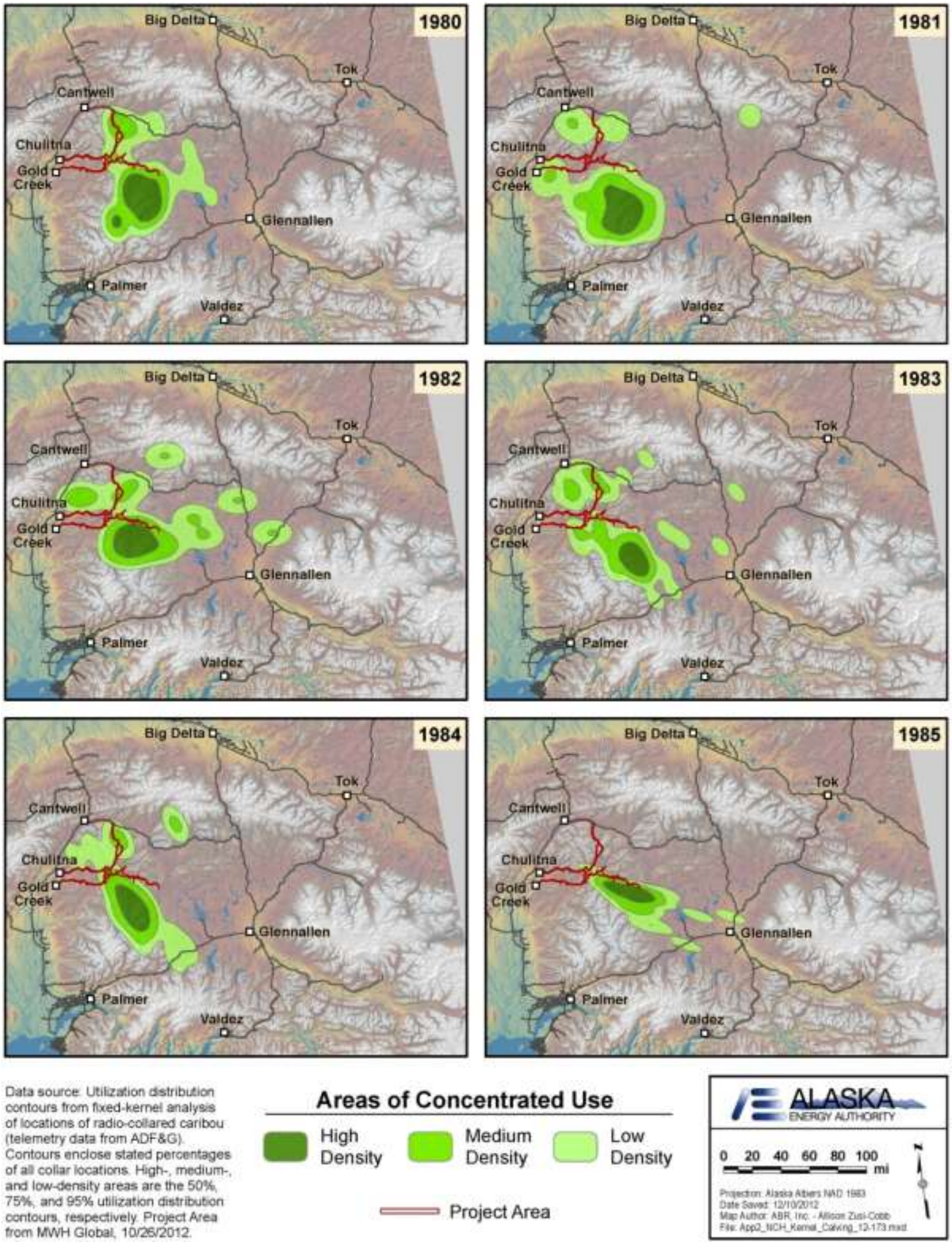
Annual distribution of radio-collared caribou during spring (April 1–May 14) 1980–1985, based on fixed-kernel density analysis of telemetry locations



Appendix 1. Annual distribution of radio-collared caribou during spring (April 1–May 14) 1980–1985, based on fixed-kernel density analysis of telemetry locations.

Appendix 2:

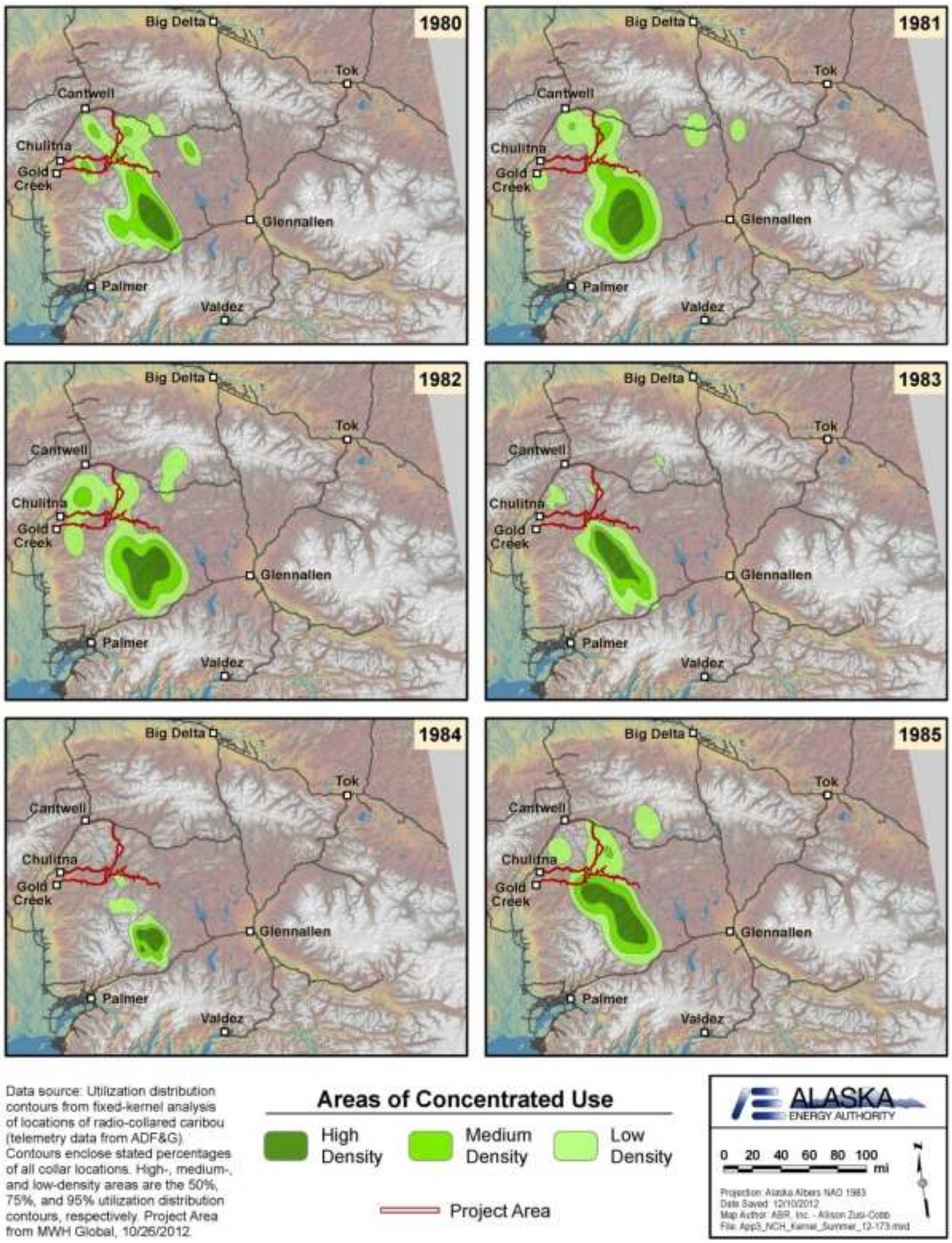
Annual distribution of radio-collared caribou during calving (May 15–June 10) 1980–1985, based on fixed-kernel density analysis of telemetry locations



Appendix 2. Annual distribution of radio-collared caribou during calving (May 15–June 10) 1980–1985, based on fixed-kernel density analysis of telemetry locations.

Appendix 3:

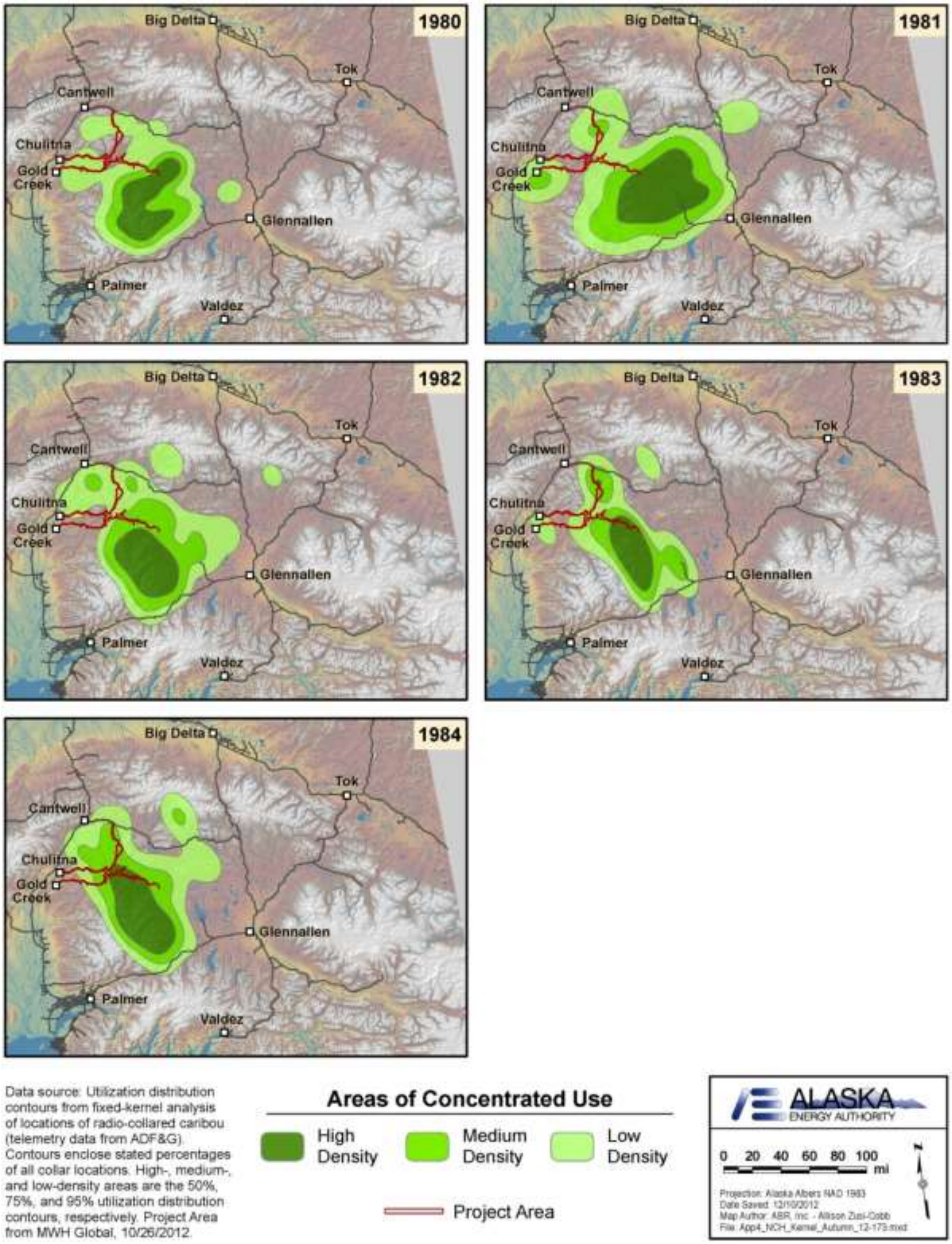
Annual distribution of radio-collared caribou during summer (June 11–July 31) 1980–1985, based on fixed-kernel density analysis of telemetry locations



Appendix 3. Annual distribution of radio-collared caribou during summer (June 11–July 31) 1980–1985, based on fixed-kernel density analysis of telemetry locations.

Appendix 4:

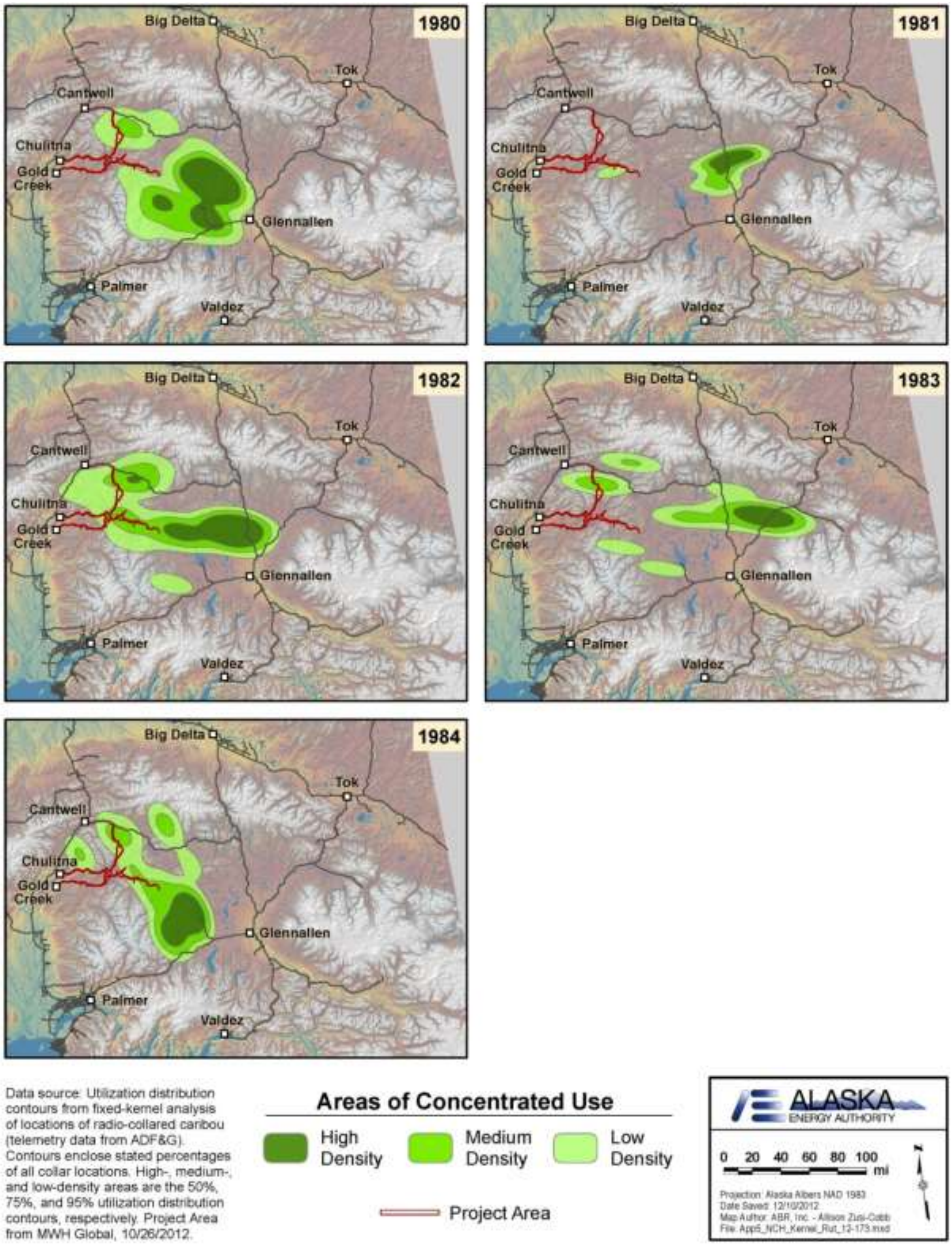
Annual distribution of radio-collared caribou during autumn (August 1–September 30) 1980–1984, based on fixed-kernel density analysis of telemetry locations



Appendix 4. Annual distribution of radio-collared caribou during autumn (Aug. 1–Sep. 30) 1980–1984, based on fixed-kernel density analysis of telemetry locations.

Appendix 5:

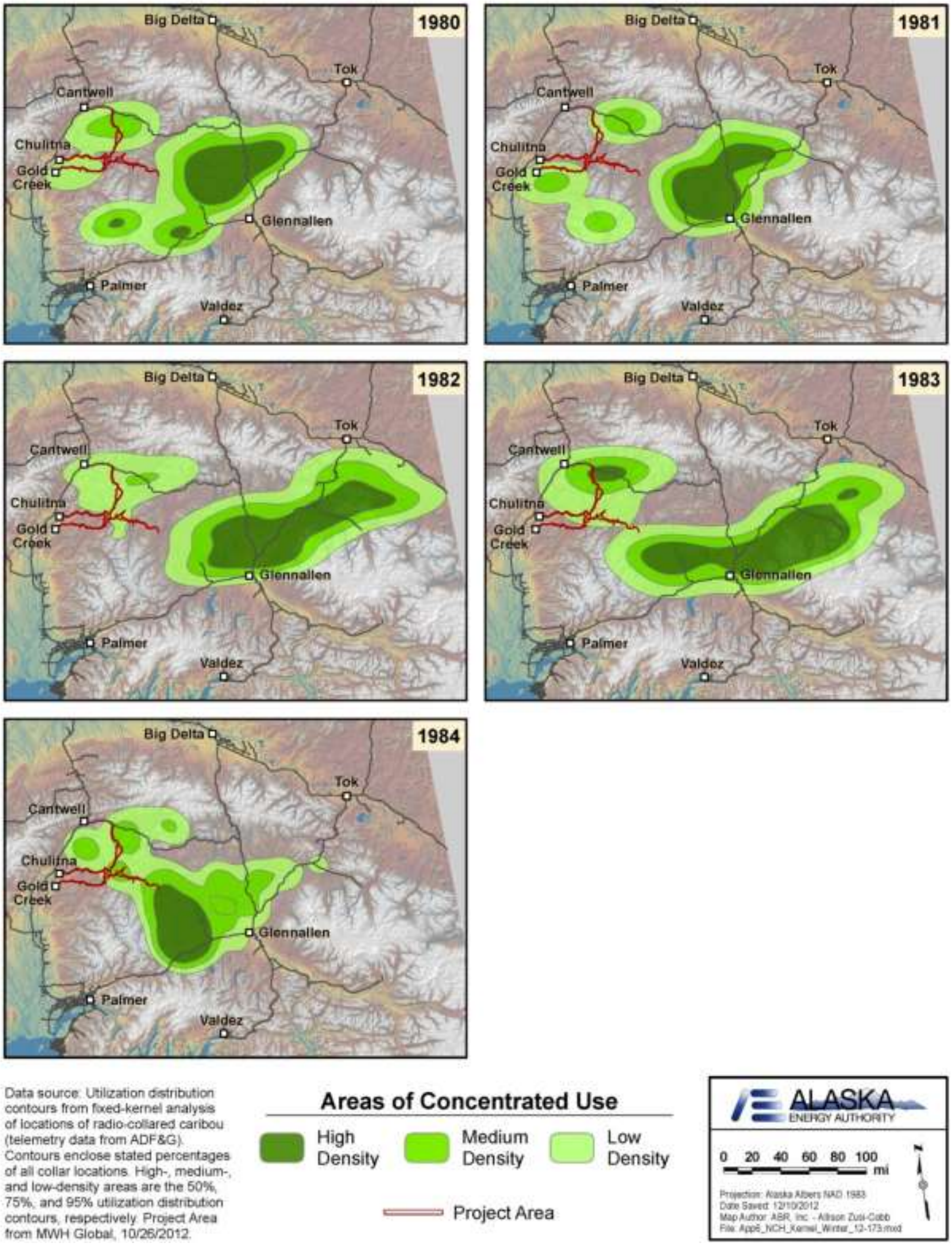
Annual distribution of radio-collared caribou during the rut (October 1–31) 1980–1984, based on fixed-kernel density analysis of telemetry locations



Appendix 5. Annual distribution of caribou during the rut (October 1–31) 1980–1984, based on fixed-kernel density analysis of telemetry locations.

Appendix 6:

Annual distribution of radio-collared caribou during winter (November 1–March 31) 1980–1984, based on fixed-kernel density analysis of telemetry locations



Appendix 6. Annual distribution of radio-collared caribou during winter (November 1–March 31) 1980–1984, based on fixed-kernel density analysis of telemetry locations.