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Distribution, movements, and survival of Dall's Sheep (*Ovis dalli dalli*) in the White Mountains, Alaska

Yukon Flats National Wildlife

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On the cover
A family group of Dall's sheep traverse elevated terrain near Victoria Mountain in the White Mountain. Photgraph courtesy of the U.S. Fish and Wildlife Service.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Distribution, movements, and survival of Dall's Sheep (*Ovis dalli dalli*) in the White Mountains, Alaska

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ABSTRACT

The study of Dall's sheep (*Ovis dalli dalli*) in the White Mountains of interior Alaska was conducted from 2004 to 2008 to acquire baseline data on home ranges, movements, and survival. This was initiated partially in response to a proposed action to establish an oil and gas pipeline corridor through sheep habitat. A total of 63 sheep, including 44 females (mean age = 6.8) and 19 males (mean age = 3.3), were fitted with global positioning system radio collars of which 56 sheep gathered over 350,000 locations. The mean Brownian bridge movement model mean (BBMM) isopleth home range estimate at the 95 percentile for females and males were 56.18 km^2 (n = 43) and 42.83 km^2 (n = 13), respectively. The minimum convex polygon home range estimate for all sheep was 213.73 km^2 (n = 56); mean home range estimates for females and males were 183.60, (n = 43) and 313.09 km^2 (n = 13), respectively. For ewes the mean BBMM isopleth home range estimates at the 95 percentile for the lambing, summer, fall, rut, and winter seasons ranged from 304.433 to 402.612 km^2. For rams the mean BBMM isopleth home range estimates at the 95 percentile for the lambing, summer, fall, rut, and winter seasons ranged from 85.069 to 207.97 km^2. The earliest observation of lambs with radio collared ewes in 2005 and 2006 was on May 16. Mineral licks were scattered throughout the study area in all regions and varied in elevation and vegetative composition. Sheep population mark-resight surveys were conducted during summer 2005 and resulted in a sightability estiamte of 0.78. Of the 63 sheep fitted with radio collars, and excluding capture-related mortality (n = 10), 13 sheep died from predators (n = 7) or other sources (n = 6). Annual survival rates for female radiocollared sheep from 2004 to 2008 were 92%, 85%, 82%, and 100%, with a mean rate of 90% (n = 115). We suspect these are minimum rates since our sample was skewed to younger age animals. We found evidence that a severe winter rain-on-snow event accompanied by high winds likely had a measurable negative effect on survival. Forage quality assessment revealed grasses and sedges dominated winter and summer diets, respectively. Lungworm (*Protostrongylus stilesi*), was present in 97% of samples taken from live sheep (n = 34); infestation rates taken from feces collected at mineral licks ranged 50-100%. Trace element analyses conducted on hair (n = 39), serum (n = 28) and whole blood (n = 24) indicated one-third to two-thirds of sampled individuals had marginal to deficient levels of copper, selenium, zinc and Vitamin E compared to domestic sheep reference ranges. Unimpeded access by sheep to critical habitats such as mineral licks, lambing and rutting areas, and connectivity corridors between regions is necessary to ensure a viable sheep population in the White Mountains. This study provided baseline data on these demographics in anticipation of a proposed pipeline corridor through sheep habitats in the Mount Schwatka and Victoria Mountain regions. We documented 149 crossings from 12 sheep across the proposed right of way for

the southern oil and gas pipeline corridor. These data will be useful to managers in the future to avoid placement of access routes through sensitive sheep habitats and to anticipate other potential impacts to sheep in this region.

INTRODUCTION

From 1993 to 2004 the Native regional corporation Doyon Limited (Doyon) offered three proposals to the Yukon Flats National Wildlife Refuge (Refuge) to pursue resource development activities on Refuge federal lands which are situated in the Yukon Flats Basin, an area of suspected oil and gas reserves. In 2004, Doyon proposed to exchange 60,703 ha of Doyon lands within or adjacent to the Refuge for approximately 44,515 ha of Refuge lands (Figure 1) which prompted the Refuge to complete an Environmental Assessment in 2005 and an Environmental Impact Statement (EIS) in 2010. The proposed action identified potential areas of oil and gas development and pipeline and access corridors. One of the proposed pipeline corridors bisected Dall's sheep (*Ovis dalli dalli*) habitats in the northern White Mountains National Recreation Area (WMNRA) that could potentially impact sensitive sheep habitats. The addition of a pipeline corridor into this region could also improve human access including for hunters, which would likely increase hunting pressure and harvest. Since adequate baseline data on Dall's sheep and their habitats were lacking, there was a clear need to collect information to better assess the potential impacts of the proposed oil and gas development activities on sheep, and to identify future mitigation strategies. Information on sheep ecology and their movements would also be beneficial to develop annual harvest recommendations, identify critical sheep use areas, and inform ongoing and future land use planning efforts (BLM 2016) which may include travel management and recreation access development.

Oil and gas activities can include a variety of disturbance factors to the landscape stemming from road and pipeline corridor construction; water pollution from drilling and production wastes, oil spills, and wastewater discharge; air pollution including road dust and facility emissions; production of solid and liquid wastes; alteration or elimination of fish and wildlife habitats; displacement of wildlife from habitats; noise emissions from facilities and support aircraft; and increased human access (Truett and Johnson 2000, NRC 2003). All of these factors can exacerbate already present natural stressors in wildlife such as inter and intraspecific competition, density, adverse weather, lack of trace minerals, parasites, and predation and, when prolonged, can cause suppression of the immune system through gastric ulcers and have adverse impacts to population growth (Boyce 1991).

Noise is a disturbance stimuli that may impact sheep behavior. Disturbance from fixed-wing aircraft flying less than 100 m above ground level was found to displace sheep more than 100 m 19% of the time (Krausman and Hervert 1983). Frid (2000, 2003) observed that sheep are more likely to flee greater distances and disrupt resting the more direct the angle of approach by fixed-wing aircraft (Cessna 206) or helicopter. They also observed that indirect approaches by helicopters were more likely to cause sheep to flee when sheep were far from rocky terrain. Lawler et al. (2004) examined the effects on behavior of a marked population of sheep at Yukon-Charley Rivers National Preserve from 1997 to 2002, in response to military aircraft overflights ranging from 100-5,000 feet above ground level during lambing season (May 10-June 15). They concluded that overflight military activity generally did not cause significant effects on sheep behavior or habitat use.

Reynolds (1974) observed Dall's sheep using a mineral lick in the Brooks Range did not alter behavior to compressor noise but did react strongly to helicopter aircraft flying within 150 m. Lenarz (1974) observed that helicopters flown within 91-152 m caused 85% of Dall's sheep to leave their position and ewes displayed more reaction than rams (94% vs 77%). Other work using radiocollared bighorn sheep (*Ovis candensis*) found that helicopter disturbance altered movement, habitat use, and foraging efficiency; sheep moved 2-5 times further away on the day following helicopter disturbance; greatest distances traveled were in spring; and sheep did not habituate to the disturbance (Bleich et al.1990, 1994). Stockwell et al. (1991) found helicopters caused bighorn sheep to feed less efficiently (43%) in winter with no significant effect in summer. They reasoned that bighorns are active during 69% of daylight hours in winter and then need more time to rest and ruminate, and postulated that if sheep do not habituate to helicopters the negative impacts to foraging efficiency become cumulative.

Frid and Dill (2002) categorized excessive noise and fast moving objects as a form of predation risk due to the induced flight response. They reasoned that time and energy expended reacting to disturbance diverts time from fitness enhancing activities such as feeding, parental care, or mating. Therefore sheep incur energy costs when disturbed by helicopters. These costs result from overt behavioral responses including fleeing, habitat shifts, increased movement, and lower foraging and resting rates. These costs may reduce reproductive success and impact population size.

The reactions of sheep to disturbance from ground-based activities including hikers, vehicles, and bicyclists have also been studied. Of these factors, hikers caused the most severe response and additionally there was avoidance of road corridors by sheep (Papouchis et al. 2001). Miller and Smith (1985) estimated that 40% of bighorns observed reacted strongly to humans, the closer and larger the human disturbance the farther away sheep fled, and rams reacted more strongly than ewes. Hicks and Elder (1979) noted that the distance, juxtaposition, age and sex composition, and herd size are important factors in reaction of bighorns to humans. Hamilton et al. (1982) documented human disturbance at mineral licks and observed that bighorn sheep avoided use of licks when humans were present but did not abandon use of sites.

In summary, helicopters elicit a stronger reaction by sheep compared to fixed-wing aircraft; ground disturbance by humans can also be a significant source of stress. Human disturbance could create adverse effects by creating energetic costs to sheep by displacing them from feeding sites, decreasing forage time, interrupting resting (ie., decreasing rumination) and increasing unnecessary movement. It is theorized that if these costs occur at a frequent rate, disturbance could have adverse impacts on body condition and reproductive success, and population size. Given the expected large amount of aircraft support and human disturbance that usually accompanies establishing and operating oil and gas activities, it is important to establish a baseline of population dynamics on Dall's sheep in the study area.

The following objectives were developed to better manage Dall's sheep and their habitats in this region.

OBJECTIVES

a) Provide baseline data on sheep ecology to address placement of oil and gas access corridor in the Mount Schwatka and Victoria Mountain regions.

b) Determine seasonal movement patterns, range fidelity, and home ranges of female and young male Dall's sheep in the White Mountains, with emphasis in the Mount Schwatka and Victoria Mountain regions.

c) Identify potentially sensitive sheep habitat, including mineral licks, lambing areas, rutting grounds, and access corridors between use areas.

d) Identify the extent of sheep interchange between use areas in the White Mountains.

e) Develop a sightability correction factor (SCF) for annual sheep population surveys using mark/recapture techniques.

f) Identify forage and forage quality in seasonal use areas.

g) Determine annual sheep harvest levels, population size, and survival rates

STUDY AREA

The sheep study area straddles the southern boundary of the Refuge and includes the WMNRA and Steese National Conservation Area, administered by the Bureau of Land Management (BLM) (Figure 2). The sheep population is distributed over a approximately 200 square kilometer (500 square mile) area in mountainous terrain known as the White Mountains and includes six regions: Mount Schwatka (peak elevation 1,270 m, 4,177 ft), Victoria Mountain (1,395 m, 4,588 ft), Limestone Ridge (1,263 m, 4,153 ft), Cache Mountain (1,451 m, 4,772 ft), Rocky Mountain (ie., Lime Peak) (1,539 m, 5,062 ft), and Mount Prindle (1,607 m, 5,286 ft). The terrain in these areas is steep with rounded ridges, barren and rocky peaks, and stony and boulder slopes and comprised of limestone, granite, schist and slate (Gross 1963). Slopes on or near Mount Schwatka are characterized by gently sloping granitic inclusions with adjoining ridges of precipitous limestone. Limestone Ridge is characterized with a prominent jagged ridge of pale limestone giving the region its name, the White Mountains (Juday 1989). The Lime Peak, Victoria Mountain, Cache Mountain, and Mount Prindle regions are mostly granitic, with steep boulder field, gravelly slopes, and granitic tor outcroppings (Juday 1988). Soils are shallow, formed in stony, weathered material from local rock, and are poorly drained with a shallow permafrost table. Soils are classified as Histic Pergelic Cryaquepts, Typic Cryochrepts, Pergelic Cryumbrepts, Lithic Cryorthents, and Typic Cryorthods (Reiger et al. 1979).   Lowlands in the study area are characterized by mixed forests dominated by white spruce (*Picea glauca*), black spruce, (*Picea mariana*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*). Shrub communities of alder (*Alnus* spp.) and willow (S*alix* spp.) are most common in riparian areas. Alpine habitats are characterized by grasses (*Calamagrostis purpurascens*), sedges (*Carex* spp.), forbs (*Equisitum* spp. *Lupinus* spp.), mosses, lichens (*Cladina* spp., *Cladonia* spp.) and shrubs (*Dryas*, *Salix* spp.). Sheep habitats in this region are characterized by little influence from maritime weather, low elevation, non-precipitous, and escape terrain is limited to small islands of habitat surrounded by boreal forest.

The White Mountains population of Dall's sheep is isolated from other populations in the Yukon-Tanana Uplands. The nearest Dall's sheep occur in the Big Windy Creek area, a distance of 97 km. The intervening habitat is mountainous but lacks escape terrain.

The 44,515 hectare (110,000 acre) Refuge parcel sought by Doyon is situated in the southern Yukon Flats adjacent to the northern foothills of the White Mountains and includes a portion of the sheep study area (Figure 1). The proposed southern pipeline route follows Victoria Creek and bisects the Schwatka and Victoria sheep use regions. The proposed northern pipeline route traverses the northern edge of the Schwatka sheep use region.

The first recorded counts of sheep in the Mount Schwatka and Victoria Mountain regions were made in 1929 and 1944, respectively (Appendix K1 and K2). Scott (1949) described the first aerial surveys of the White Mountains population. The White Mountains sheep population in all regions (Game Management Units 25C and a small portion of 25D) has been censused following consistent protocol through a cooperative effort by Alaska Department of Fish and Game (ADF&G), BLM and the Refuge since 1994 (Hollis 2014, USFWS 1998, USFWS 2015). Baseline distribution and movement data was first collected by BLM on ten sheep, three female sheep collared at Victoria Mountain, and 7 sheep collared at Rocky Mountain (2 males, 5 females) from 1983 to 1987 (Durtsche et al. 1990). Hunting pressure and harvest has historically been low in this population due to the low availability of legal rams. BLM has one permitted guide using the area for Dall's sheep hunting.

METHODS

Capture and handling

Sheep were captured with a hand-held net gun shot from a Robinson R-44 helicopter with a door removed and gunner harnessed. Tandem fixed-wing aircraft (Aviat Husky, PA-18, and Bellanca 8GCBC Scout) were used to locate sheep, guide the helicopter to the sheep, and record pursuit times. The helicopter pilot (with only the gunner on-board) typically maneuvered sheep gently uphill in an effort to slow their travel prior to netting in moderate terrain. Capture efforts were discontinued when a sheep had been pursued for 2 minutes or if the animal moved to unsafe terrain for either the animal or capture crew. Chase times were typically 0.5 to 1 minute. We avoided capturing >1 sheep per group within a 24-hour period. Older rams were also avoided due to their high susceptibility to harvest.

Initial captures, in late March of 2004, resulted in death of two of the three sheep captured. Capture was stopped until an evaluation and modifications to protocols were made. We subsequently administered xylazine intranasally as quickly as possible following netting to calm the animal and a vitamin E and selenium supplement Bo-Se®, as described below. In addition, we limited captures to fall and early winter (avoiding late-winter and spring, when sheep were presumably in poorer physical condition).

After netting, the gunner was dropped off in the vicinity of the sheep and immediately administered a mixture of 0.15 ml (100mg/ml) xylazine (TranquiVed®; VEDCO, St. Joseph, Missouri, USA) diluted in 5 ml of physiologic saline to the sheep intranasally via a 6F rubber catheter (length 35 cm, dia 4 mm) and began hobbling the animal. Xylazine was given to minimize stress and animal struggling and reduce the risk of capture myopathy or other injury. The helicopter recorded the capture location on a global positioning system (GPS) and then ferried one or two biologists to within 100 m of the capture site to continue processing. The handlers then blindfolded the animal, removed it from the net, positioned the sheep with the head elevated to prevent inhalation of regurgitated digesta. A GPS/ARGOS model TGW-3580 radio collar (Telonics®, Mesa, Arizona, USA) with a motion sensitive mortality indication switch on a 12-hour delay or a model GSP3300L (Lotek Wireless®, Inc., Ontario, Canada), with a 8-hour delay was fitted to each sheep. Each Telonics GPS radio collar had a 12 x 6 inch piece of orange Cordura® nylon riveted to the outer periphery of the radio collar to enhance visibility of the white radio collar. Telonics GPS radio collars collected locations every 12-48 hours and Lotek GPS radio collars every 1-2 hours. Telonics GPS radio collars included a programmable automatic release mechanism; the release mechanism on the Lotek GPS radio collar was activated with a remote control device with a programmable timed-release backup. See Appendix A for additional Telonics GPS radio collar configuration description details. Standard morphometric measurements which included total body length, chest girth, neck circumference, hind foot length, length and base circumference of horns (and any abnormalities), jaw length, and weight were taken as time allowed. Age was determined primarily from counting horn annuli (Hemming 1969; Geist 1971) although we examined incisor wear. A hair sample was taken from the withers. Body condition was evaluated by subjectively categorizing the presence of muscle and fat in three areas: ribs, withers, and hips. Approximately 20 cc's of blood were collected (from the jugular or cephalic vein) to evaluate pregnancy status, trace mineral status, and potential exposure to select bacterial and viral pathogens of concern. Excess blood sera were archived with the ADF&G Wildlife Heath and Disease Surveillance Program. Fecal pellets were obtained per rectum to screen for internal parasites. Initially dry nasal swabs were collected but this was discontinued when it was determined this was not effective for detecting the pathogenic strains of interst for *Pastuerella* spp. (Dunbar et al. 1990). Prior to release, biologists administered 0.6 ml (200mg/ml, intramuscular) of the antagonist tolazoline (ZooPharm®, Laramie, Wyoming) and 2.5 ml (1mg/ml, intramuscular) of selenium (Bo-Se®; Schering-Plough Animal Health Corporation, Union, New Jersey). Total processing time from capture to release was typically less than 30 minutes. If the animal's breathing was abnormally labored, or the animal was struggling, further sampling was terminated, a radio collar quickly attached, the antagonist and selenium administered and the animal was released. The biologists remained at the capture site until the sheep was mobile and had left the capture site.

We allocated the majority of collars to the Schwatka and Victoria regions, and fewer to the more southern portions of the White Mountains. Within those two broad zones, we allocated collars roughly in proportion to the number of sheep observed in each region during recent summer aerial censuses. We allocated most collars to ewes, due to their importance in raising lambs to recruitment. To maximize movement data in males we targeted two to three year olds to avoid harvest of marked males during the course of the four year study.

Monitoring of radiocollared sheep

Sheep were monitored by fixed-wing aircraft one day following radio collar deployment to assess sheep status and radio collar function. Thereafter sheep movements were monitored weekly using Argos transmitted GPS locations. Aerial monitoring was conducted bimonthly to document animal associations and test for proper radio collar function. We used radiotelemetry and satellite data to identify mortality. In most instances kill sites were not visited immediately after detection and our ability to identify predators and separate predation from other potential causes of death and scavenging events was limited. Upon visiting a kill site the surrounding area was searched for tracks and hair, and carcasses were examined for bite marks. Skeletal remains were collected when available. Lambing flights were conducted weekly from mid May to early June, 2005 and 2006 to assess parturition. Ewes were determined to have given birth to a lamb if the lamb was at the heel of the ewe and they appeared to be moving together. Lambing estimates are minimal because it is possible that lamb birth and subsequent predation occurred prior to the first lambing radiotelemetry flight or between radiotelemetry flights.

Sheep population surveys

Sheep surveys were conducted annually from early July to early August, 2005-2008) to estimate minimum population size and sex and age composition. Three survey teams (ADF&G, BLM, Refuge) flew fixed-wing aircraft to count, sex, and age sheep. Survey protocol is outlined in the Yukon Flats Sheep Inventory Plan (UFWS 1998). Radiocollared sheep provided an opportunity to use mark and recapture techniques (White and Garrott 1990) to estimate a SCF for the population estimate. The survey was flown as normal, but sheep observed with radio collars were noted, aloing with the collar type. We note, our correction factor is not solely the probability of sighting a sheep, but the combined probability of sighting a sheep and sighting its radio collar. The correction factor of sighting a sheep is likely slightly higher than we report if a radiocollared sheep was sighted but its radio collar was not.

Sheep harvest

Sheep harvest in the White Mountains occurs in Game Management Units 25C and 25D. Sheep hunters are required to report harvest with a harvest ticket. Annual sheep harvest is compiled by ADF&G and available online at: https://secure.wildlife.alaska.gov/index.cfm?fuseaction=harvestreports.main.

Forage quality assessment

Fecal pellets were collected annually by season from 2004 to 2007 to determine sheep diet composition and quality. Samples were composited by season and region to determine plant species level using 4-6 slides per sample and by looking at 25 views per slide. Nitrogen content of fecal samples was determined by the Dumas method of combustion in a LECO carbon/nitrogen analyzer (LECO 1990). Microhistological and nitrogen content analyses were conducted by the Wildlife Habitat Nutrition Laboratory, Washington State University, Pullman, Washington.

Parasite, trace element and histopathology assessments

Fecal pellets were collected from captured individuals from the six regions included in the study area in 2004 and from mineral licks from three of the six regions in 2006. Fecal pellets were analyzed for presence of nematode larvae using the beaker Bearmann technique (Forrester and Lankester (1997). Tests from the 2004 samples were conducted by University of Alaska Fairbanks (UAF); tests from the 2006 samples were conducted by the Washington Animal Disease Diagnostic Lab, Pullman, Washington.

Hair, serum, and whole blood were analyzed from sheep captured in 2004 by the Wildlife Toxicology Laboratory, University of Alaska, Fairbanks, Alaska (Moses 2006). Copper, iron and zinc concentrations were determined using atomic absorption spectrometry (AA; Perkin Elmer, AAnalyst 800). Cadmium concentrations were determined using an AA furnace technique, selenium concentrations were estimated using a mercury hydride system/flow injection analysis system (MHS/FIAS) AA technique, and mercury concentration was determined using closed microwave digestion and cold vapor atomic fluorescence spectrometry (CVAFS; Brooks Rand; method modified from EPA Method 1631). Lactate concentrations in whole blood were quantified (within 24 hours of field collection) with a Lactate Pro portable blood lactate analyzer (FaCT Canada Consulting Ltd, British Columbia, Canada) to access risk of capture myopathy. Reference values for mineral levels in the wool, serum and whole blood of domestic sheep were taken from Puls (1994) and used to classify results as deficient, marginal, adequate, normal, high or toxic.

Serum blood samples from sheep captured in 2007 were analyzed by Wyoming State Veterinary Lab, University of Wyoming, Laramie, Wyoming. Selenium, copper, iron, manganese, molybdenum, and zinc concentrations were determined using TCA precipitation, dilution and direct injection in an ICP-MS (Standard Operating Procedure # T48).

Detailed gross necropsies were performed by ADF&G wildlife veterinarian Kimberlee Beckmen on capture-related sheep mortalities to determine cause of death and to identify other conditions that may have had adverse impacts on sheep health. Histopathology was conducted by Dr. Terry Spraker, Veterinary Diagnostic Laboratories, Colorado State University, Fort Collins, Colorado and Dr. Kathy Burek, Alaska Veterinary Pathology Services, Eagle River, Alaska.

Statistical analyses
Although we first considered using fixed kernel with Least Squares Cross Validation (Seaman et al. 1996, 1998, 1999), and Minimum Convex Polygon (Mohr 1947) methods to describe sheep movements due to their wide use, we selected an alternative approach, the Brownian bridge movement model (BBMM) using "R" package BBMM (Nielson et al. 2011, that accounted for time dependence between animal relocations and not only the position of the relocations (Bullard 1999, Horne et al. 2007), but also the path traveled by the animal between relocations (ie., movement path) (Calenge 2011). Unlike the fixed kernel method which assumes that locations are independent, the BBMM assumes locations are dependent. Due to our high volume of data, data collected at relatively short time intervals, and focus on a species that exhibited a predictive movement pattern, the BBMM was well suited for analyzing movement in this study. Use of BBMM required us to measure error associated with each observed location and then estimate the variance related to the animal's mobility. We also calculated Minimum Convex Polygons (Mohr 1947) in order to make comparisons with previous studies. Bootstrap resampling code for estimating home ranges is in Appendix B.

We used seasonal distribution periods identified in previous studies in interior Alaska: winter (January to April), lambing (May and June), summer (July and August), fall (September and October), and rut (November and December) (Burch and Lawler 2001, Lawler 2001).

Sheep survivorship was estimated using the Kaplan-Meier method (Pollack et al. 1989). The Kaplan-Meier method is versatile and allows for censorship of animals removed from the population due to radio failure, radio collar loss, or emigration, and allows for new animals to be added after initiating the study. Z-tests were conducted to examine between-year and intra-year variation in adult survival rates (Freund and Wilson 1997:200). Macro-site identification and mapping of sheep use areas were conducted with ArcGIS (ESRI, Redlands CA).
This research followed safe animal-handling protocol in accordance with acceptable field methods outlined by the American Society of Mammalogists (Animal Care and Use Committee 1998) and

operated under Alaska Department of Fish and Game Animal Care and Use Committee Assurance No. 04-015.

RESULTS

Sheep captures

A total of 102 captures were made using a hand-held netgun from a helicopter from March 2004 to September 2008 (Table 3). This included 73 individual sheep, some of which were recaptured. Sixty-three sheep were fitted with radio collars (44 females, 19 males). Ten captures resulted in mortality, likely from capture myopathy (8 females, 2 males). Table 4 depicts regional distribution of radiocollared sheep by sex and radio collar type (Table 4). The distribution of radiocollared sheep ranged from 8 sheep at Mount Prindle to 23 sheep at Mount Schwatka (Figures 3 and 4). The mean ages for females (range 3 to 12, n = 41) and males (range 2 to 8+, n = 12) were 6.8 and 3.3, respectively. Morphological measures for captured sheep are in Appendix C.

Home ranges and movements

A total of 350,477 locations were recorded on 38,372 radio collar days for 56 monitored sheep (mean 9.1 locations/radio collar day). Seven sheep (1 female, 6 males) were excluded from movement analyses because of insufficient sample sizes of locations due to death or imprecise location data (see Radio Collar Performance). Females (n = 43) included 228,235 locations on 30,862 radio collar days; males (n = 13) comprised 122,242 locations on 7,510 radio collar days (Appendix D-1, individual statistics; Appendix D-3, maps).

The mean BBMM isopleth home range estimate at the 95 percentile for all sheep was 53.07 km^2 (range 11.74 to 170.71 km^2, SD = 4.84, n = 56); mean home range estimates for females and males were 56.18 km^2 (range 11.74 to 170.71 km^2, SD = 6.14, n = 43) and 42.83 km^2 (range 16.71 to 65.36 km^2, SD = 3.59, n = 13), respectively (Appendix D-1, individual statistics; Appendix D-3, maps; Appendix F1 and F2, group statistics).

The mean minimum convex polygon home range estimate for all sheep was 213.73 km^2 (range 31.63 to 768.01 km^2, SD = 21.07, n = 56); mean home range estimates for females and males were 183.60, (range 31.63 to 651.20 km^2, SD = 19.75, n = 43) and 313.09 km^2 (range 93.14 to 768.01 km^2, SD = 54.80, n = 13), respectively (Appendix D-1, individual statistics; Appendix D-3, maps; Appendix F1 and F2, group statistics).

Mean BBMM isopleth home range estimates at the 95 percentile, minimum convex polygon home range estimates, and radio collar days by region and sex are found in Appendix D-2.

For ewes, the mean BBMM isopleth home range estimates at the 95 percentile for the lambing, summer, fall, rut, and winter seasons ranged from 304.433 to 402.612 km^2 (Appendix E1, mean statistics; Appendix E2, maps). For rams the mean BBMM isopleth home range estimates at the 95 percentile for the lambing, summer, fall, rut, and winter seasons ranged from 85.069 to 207.97 km^2 (Appendix E1, mean statistics; Appendix E2, maps).

Lambing (May-June)
Lambing was monitored in 2005 and 2006 from May 12 to June 8. The earliest presence of lambs was on May 16 both years.

Mineral licks
Mineral licks were scattered throughout the study area and located in all of the regions. Licks varied in topographic position, soils and water, and surrounding vegetation composition. Most commonly, licks occurred along drainage bottoms. The most heavily used licks occurred in higher elevations near Rocky Mountain, Mount Schwatka, and Jefferson Creek (near Mt. Schwatka). The Mount Schwatka lick was below timberline in well-shaded, spruce forest, and included muddy areas interspersed with ponded or slowly flowing waters, regularly disturbed by regular use. These disturbed muddy wetlands were up to 30m diameter. Mascot Creek (near Rocky Mountain) and Jefferson Creek occurred adjacent to headwater streams with less soil disturbance visible. Use of the Mascot Creek lick focuses in the stream floodplain rather than adjacent slopes. Sheep in the Mount Prindle area travel up to 20 km away from Mount Prindle to mineral licks along an unnamed tributary of Preacher Creek.

Sheep population surveys
From 2005 to 2008 the sheep population total minimum counts slowly decreased, from a high of 513 in 2005 to a low of 366 in 2008 (Table 1). Sheep population mark-resight surveys were conducted July 23-August 4, 2005 in all regions of the study area. In the Schwatka and Victoria Mountain regions we observed 15 of 18 available marked sheep; in all other regions of the study area we observed 10 of 14 marked sheep for a total of 25 observed sheep of 32 available sheep. The 2005 SCF for the entire study area was 1.22 (Table 5) resulting in a corrected population estimate of 626.

Sheep harvest
From 2004 to 2008, both hunter participation and hunter harvest increased annually, however, hunter success remained stable at about 0.24 (Table 2).

Mortality, Survival rate

Capture myopathy and histopathology
Necropsies were conducted on presumed capture-related mortalities to determine the proximate cause of death and evaluate potential contributing factors such as poor body condition. Initial capture operations in March 2004 resulted in capture- related deaths for two of three captured adult females in the Lime Peak region. As a result, capture operations were suspended immediately to thoroughly examine mortalities and reassess capture protocol. Necropsies documented fractured spines and capture myopathy in both sheep. Further analysis indicated each sheep had osteoporosis and osteopenia as well as selenium and vitamin E deficiencies. In response to these findings, and, in an effort to reduce the risk of capture myopathy, capture operations were rescheduled to the fall when sheep were expected to be in better condition; administration of intranasal xylazine was added to the protocol to reduce stress and minimize struggling; and selenium and Vitamin E injections were given. Despite these precautionary measures we incurred 8 additional capture-related deaths during the study. Of these 8 deaths, two were suspected to be predisposed to predation and died 1 to 5 days from radiocollaring. Another individual had an existing leg injury and died within 24 hours of capture. Excluding these three individuals, the longest interval between captures without capture-related mortality was 29 months (56 captures). Necropsies were performed on 7 of 10 suspected capture-related deaths (Table 6). Capture-related

deaths occurred in each region of the study area (range 1-3). Table 4 summarizes capture-related deaths by region, sex and radio collar type. Lactate was quantified on sheep captured in 2004 (mean 14.2 mmol/L, range 11.9-17.8 mmol/L, SD = 1.27, *n* = 22) (Table 3).

Natural mortality

Of the 63 sheep fitted with radio collars, and excluding capture-related mortality, 12 sheep died while radiocollared (Table 3). Of the 12, evidence at the site (blood on the radio collar, wolf scat present, teeth marks on radio collar, grizzly or wolf tracks present), indicated that 6 sheep were likely killed by predators. Grizzly tracks were documented at two kill sites and wolf tracks were also observed at one of those sites. The remaining 6 may have been predator-related or another source because evidence was less conclusive (aged kill site with partial carcass and scattered bones or large amounts of hair present with no carcass).

Survival rate

Annual survival rates were calculated for the period March 22 in year one to March 21 the following year from 2004 to 2009. Two to eleven sheep were censured annually due to slipped radio collars (*n*=5), recaptures for radio collar removal (*n*=10) or unknown fate (*n*=4). The number of annual deaths ranged from 0 to 5. Annual survival rates for female radiocollared sheep from 2004 to 2008 were 93%, 85%, 82%, and 100% (Table 7), with a mean rate of 90% (*n* = 115). Annual survival rates for male radiocollared sheep from 2005 to 2007 were 93% and 100% (Table 7), with a mean rate of 97% (*n* = 28). We did not include 2008 to 2009 due to low sample size and partial year data. Appendix G includes annual Kaplan Meier survival estimates by sex. We tested for intra- and inter-year differences in survival rate by sex and successive year. Due to the low annual sample size of rams in years 2007 and 2008 (*n* = 2) and 2008 and 2009 (*n* = 1) and partial year samples in years 2004 and 2005, we only tested differences for rams in years 2005 and 2006 (*n* = 14) and 2006 and 2007 (*n* = 14). The mean annual survival rate within 2006 and 2007 was higher (Z = 1.98, P = 0.02) for males (1.00, 95% CI = 0.00, *n* = 14) compared to females (0.82, 95% CI = 0.14, *n* = 34). The mean annual survival rate between years for females was higher (Z = 2.39, P = 0.008) in 2007 and 2008 (1.0, 95% CI = 0.00, *n* = 25 compared to 2006 and 2007 (0.82, 95% CI = 0.14, *n* = 34). The survival rate for all sheep combined was higher (Z = 2.5, P = 0.006) in year 2007 and 2008 (1.0, CI = 0.00, *n* = 34) compared to 2006 and 2007 (0.85, 95% CI = 0.12, *n* = 44).

Forage quality assessment

Eight forage groups were identified from fecal pellets collected in each of the six regions from 2004 to 2007 (Table 8). Grasses were the largest forage class in winter (Feb and Mar) diet in all areas except Mount Schwatka where sedges and forbs dominated. Sedges were the largest summer (June and July) forage group in all regions, and Mount Schwatka and Limestone Ridge displayed the most even distribution of sedges, grasses and forbs. Lichens, followed by grasses, dominated fall (Sept and Oct) forage and were analyzed as a single composite sample from all regions except Victoria Mountain. The most browsed plant species and parts included: *Carex* species, *Calamagrostis purpurascens*, *Lupinus*, *Cladina/Cladonia*, *Classic Moss*, *Dryas leaves* and *Salix spp.* stem. Appendix H 1-4 includes percent occurrence of plant species and parts by region, month and year. Table 9 includes percent nitrogen in fecal pellets by region, month and year.

Parasites

The lungworm (*Protostrongylus stilesi*), a small white nematode, infestation rate was 97% on samples (*n* = 34) taken from live sheep during capture in 2004 (Appendix I 1-2). Lungworm was present in all regions and there were no significant differences in larvae per gram of feces by regions, sex, or age (Table 10). Holcomb and Beckmen (2006) reported a range of 0-90,396 larvae per gram of feces with a mean of 6,813 larvae per gram of feces, in samples obtained from sheep in this herd and in Yukon-Charley Rivers National Preserve.

Of the 30 fecal pellet samples collected from mineral licks in the Victoria Mountain (*n* = 1), Mount Schwatka (*n* = 20), and Rocky Mountain (*n* = 8) regions, infestation rates were 100%, 62%, and 50%, respectively (Table 11). At mineral licks across the region, infestation rate was 100%, and larvae per gram of feces ranged from 1 to 135 with a mean of 10.2.

Dorsal spine larvae (*Parelephostrongylus odocoili*), which is often associated with pneumonia in wild sheep, was not detected in any fecal sample.

Trace minerals

Hair (*n* = 39), serum (*n* = 28), and whole blood (*n* = 24) from sheep captured in 2004 were analyzed by Moses (2006) for trace minerals including copper, selenium, cadmium, zinc and iron (Table 12). Livers were assessed for mercury levels. Appendix J provides a detailed report of findings and an explanatory letter of findings. Serum (*n* = 9) from 2007 captured sheep were analyzed for trace minerals including selenium, copper, iron, manganese, molybdenum, and zinc. Of the nine samples, eight were taken from the Mount Schwatka region. Three sheep, sampled in 2004, were also analyzed for levels of Vitamin E.

DISCUSSION

We used a hand-held netgun for all captures which allowed for efficient capture by immediately immobilizing animals and preventing them from traveling into dangerous terrain. We used an experienced gunner/pilot team that had previously captured over 150 sheep with only three capture-related deaths. Although use of netguns is not without risk and does have potential to injure animals entangled in the net or strike an animal with a weight used to propel the net through the air, we minimized risk by selecting animals not in groups and we kept average chase time to less than one minute to minimize capture stress; subsequently most captures were completed quickly. The capture team was able to capture and radiocollar up to 11 animals daily using these methods. We avoided chemical immobilization techniques to avert compromised thermoregulation and prevent drugged sheep from wandering into terrains that would be dangerous to either sheep or capture team members, or that prevented reaching the animal quickly to assure health of the animal.

However, our incidence (10%) of capture-related deaths (10 of 102) using hand-held net guns was high compared to other studies in Alaska using similar methods. Incidence was low (range 0-3%) in Yukon-Charley Rivers National Preserve (0 of 40), Gates of the Arctic National Park and Preserve (1 of 27), Yukon-Tanana Uplands (2 of 84), and the western Baird Mountains (4 of 123), (Burch and Lawler 2001, Lawler 2004, Lawler et al. 2005, Udevitz et al. 2006, Adams pers. comm. 2017). No incidence of capture-related death was reported for drug immobilization captures previously in our study area (Durtsche et al. 1990). Burch and Lawler (2001) did report one incident of capture-related death using drug immobilization methods in Yukon-Charley Rivers National Preserve. Three sheep in our study incurred either a broken back or neck. Movement data indicated that five sheep died 1 to 13 days following capture and death was likely influenced by capture myopathy. One of these individuals stopped moving nine days following capture and was euthanized. Necropsies on seven sheep examined indicated six of severn had peracute capture myopathy, three had mild to moderate parasites loads, two had acute pulmonary edema, and two had fat covered kidneys and bones with marrow fat (Table 6). Of the ten capture-related deaths, six were attributed to capture myopathy.

Sheep generally exhibited low levels of selenium, copper, zinc and Vitamin E, and elevated levels of blood lactate (mean 14.2 mmol/L, measures above 4 mmol/L are considered elevated) during capture across all sampled regions. We suspect sheep in this region have inadequate dietary mineral intake which make them susceptible to capture stress and capture myopathy. Animals that suffered a broken back or neck were suspected to have mineral deficiencies based on histological and functional analysis of long bones as well as calcium and phosphorous analyses not reported here. Trace mineral imbalances may be expressed by lesions in keratinized tissues including hooves or horns. Horn fissures in ewes and rams were common; we handled five ewes with broken horns. Lawler (person. comm. 2008) compared the incidence of ewes with broken horns in five regions of Alaska (range 5 to 22%); White Mountains sheep incurred the second highest rate of broken horn (12%, n = 5). The White Mountains region is also well known in Alaska for producing stump-horned rams that exhibit sloughing horns. We captured one ram that displayed stump-horn on both right and left sides. Inexplicably, this stump-horned ram, captured at Mount Schwatka, also exhibited one of the highest selenium levels of captured sheep. However, other explanations besides nutritional or trace mineral deficiencies may explain the horn or hoof lesions. Infectious diseases (i.e. Bluetongue virus) and toxin exposure (ie., ergot) as well as other conditions causing restriction of blood flow to or inflammation of the laminae have not been ruled out.

Adequate protein and energy intake for normal growth was evidenced by total length measurements. We compared total body length of ewes in the White Mountain population (152 ± 7.4 cm, n = 41) and found mean measures similar to female sheep in Yukon-Charley Rivers National Preserve (155 ± 6.4 cm, n = 17), (Burch and Lawler 2001), Gates of the Arctic National Park and Preserve (149 ± 4 cm, n = 8), (Lawler 2004), and Yukon-Tanana Uplands (151 ± 5.0 cm, n = 570), (Lawler et al. 2005). We were unable to compare body weight data from these nearby regions since our sheep were measured in fall and the majority of weights from other regions where in mid to late winter.

We found few comparisons in the literature for home ranges estimates of Alaska Dall's sheep. Our MCP estimates for males (313.1 km^2) and females (183.6 km^2) were similar to those documented in the Yukon-Charley Rivers National Preserve (males, 367 km^2, females, 266 km^2) (Burch and Lawler 2001).

During lambing, movement data and aerial observations indicated that ewes typically traveled to a remote location, often at a lower elevation just above timberline, a day or two prior to giving birth. This propensity to travel, just prior to birth, may explain why ewes displayed the second largest BBMM home range estimates (395 km^2, n = 39) during lambing compared to other seasons. Ram movements were most extensive during the lambing period with a BBMM home range estimate of 208 km^2 (n = 13). Rams in the Prindle Mountain region routinely traveled up to 35 km northeast of Prindle Mountain. Extensive ram movements in spring may be due to seeking newly available spring food sources with recent snow melt.

Movement corridors between regions were observed during lambing between Victoria Mountain and Schwatka and Limestone Ridge, and between Lime Peak and Limestone Ridge and Mount Prindle (Figure 3). The majority of movements were across upland areas, except for lowland crossings on Beaver and Victoria creeks (Appendix D2). Core lambing areas in the Victoria Mountain region were bisected by the proposed southern oil and gas pipeline right of way; the proposed northern oil and gas pipeline right of way paralleled the Mount Schwatka region and was situated 1 to 4 km from core sheep lambing areas (Figure 5).

Both ewes and rams were not exceedingly mobile during rut and had BBMM home range estimates of 312 km^2 (n = 43) and 104 km^2 (n = 12), respectively. Home ranges were larger for ewes in fall and lambing periods and for rams in spring, summer, and fall (Appendix E1). We suspect that since our marked rams included a majority of young rams (mean age 3.3, range 2 to 8+, n = 12), and was not representative of the mature breeding ram population, that we may have underestimated ram movements during rut.

Movements by ewes and rams were most protracted during winter with mean BBMM home ranges of 309 km^2 (n = 41) and 85 km^2 (n = 12), respectively. Above average snowfall, winter rain-on-snow, and wind storms can restrict animal movement. We examined the Windy Gap annual March 1 snow accumulation records (NRCS 2017 https://www.wcc.nrcs.usda.gov/BOR/basin.html) from 2000 to 2017 to estimate mean snowfall and make comparisons to previous years. Windy Gap is located in the Limestone Ridge region and is representative of weather patterns in the sheep study area. The first two winters of the study, 2005 and 2006, had above average snowfall with mean depths ranging from 38 to 30 inches, respectively, which was 192-127% above the 18-year mean of 26 inches. In addition, the winter of 2005 also had several mid-winter rain-on-snow events accompanied by severe winds. During the summer of 2006 we noticed many areas across the Schwatka and Victoria Mountain regions with live spruce trees that were without tops, presumably due to wind shear. Winters of 2007 and 2008 were more moderate with 16-inch mean annual snowfalls that were 67-52% of the 18-year mean.

As noted during lambing, movement was common between adjacent regions throughout the study area (Figure 3). Connectivity corridors occurred between Victoria Mountain and Schwatka and Limestone Ridge, and between Lime Peak and Limestone Ridge and Mount Prindle. North to south movements generally occurred between Schwatka and Victoria Mountain and the Limestone Ridge region. East to west movements occurred between Prindle Mountain and Limestone Ridge. Major stream crossings occurred at two locations on Victoria Creek and near the confluence of Willow and Beaver creeks. Mineral licks are present at both of these crossings. A total of 12 sheep (9 females, 3 males) made 149 crossings at two locations on Victoria Creek within the proposed southern oil and gas pipeline corridor (Table 13). Over 98% of Victoria Creek crossings occurred between May and November. Water crossings were made on Beaver Creek by 10 sheep (7 females, 3 males); the majority of these sheep were resident of the Limestone Ridge region. Approximately 94% of Beaver Creek crossings occurred between June and September. One 2 year old ram, radiocollared on Victoria Mountain, regularly used both the Victoria and Beaver creek crossings. Mineral licks were situated in all sheep regions and in or near all movement corridors. Both ours and earlier studies (Durtsche et al. 1990), have documented sheep use of mineral licks near stream crossings on both Victoria Creek and Beaver Creek; corridors and licks should be safeguarded from any activity that limits sheep movement, particularly during the summer months.

Our sightability estimate (0.78) is within the range found in other studies in Alaska using similar methods: western Baird Mountains (0.88), Alaska, USA (Udevitz et al. 2006); Yukon-Charley Rivers National Preserve (0.84), Alaska, USA (Lawler et al. 2005); Arctic National Wildlife Refuge (0.68), Alaska, USA (McDonald et al. 1990); Kenai National Wildlife Refuge (0.76), Alaska USA (Strickland et al. 1994); and Gates of the Arctic National Park and Preserve, Delta Controlled Use Area, and Game Management Unit 20A (0.76), Alaska USA, (Whitten 1997). Arthur and Prugh (2010) using a helicopter in the Central Alaska Range recorded a mean sightability of radiocollared sheep of 0.74 from 1999 to 2005. The Telonics radio collars were marked with an orange band, the Lotek radio collars were constructed of a dark grey material and less visible. It is possible the color of the Lotek radio collar influenced the ability of an observer to see sheep wearing a radio collar. Thus, we suspect our sightability estimate is a minimum estimate. Other factors that decrease sightability in our region include sheep regular use of shallow caves and mineral licks in timber.

The sheep population found in the White Mountains, which occurs entirely on public lands, provides viewing and hunting recreational opportunities to Fairbanks, the second largest community in Alaska, with limited access by road, aircraft or boat (Hollis 2014). From 2010 to 2012, over 52% of successful hunters accessed the region by aircraft and 25% by off-road vehicles (Hollis 2014).

Sheep population surveys indicate the population doubled from 1994 to 1999, stabilized at about 500 sheep through 2011, and has since been stable or slowly decreasing (Table 1). Since the population increase in the 1990s the reported numbers of hunters and harvested sheep have doubled (Table 2). The increases in harvest have been lower in the Mount Schwatka and Victoria Mountain regions, the most inaccessible sheep habitats in the White Mountains. Although hunter effort steadily increased through the 1980s and 1990s, peaked in 2008 (n = 84) and has been slowly decreasing in recent years, hunter harvest success, which has averaged 0.29 since 1968 and in the past ten years has decreased to 0.20, has remained relatively stable.

Biologists observed a winter rain-on-snow event accompanied by broken snag trees in February 2006 while retrieving radio collars. It was suspected the rain-on-snow event happened between October 2005 and February 2006. The following summer it became apparent that the winter storm likely included a severe wind event as indicated by hundreds of uprooted spruce trees with broken trunks at several sites in the Mount Schwatka region. This event coincided with the period of highest mortality during the study. From October 2005 to April 2006, seven of the 12 total mortalities occurred, including four of the six natural source mortalities. In addition, low lamb production (12 lambs/100 ewes) was documented in the summer 2006 sheep population survey. Burch and Lawler (2001) noted a significant decrease in available female sheep to radio collar in March 2000 following an icing event in 1999-2000 in Yukon-Charley Rivers National Preserve. Their findings suggested that severe weather may have had a stronger impact on the sheep population then current levels of human harvest, predation or human disturbance. We merged minimum convex polygon data for ewe annual movements between 2004 and 2008 and noted movement data between November 2005 and October 2006 was down 13% compared to the four year mean (Table 14). This may provide some evidence that severe winter weather between October 2005 and April 2006 had influence on ewe sheep movement

Our mean annual survival rate for male and female sheep (0.91) was higher than rates reported from Gates of the Arctic National Park and Preserve (0.78), (Lawler 2004), and Yukon-Charley Rivers

National Preserve (0.81), (Lawler et al. 2005, Alaska, USA). Since we targeted younger rams in our sample it is likely our survival rate for males was biased high due to the lack of marked mature rams that would have been available for legal harvest. White Mountain sheep survival rate for females (0.90) was higher than Kluane National Park (0.80), (Hoefs and Cowan 1979, Yukon Territory, Canada), the Mackenzie Mountains and Denali Park (0.85), (Simmons et al. 1984, Northwest Territories, Canada) and central Alaska Range (0.85), (Arthur and Prugh 2010). As mentioned previously, the winters of 2004 to 2005 and 2005 to 2006 had above average snowfall, up to 192% above the historical mean. In addition, between October 2005 and February 2006 at least one winter rain-on-snow event occurred, accompanied by severe winds. We suspect these weather patterns contributed to the lower female survival rate exhibited in 2006 and 2007.

Similar fecal pellet methods were used at Yukon-Charley Rivers National Preserve, situated about 161 km southeast of our study area in the Yukon-Tanana Uplands, to gather and analyze fecal pellets from 2000-2002 (Lawler et al. 2005). Although grasses predominated winter forage in both the White Mountain and Yukon-Tanana Uplands study areas, the Yukon-Charley Rivers National Preserve was also dominated by mosses. Both study areas included a significant component of sedge and rush forage during the summer months. The most used plants and parts at Yukon-Charley Rivers National Preserve included: *Festuca altaica*, *Carex bigelowii* and other spp., *Classic Moss*, *Peltigera*, *Salix spp*. stem and *Artemisia*. Fecal pellets gathered in both our study area and the Yukon-Charley Rivers National Peserve study area displayed increasing percent nitrogen levels from February to October with comparable lower bounds (1.65-3.41 and 1.5-2.5, respectively). However the upper bounds in late year percent nitrogen levels were noticeably higher in the White Mountains. In Kluane National Park, outside of our Alaska study region, sedges and grasses also dominated sheep annual diet; the three most common forage species included: *Carex filifolia*, *Calamagrostis purpurascens*, and *Salix glauca* (Hoefs and Cowan 1979).

Although lungworms are common in Alaska Dall's sheep, observations of signs of verminous pneumonia such as labored breathing are extremely rare (Holcomb and Beckmen 2006). Only chronic, sporadic lungworm lesions were detected postmortem and were not significant to the mortalities. Lungworm larval shedding and prevalence rates in sheep in Yukon-Charley Rivers National Preserve were similar to this study with prevalence rates of 93% (range 0-66,300 larvae per gram, mean 11,913 larvae per gram). No correlations were noted between age and larvae per gram in either study area (Holcomb and Beckmen 2006); tests were not conducted between sexes in the Yukon-Charley Rivers National Preserve due to low sample sizes.

Of hair (n = 39), serum (n = 28), and whole blood (n = 24) samples taken from 2004 captured sheep, approximately 7% of hair were deficient in copper and 41% were marginal when compared to domestic sheep; all serum samples were in the adequate range (Holcomb and Beckmen 2006). Two-thirds of hair samples were in the marginal range for selenium; of the whole blood samples, 24% were marginal. All but one of the sheep hair samples were within the normal range for cadmium. About 82% of serum samples, including the mean, tested for zinc were deficient to marginal. Hair samples were not analyzed for zinc levels. Iron concentrations of sheep hair and serum were all above the adequate reference range. Since high iron intake impairs copper availability, this may have contributed to the low copper levels. Mercury level concentrations in livers were in a range not of human health concern. Of the three sheep sampled in 2004 for levels of Vitamin E, all were severely deficient.

Of the nine serum samples for sheep captured in 2007 and analyzed for trace minerals including selenium, copper, iron, manganese, molybdenum, and zinc, all selenium results were in the adequate range for domestic sheep however, adequate serum and blood levels for wild sheep such as Dall's sheep are not fully understood. The iron levels ranged from adequate to high; and eight of nine copper and zinc samples ranged from deficient to marginal; all molybdenum samples were in the normal range; and all manganese samples were in the deficient range, but again, that is compared to domestic sheep. A detailed analysis of the blood selenium from this study including the 2007 samples, compared to four other Dall's sheep populations by Schwafel (2013), implicated the published adequate values for selenium in domestic sheep as insufficient to maintain health in Dall's sheep. Schwafel (2013) found the mean selenium concentration in White Mountains ewes that died of capture-related causes was 0.097 ppm (SD = 0.079, range 0.030 ppm – 0.125 ppm), while in White Mountains animals that survived the post-capture period, mean blood selenium concentration was 0.245 ppm (SD = 0.162, range 0.096 ppm – 0.850 ppm). The model presented by Schwafel determined that a blood selenium concentration below 0.2 ppm was associated with a sharply increased risk of capture mortality in White Mountains ewes. Homeostatic mechanisms maintain serum copper within a physiologically functional range until the liver is completely depleted. Thus serum copper in isolation is not a reliable indicator of copper status in ruminants. Additionally, elevated zinc or iron, interfere with copper uptake and availability. The one conclusion we can come to is that the low copper was not secondary to molbbdenum toxicosis. It appears from our findings that selenium, copper, and zinc were insufficient in about one-third to two-thirds of the sampled population.

Selenium, copper, and zinc are essential trace minerals for immune function, reproduction, muscle, bone and integument (hair, skin, hooves) and resistance to pathogens and parasites. The interactions between trace minerals within the environment, forage, and the animal are complex and extremely difficult to understand in a field study such as this. Keeping this in mind, it appears from our study that there are deficiencies in these minerals which may be insufficient to maintain health in about one-third to two-thirds of the sampled population.

We had mixed results with the functionality of the components of the Telonics GPS radio collars. We detected no problems with mortality sensors and the programmed timing of VHF beacon transmissions was accurate. The majority of Argos satellite uplinks were successful but some location data were incomplete. Following 24 months of service, three of 20 radio collars failed to uplink movement data to the satellite. We did not conduct a thorough analysis comparing the accuracy of transmitted satellite data with store on board GPS location data. Two (n = 0.10) of the drop-off mechanisms released early (at 22 months) but we were able to recover the radio collars using the VHF beacon. VHF beacons were programmed to deliver 52 months of service but all ceased operation after 36 months. Lack of functioning VHF beacons posed challenges for recovering radio collars since our drop off mechanisms were programmed to activate after 46 months of service. Although we recovered 15 of the radio collars through aerial search and recapture methods, five were left in the field, presumably on the ground, with no means to locate them. Abandoning these radio collars in the field forced us to use only the satellite location data to estimate home ranges. In some instances these transmitted data sets were incomplete and not useful for estimating home ranges. The above issues were partially or wholly responsible for removing 7 sheep (6 female, 1 male) from the movement analysis. To avoid store on board data loss on Telonics radio collars with drop-off mechanisms, we recommend conservative programming of drop-off mechanisms to release well before radio collar VHF battery expiration.

Lotek collars were designed to store GPS locations on board until retrieval (no transmission through satellites). They were programmed to collect locations at a much higher frequency than the Telonics collars, release after two years, and then be re-deployed on new animals, thus increasing the number of animals sampled. All except one Lotek VHF beacon performed throughout the duration of the deployment; one male sheep could not be located at the end of the study preventing collar retrieval. All but one collar provided GPS data as programmed for the duration of the deployment; one male sheep had a collar with a cracked housing which resulted in lost data.

All Lotek drop-off and time –controlled mechanisms malfunctioned which required all collars to be retrieved through netgun recapture. All attempts to trigger the dropoff with the remote trigger transmitter from the helicopter while in close proximity to the collar failed. Due to the low likelihood of success we did not attempt trigger release of all collars to avoid the additional helicopter disturbance. One of the drop-offs was triggered with the remote trigger transmitter after retrieval, but only when moved to within 3 feet of the collar.

MANAGEMENT RECOMMENDATIONS

Sheep in the White Mountains, due to their small population size and isolation from other herds, are both vulnerable to disturbances and susceptible to extinction (Berger 1990). Sheep generally require access to critical habitats such as mineral licks, lambing and rutting areas, and movement corridors within their home range to ensure a viable population. It is therefore important to maintain habitat connectivity between all six regions in the White Mountains that encompass this herd to ensure long-term health. Impediments to connectivity include encroachment of woody vegetation, presence of domestic sheep, habitat degradation and fragmentation, development, and human disturbances (Brewer et al. 2014). Our study was initiated in response to a proposed land trade between the Refuge and Doyon that identified the establishment of an oil and gas pipeline corridor through sheep habitat which straddles the Yukon Flats Basin, an area of suspected oil and gas reserves. This action had the capacity to degrade and fragment habitat, impact sheep movement corridors, and increase access into the region thereby elevating human use. The impetus for this study was then to acquire baseline information on home ranges, movements, survival rates, and the locations of sensitive habitats for the White Mountains sheep population to address these potential impacts.

Baseline movement data illustrated that both of the proposed oil and gas pipeline right of ways (ie., northern and southern routes) bisected and/or paralleled sensitive sheep habitats (lambing areas, mineral licks, and movement corridors) in the Mount Schwatka and Victoria Mountain regions of the White Mountains. Notably, between 2004 and 2008, 10 sheep made 149 crossings through the proposed southern oil and gas pipeline corridor. We documented sheep movement during lambing periods between Victoria Mountain and Mount Schwatka and Limestone Ridge, and between Lime Peak and Mount Prindle and Limestone Ridge. The majority of travel between regions was in upland areas, but sheep also crossed in riparian areas on both Beaver and Victoria creeks; the latter area had been identified as a potential pipeline corridor in the land trade proposal.

This population may be especially sensitive to nutrient shortages as indicated by trace mineral deficiencies in copper, selenium, zinc and Vitamin E in one-third to two-thirds of sampled animals in this study. Mineral licks were noted in all regions throughout the study area, and were often situated in connectivity corridors and below timberline. Mineral licks are important year-round use areas which provide essential minerals to maintain metabolic and skeletal function (Packard 1946). Any activities that limit sheep use of these areas may be detrimental to the sheep population and should be avoided (Durtsche et al. 1990).

The management goal for the White Mountain herd, to maintain a harvestable population of sheep in this region (Hollis 2014), has been met in the long term despite fluctuations in the population, limited available escape terrain as indicated by sheep use in forested areas, mineral deficiencies, and occasional severe weather that limits foraging and survival. Notwithstanding these challenges, females in the population maintain a survival rate that meets or exceeds other Alaska sheep populations.

Although the land trade was rejected by the U.S. Fish and Wildlife Service (USFWS) (USFWS 2010), it is clear that, due to the proximity of sheep habitat in the Victoria Mountain and Mount Schwatka regions to projected locatable oil and gas reserves in the southern Yukon Flats uplands and associated pipeline corridor access routes, the sheep population will continue to be a future focal point of potential impact due to their heavy use of riparian corridors in this region. If ground access is provided into this region in future, it will facilitate public access. It will then be incumbent on land and resource managers to closely monitor potential entry points into critical sheep habitats such as mineral licks, lambing and rutting areas, and riparian connectivity corridors between regions in the study areas. Data provided from this study will be useful to managers in the future to avoid placement of access routes through sensitive sheep habitats and to anticipate other potential impacts to sheep in this region.

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LITERATURE CITED

Arthur, S. M., and L. R. Prugh. 2010. Predator-mediated indirect effects of snowshoe hares on Dall's sheep in Alaska. Journal of Wildlife Management 74:1709–1721.

Berger, J. 1990. Persistence of different-sized populations: An empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology 4: 91-98.

Boyce, W.M. 1991. Panel Discussions on Stress and Bighorn Sheep. 1991 Desert Bighorn Council Meeting.

Brewer C. E., V. C. Bleich, J. A. Foster, T. Hosch-Hebdon, D. E. McWhirter, E. M. Rominger, M. W. Wagner, and B. P. Wiedmann. 2014. Bighorn Sheep: Conservation Challenges and Management Strategies for the 21st Century. Wild Sheep Working Group, Western Association of Fish and Wildlife Agencies, Cheyenne, Wyoming, USA.

Bullard, F. 1999. Estimating the home range of an animal: a Brownian bridge movement model approach. M.Sc. thesis, University of North Carolina, Chapel Hill, NC.

Bureau of Land Mangement. 2016. Eastern Interiour Proposed Resouce Management Plan and Final Environmental Impact Statement. BLM/AK/PL-16/006+1610+F0200.

Burch, J., and J. Lawler. 2001. Ecology and demography of Dall's sheep in Yukon-Charly Rivers National Preserve: identifying critical Dall's sheep habitat and habitat use patterns. Technical Report NPS/AR/NRTR-2001/39.

Calenge, Clement. 2011. Home range estimation in R: the adehabitat HR Package. Office national de la classe et de la faune sauvage. Saint Benoist-78610 Auggargis-France.

Durtsche, B.M., W. Hobgood, and J. Burris. 1990. Distribution, movements, and seasonal use areas of radio-tagged Dall sheep in the White Mountains, Alaska, 1983-1989. BLM-Alaska Open File Report 30, 10pp.

Forrester, S.G, and M.W. Lankester. 1997. Extracting protostrongylid nematode larvae from ungulate feces. Journal of Wildlife Diseases, 33:51-516.

Hoefs, M., and I.M. Cowan. 1980. Ecological investigation of a population of Dall sheep (*Ovis dalli dalli* Nelson). Syesis 12(1):1-83.

Holcomb, D. and K. Beckmen. 2006. A survey of lungworm infestation in Dall Sheep (Ovis dalli) and Moose (Alces alces) in Alasks. Poster presented at Alaska Chapter, The Wildlife Society Meeting, Fairbanks, Alaska.

Hollis, A.L. 2011. Units 20B, 20F, and 25C Dall sheep. Pages 111-122 *in* P. Harper, editor. Dall sheep management report and survey and inventory activities 1 July 2007-30 June 2010. Alaska Department of Fish and Game. Project 6.0. Juneau, Alaska.

Hollis, A.L. 2014. Units 20B, 20F, and 25C Dall sheep. Chapter 12, pages 12-1 through 12-12 [*In*] P. Harper and L.A. McCarthy, editors. Dall sheep management report and survey and inventory activities 1 July 2001030 June 2013. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2014-4, Juneau.

Horne, J.S., E.O. Garton, S.M. Krone, and J.S. Lewis. 2007. Analyzing animal movements using Brownian bridge movement models. Ecology, 88(9), pp. 2354-2363.

Juday, G.P., 1988. Alaska Research Natural Areas. 1: Mount Prindle. Gen. Tech. Rep. PNW-GTR-224. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 34p.

Juday, G.P., 1989. Alaska Research Natural Areas. 2: Limestone Jags. Gen. Tech. Rep. PNW-GTR-237. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58p.

Kellie, K.A. and R.A. DeLong. 2006. Geospatial survey operations manual. Alaska Department of Fish and Game. Fairbanks, Alaska, USA.

Lawler, J. 2004. Demography and home ranges of Dall's sheep in the Central Brooks Range, Anaktuvik Pass, Alaska. Gates of the Arctic National Park and Preserve. Technical Report NPS/AR/NRTR-2004-43

Lawler, J., B. Griffith, D. Johnson, and J. Burch. 2005. The effects of military jet overflights on Dall's sheep in interior Alaska report to the Department of the Air Force, 11th U.S. Air Force, Elmendorf Air Force Base, Alaska. U.S. National Park Service, Alaska Support Office. I29:109:NPS/AR/NRTR/2005-50.

Lawler, J. 2008. Personal communication. Table: Summary of broken horned sheep. U.S. National Park Service, Alaska Support Office.

LECO. 1990.Protein (Crude) in Animal Feed: Combustion Method. (990.03) Official Methods of Analysis. 1990. Association of Official Analytical Chemists. 15th Edition.

McDonald, L.L., H.B. Harvey, F.J. Mauer, and A.W. Brackney. 1990. Design of aerial surveys for Dall sheep in the Arctic National Wildlife Refuge, Alaska. Biennial Symposium of the Northern Wild Sheep and Goat Council 7:176-193.

Moses, S. 2006. Trace minerals in White Mountains Dall's sheep hair, serum and whole blood. Unpublished report. University of Alaska Fairbanks Wildlife Toxicology Laboratory. Fairbanks, Alaska. 13pp.

Nielson, R.M., H. Sawyer, and T.L. McDonald. 2011. Package "BBMM" Brownian bridge movement model for estimated the movement path of an animal using discrete location data.

National Resource Conservation Service. 2017. National Water and Climate Center, Basin Data Reports found at: https://www.wcc.nrcs.usda.gov/BOR/basin.html

Packard, F.M. 1946. An ecological study of the bighorn sheep in Rocky Mountain National Park, Colorado. Journal of Mammalogy 27: 3-28.

Puls, R. 1994. *Mineral levels in animal health: Diagnostic data (2nd ed.)*. Sherpa International, Clearbrook, British Columbia, Canada.

Seaton, C.T. 2005. Units 20B, 20F, and 25C Dall sheep. Pages 121-135 *in* C.Brown, editor. Dall sheep management report of survey and inventory activities 1 July 2001-30 June 2004. Alaska Department of Fish and Game. Project 6.0. Juneau, Alaska.

Seaton, C.T. 2008. Units 20B, 20F, and 25C Dall sheep. Pages 123-127 *in* P. Harper, editor. Dall sheep management report of survey and inventory activities 1 July 2004-30 June 2007. Alaska Department of Fish and Game. Project 6.0. Juneau, Alaska.

Schwafel, H.S. 2013. Selenium Deficiency in Dall's Sheep in Alaska. Master thesis. Cummings School of Veterinary Medicine, Tufts University. 54pp.

Scott, Robert F. 1949. Sheep census on the Alaska Range of Mountains and South in Alaska. Work Plan No. 10, Job No. 1, Volume 4 No. 1, Alaska Department of Fish and Game, Fairbanks, Alaska.

Simmons, N.M., M.B. Bayer, and L.O. Sinkey. 1984. Demography of Dall's Sheep in the Mackenzie Mountains, Northwest Territories. Journal of Wildlife Management 48(1):156-162.

Strickland, D.L., L.L. McDonald, J. Kern, T. Spraker, and A. Loranger. 1994. Analysis of 1992 Dall's sheep and mountain goat survey data, Kenai National Wildlife Refuge. Biennial Symposium of the Northern Wild Sheep and Goat Council 9:35-42.

Udevitz, M.S., B.S. Shuts, L.G. Adams, and C. Kleckner. 2006. Evaluation of aerial survey methods for Dall's sheep. Wildlife Society Bulletin 34(3):732-740.

U.S. Fish and Wildlife Service. 1998. Wildlife Inventory Plan, Yukon Flats National Wildlife Refuge, U.S. Fish and Wildlife Service, Fairbanks, Alaska.

U.S. Fish and Wildlife Service. 2010. Record of Decision: Proposed Land Exchange Yukon Flats National Wildlife Refuge Final Environmental Impact Statement, U.S. Fish and Wildlife Service, Region 7, Anchorage, Alaska.

U.S. Fish and Wildlife Service. 2015. Inventory and Monitoring Plan for Yukon Flats National Wildlife Refuge, Yukon Flats National Wildlife Refuge, U.S. Fish and Wildlife Service, Fairbanks, Alaska.

Whitten, K.R. 1997. Estimating population size and composition of Dall sheep in Alaska: assessment of previously used methods and experimental implementation of new techniques. Alaska Department of Fish and Game, Federal Aid Wildlife Restoration Progress Report Project W-24-5.

Figure 1. Location of Doyon and USFWS exchange lands and access routes, Alaska, USA.

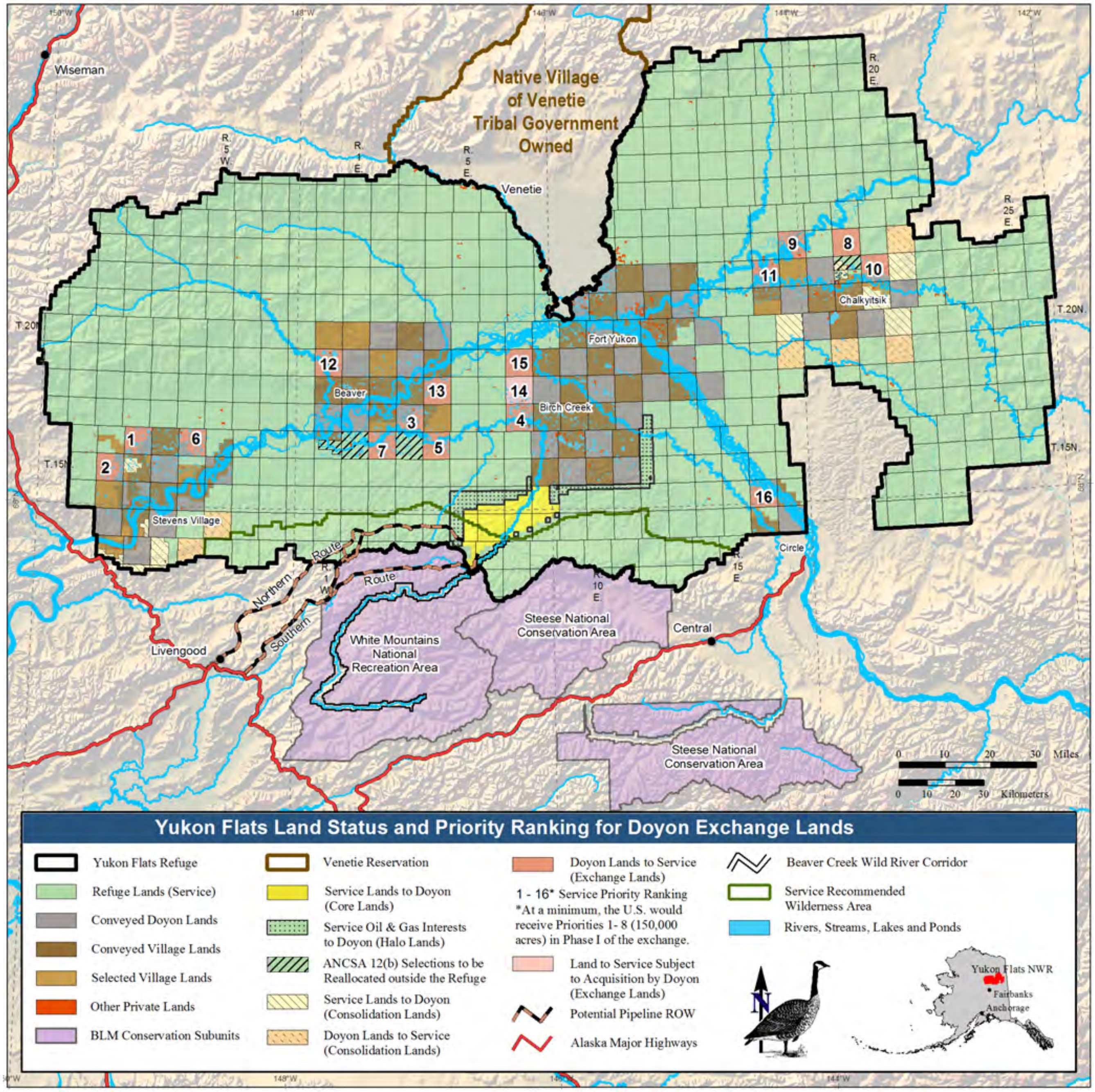


Figure 2. Study area, White Mountains sheep, Alaska, USA.

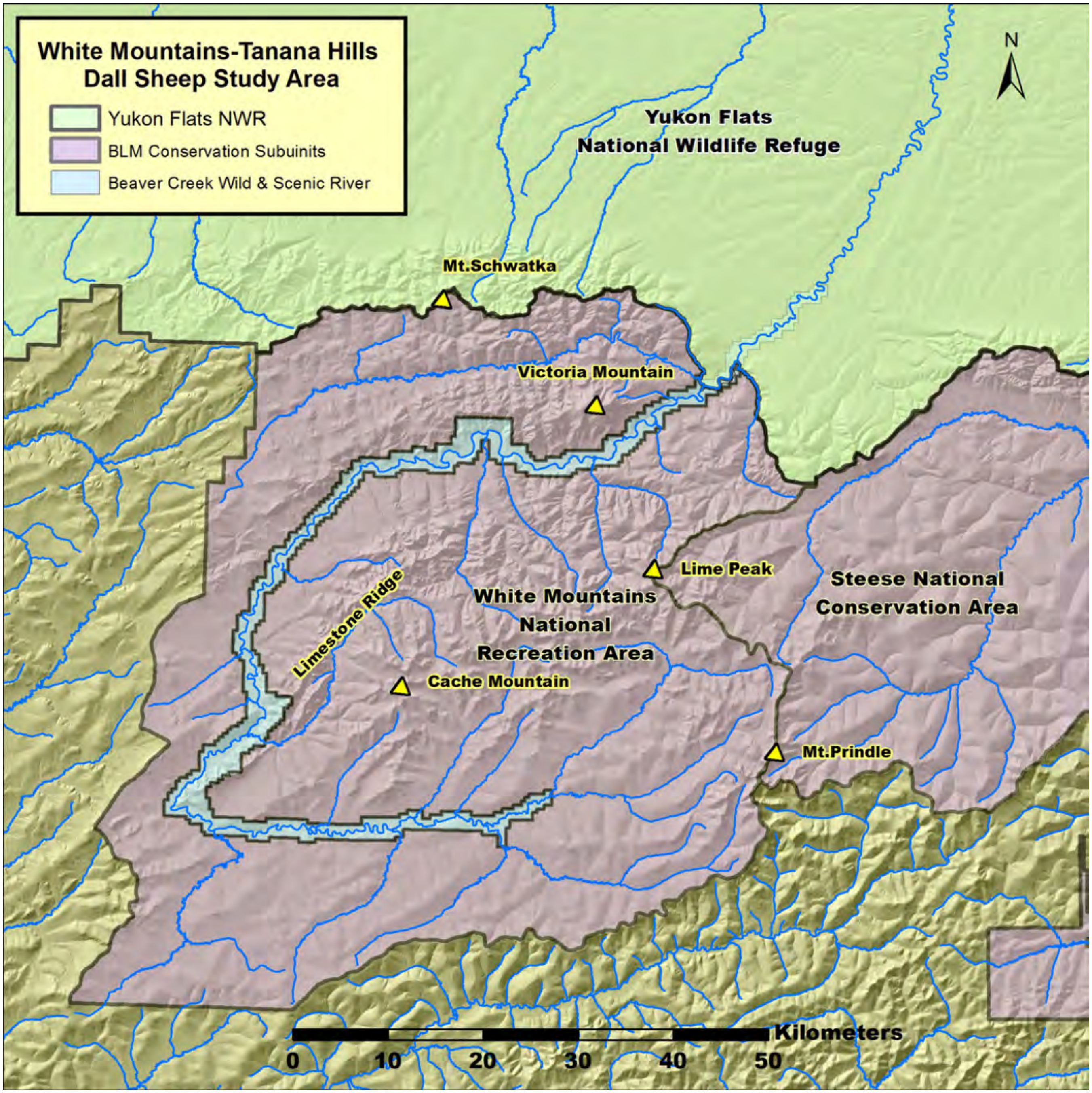


Figure 3. Distribution of radiocollared sheep, White Mountains, Alaska, USA, 2004-2008.

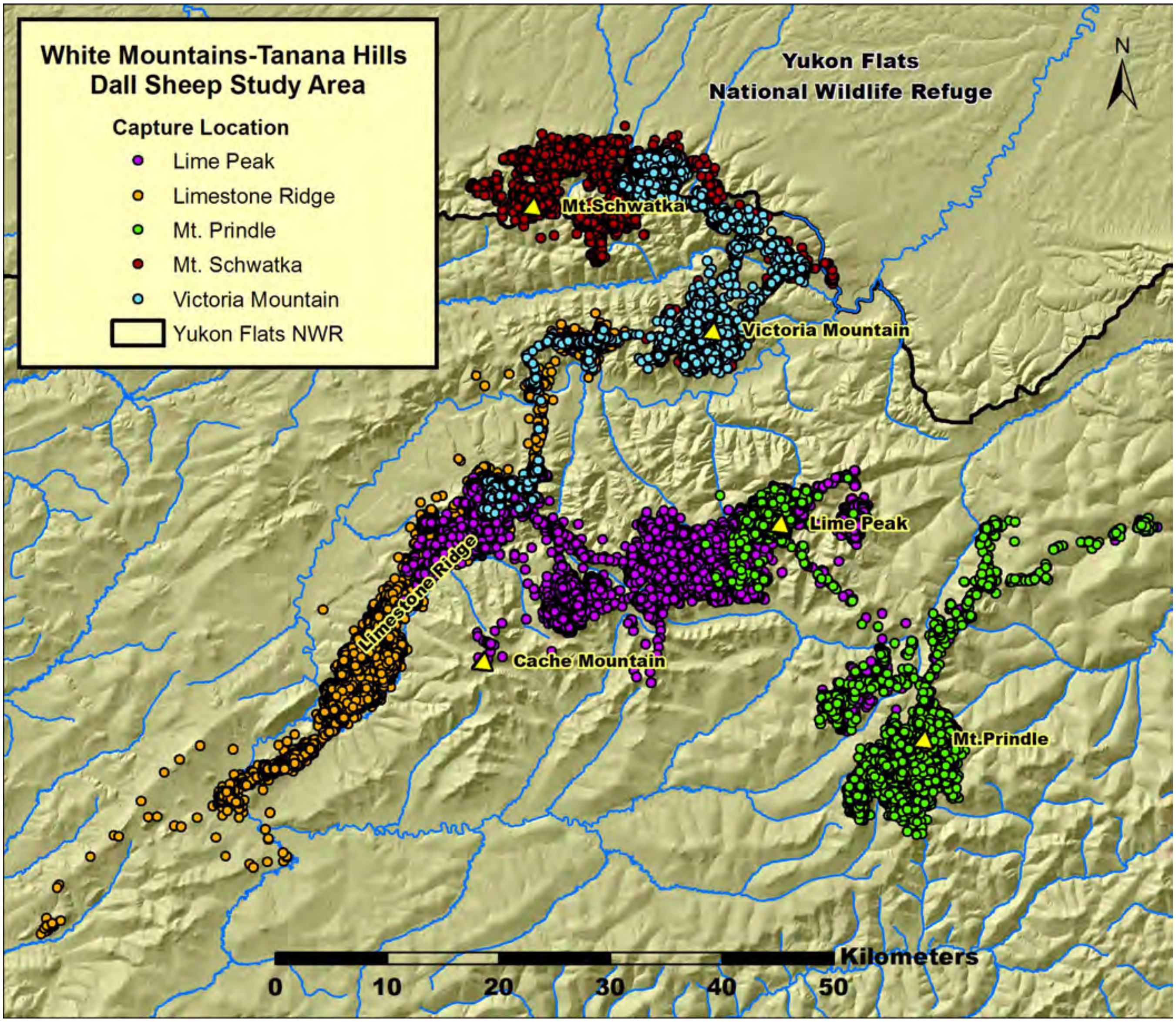


Figure 4. Distribution of radiocollared sheep by sex and region, White Mountains, Alaska, 2004-2008.

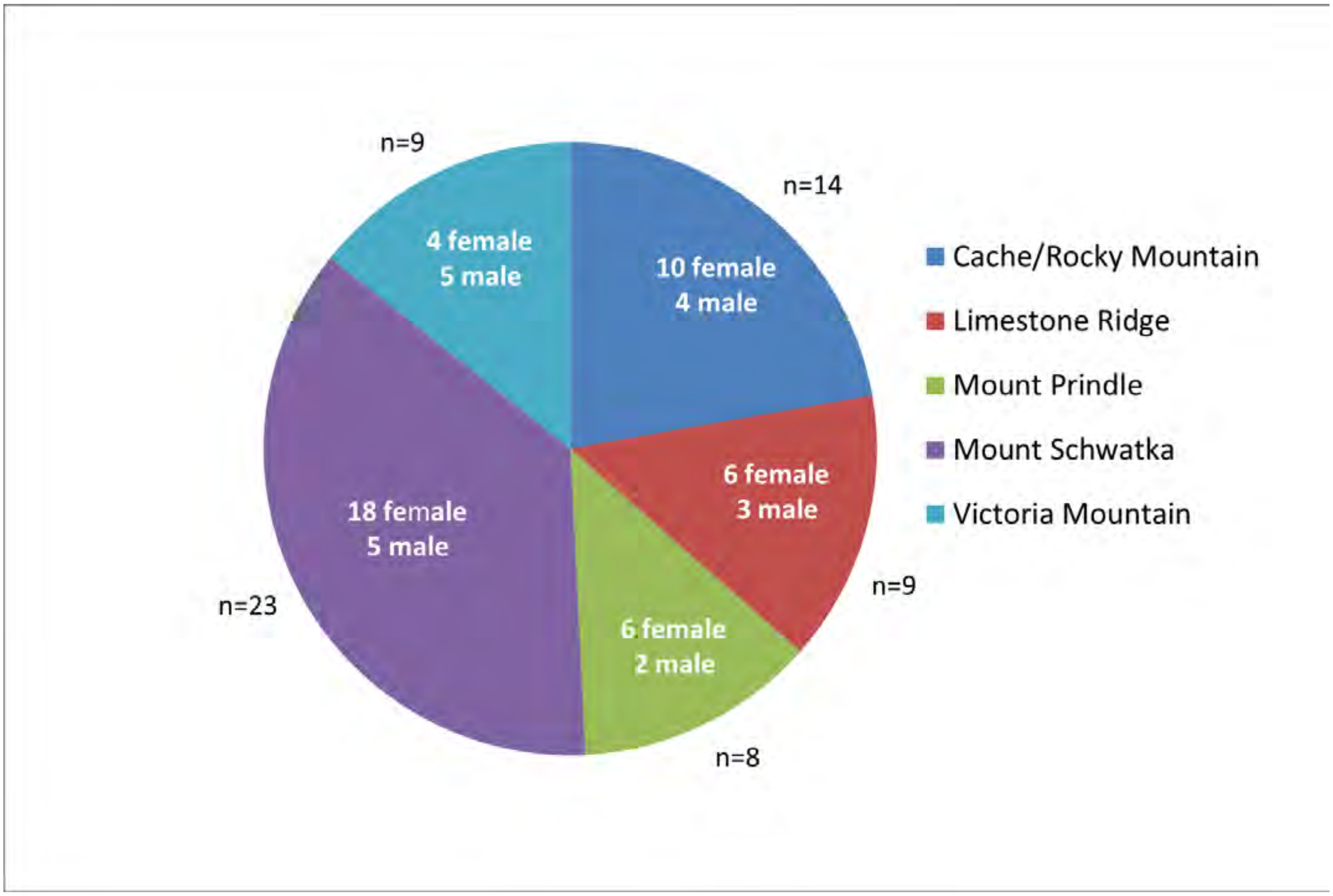


Figure 5. Location of sheep lambing areas realative to proposed oil and gas pipeline corridors.

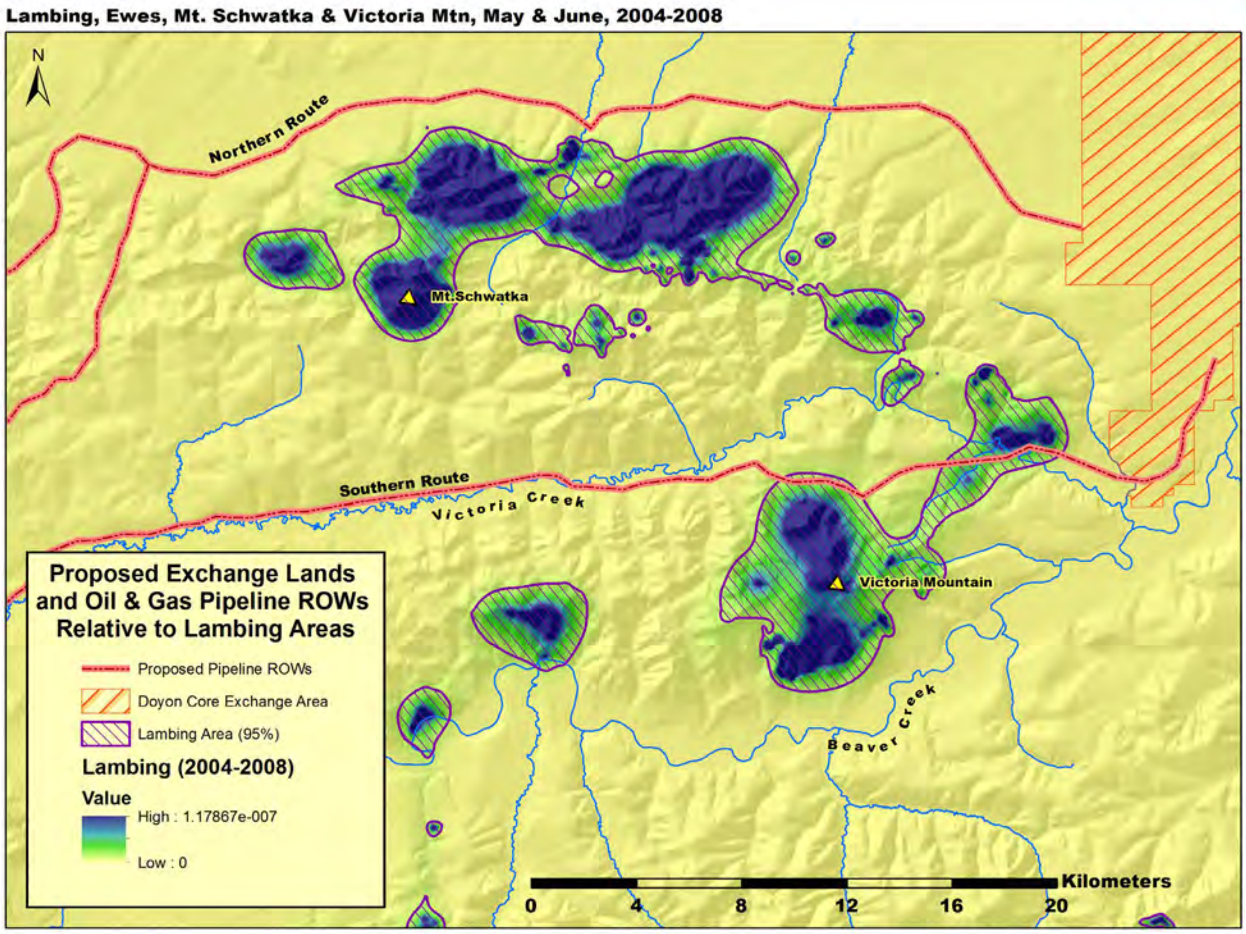


Table 1. Historical summary sheep surveys, White Mountains, Alaska, USA, 1970 to 2017[1]

Year	Mt. Schwatka	Victoria Mtn	White Mtns	Prindle/Lime Pk[8]	Total
1970	101	60	87	37	285
1977 (Aug)	56	27	2	23	124[a]
1982 (May)	39	18	18	37	112
1982 (June)	74	6	17	35	132
1986 (June)	75	26	30	109	240
1989 (Aug)	77	no survey	36	124	237
1991 (Oct)	129 [2]	no survey	70	157	354[a]
1992 (Aug)	118 [3]		63	141	324[a]
1993	no survey				
1994 (Aug)	70	32	66	176	344
1995 (Aug)	95	50	82	182	409
1996 (Aug)	129	47	84	204	464
1997 (Aug)	120	no survey	79	218	417
1998	no survey				
1999 (July)[6]	216	103	128	270	717
2000 (July)[6]	168	34	134	232	568
2001 (Aug)	103	33	48 [4]	184	368
2002 (July)[6]	152	37	94	202	485
2003 (June)[6]	137	88	92	198	515
2004 (August)[6]	115	39	103	206	463
2005 (Jul/Aug)[6]	146	56	92	219	513
2006 (July)[6]	114	55	116	198	483
2007 (July)	129	71	179		379
2008 (July)[5]	169	70	127		366
2009 - 2010	no survey				
2011 (July)[6]	193	59	122	206	580
2012 (July)[6]	171	39	106	175	491
2013 (July)[6]	102	43	122	147	414
2014 (July)[7]	95	19	no survey	134	248
2015 (July)[7]	57	52	no survey	246	355
2016 (July)	70	4	132	78	283
2017 (July)	116	19	128	60	323

[1] data from Kaye 1982, Eagen 1993, Herriges 1993 to 2002, Seaton 2004, 2008, Hollis 2011.

[2] incomplete survey

[3] includes Victoria Mountain observations

[4] incomplete survey

[5] Windy Gap to Willow Creek and Lime Peak not included in survey.

[6] Big Bend to Windy Gap, Windy Gap to Willow Creek, Cache Mtn, Lime Peak, Mt Prindle, Mt Schwatka, and Victoria Mtn

[7] Excludes Big Bend to Windy Gap and Windy Gap to Willow Creek (ie., Limestone Ridge)

[8] Includes Limestone Ridge and Cache Mountain

[a] subtotals do not equal totals

Table 2. Historical summary of sheep harvest, White Mountains, GMUs 25C-D, Alaska, USA, 1970 to 201(

	Number of Hunters			Sheep Harvested		
Year	GMU 25C	GMU 25D	Total	GMU 25C	GMU25D	Total
1968			5			5
1969			1			0
1970			6			3
1971			4			3
1972			3			0
1973			5			1
1974			5			3
1975			4			3
1976			4			2
1977			10			3
1978			3			2
1979	no individual reports for 25C and D					
1980	no individual reports for 25C and D					
1981	no individual reports for 25C and D					
1982	no individual reports for 25C and D					
1983	10	4	14	0	3	3
1984	17	6	23	1	1	2
1985	12	1	13	4	1	5
1986	8	2	10	3	2	5
1987	9	3	12	2	0	2
1988	12	unk	15	1	unk	1
1989	15	unk	15	5	unk	6
1990	20	1	21	3	0	4
1991	22	1	23	2	0	3
1992	25	5	30	5	4	6
1993	35	7	42	5	3	5
1994	22	4	26	2	1	6
1995	28	2	30	5	2	8
1996	31	2	33	8	1	9
1997	33	3	36	8	2	10
1998	19	2	21	4	2	6
1999	42	3	45	11	1	12
2000	34	4	38	4	1	6
2001	38	2	40	7	0	11
2002	49	1	50	5	1	6
2003	51	5	56	16	3	19
2004	36	1	37	9	1	10

1 data from online state hunter harvest tickets, 1968-1981 data taken from Kaye 1982

Table 2. cont. Historical summary of sheep harvest, White Mountains, GMUs 25C-D, Alaska, USA, 1970 to 2017[1]

	Number of Hunters			Sheep Harvested		
Year	GMU 25C	GMU 25D	Total	GMU 25C	GMU25D	Total
2005	49	unk	49	6	unk	6
2006	52	4	56	13	3	16
2007	59	6	65	10	6	16
2008	76	8	84	16	5	21
2009	47	7	54	4	2	6
2010	69	6	75	12	4	16
2011	33	8	41	7	4	11
2012	51	6	57	9	1	10
2013	51	4	55	4	0	4
2014	41	2	43	8	0	8
2015	33	5	38	10	0	10
2016	48	2	50	11	0	11
2017	41	4	45	6	0	6

1 data from online state hunter harvest tickets, 1968-1981 data taken from Kaye 1982

Table 3. Dall's sheep capture statistics, White Mountains, Alaska, USA, 2004-2007.

ID	Location	Sex	Max Annuli	Collar	Transmitter Frequency	Lamb	Capture Date	Movement Stop Date	Collar Recovery Date	Lactate mmol/L	Fate
0	Victoria	F	7	Telonics	166.194	unk	10/16/2004	9/26/2008	9/26/2008		Collar removed 09/26/08
1	Lime Pk	F	6	Lotek	165.432	yes	3/22/2004	9/28/2006	9/28/2006		Collar removed 09/28/06
2	Lime Pk	F	7	none		yes	3/22/2004	n/a	n/a		Dead - capture myopathy 03/22/04
3	Lime Pk	F	4	none		yes	3/22/2004	n/a	n/a		Dead - capture myopathy 03/22/04
4	Schwatka	M	6	Telonics	166.319	no	10/18/2004	8/4/2006	12/3/2006		Unknown - slipped collar 08/4/06
5	Prindle	F	6	Lotek	165.530	no	9/22/2004	10/2/2004	11/19/2004	14.4	Dead - capture myopathy 09/23/04
6	Prindle	F	6	Telonics	166.006	no	9/22/2004	7/13/2008	no recovery	14.8	Unknown - collar malfunction 05/29/08
7	Lime Pk	F	10	Lotek	165.395	no	9/22/2004	3/21/2005	7/26/2005	14.2	Unknown - slipped collar 03/21/05
8	Lime Pk	M	1	Lotek	165.380	no	9/22/2004	2/24/2006	5/11/2006	14	Dead - unknown predator 02/24/06
9	Lime Pk	F	7	Telonics	166.056	unk	9/22/2004	9/29/2008	9/29/2008	13.3	Collar removed 09/29/08
10	Lime Pk	F	11	Lotek	165.555	yes	9/22/2004	9/24/2006	9/28/2006	13.6	Dead - unknown mortality 09/24/06
11	Lime Pk	M	3	Lotek	165.295	no	9/22/2004	12/6/2006	12/6/2006	17.8	Collar removed 12/6/06
12	Lime Pk	F	9	Lotek	165.570	no	9/22/2004	12/27/2004	3/23/2005	16.4	Dead - unknown predator 11/20/04
13	Limestone R.	F	9	Lotek	165.355	no	9/25/2004	9/28/2006	9/28/2006	12.6	Collar removed 09/28/06
14	Limestone R.	F	8	Telonics	166.119	no	9/25/2004	3/6/2006	5/11/2006	12.9	Unknown - slipped collar 02/24/06
15	Limestone R.	F	7	Lotek	165.370	no	9/25/2004	12/3/2006	12/3/2006	13.4	Collar removed 12/03/06
16	Limestone R.	M	2	Lotek	165.330	no	9/25/2004	12/3/2006	12/3/2006	13.8	Collar removed 12/03/06
17	Limestone R.	F	7	none		yes	9/25/2004	n/a	n/a	13.9	Dead - capture myopathy 09/25/04
18	Victoria	M	2	Telonics	166.245	no	10/16/2004	5/24/2007	no recovery		Unknown - collar malfunction 05/18/07
19	Victoria	F	6	Telonics	166.032	yes	10/16/2004	8/19/2006	12/3/2006		Dead - unknown predator 10/07/06
20	Victoria	F	4	Telonics	166.131	unk	10/16/2004	8/30/2008	no recovery		Unknown - collar malfunction 08/30/08
21	Schwatka	F	3	Telonics	166.069	yes	10/17/2004	9/26/2008	9/26/2008		Collar removed 09/26/08
22	Victoria	F	0	Lotek	165.305	unk	10/16/2004	2/3/2007	2/3/2007		Collar removed 02/03/07
23	Schwatka	F	12	Lotek	165.245	yes	10/17/2004	4/5/2006	5/11/2006		Dead - unknown predator 04/05/06
24	Schwatka	M	3	Lotek	165.255	no	10/17/2004	11/1/2004	11/19/2004		Dead - capture myopathy 10/31/04
25	Limestone R.	F	8	Telonics	166.282	yes	10/17/2004	9/26/2008	9/26/2008		Collar removed 09/26/08
26	Prindle	F	6	Telonics	166.019	no	10/20/2004	5/16/2007	9/29/2008		Unknown - slipped collar 05/16/07
29	Prindle	F	5	Telonics	166.232	yes	11/8/2004	8/19/2008	9/24/2008		Unknown - slipped collar 08/19/08
30	Prindle	M	5	Lotek	165.520	no	11/8/2004	8/12/2006	9/28/2006		Collar removed 09/28/06
31	Schwatka	M	0	Telonics	166.292	no	10/18/2004	8/9/2006	5/11/2007		Unknown - slipped collar 08/09/06
32	Schwatka	F	8	Telonics	166.257	yes	10/18/2004	11/12/2005	5/11/2006		Dead - unknown mortality 10/04/05
33	Schwatka	F	10	Telonics	166.106	yes	10/18/2004	12/15/2005	5/11/2006	14.2	Dead - unknown predator 12/01/05
34	Schwatka	F	8	Telonics	166.306	yes	10/18/2004	5/27/2005	7/26/2005	14.9	Dead - unknown mortality 05/27/05
35	Schwatka	F	6	Lotek	165.631	unk	10/18/2004	12/25/2005	5/11/2006	14.2	Dead - unknown mortality 01/25/05
36	Schwatka	F	9	Telonics	166.270	yes	10/18/2004	12/27/2005	5/11/2006	12.8	Dead - unknown mortality 11/14/05
37	Schwatka	F	9	Lotek	165.415	yes	10/18/2004	1/25/2006	5/11/2006	15.2	Dead - unknown predator 01/19/06

Table 3. Dall's sheep capture statistics, White Mountains, Alaska, USA, 2004-2007.

ID	Location	Sex	Max Annuli	Collar	Transmitter Frequency	Lamb	Capture Date	Movement Stop Date	Collar Recovery Date	Lactate mmol/L	Fate
38	Schwatka	F	7	Lotek	165.345	unk	10/18/2004	2/3/2007	2/3/2007	15.5	Collar removed 02/03/07
39	Schwatka	F	4	Telonics	166.220	yes	10/18/2004	9/29/2008	9/29/2008	11.9	Dead - recapture myopathy 09/
40	Schwatka	F	8	Telonics	166.208	yes	10/18/2004	2/2/2007	2/3/2007	14	Collar removed 02/02/07
41	Schwatka	F	6	Telonics	166.092	yes	10/18/2004	8/25/2008	9/24/2008	14.9	Unknown - slipped collar 08/25/
42	Prindle	F	9	Lotek	165.395	no	10/6/2005	9/28/2007	9/28/2007		Dead - recapture myopathy 09/
43	Lime Peak	F	11	Lotek	165.530	no	10/6/2005	4/29/2006	5/11/2006		Dead - unknown mortality 04/29
44	Lime Peak	F	5	Lotek	165.570	no	10/6/2005	9/28/2007	9/28/2007		Collar removed 09/28/07
45	Lime Peak	M	5	Lotek	165.415	no	9/28/2006	9/28/2008	9/28/2008		Collar removed 09/28/08
48	Schwatka	M	3	Telonics	166.032	no	2/3/2007	unk	no recovery		Unknown-collar malfunction
49	Lime Peak	F	4	Lotek	165.380	no	9/28/2006	9/28/2008	9/28/2008		Collar removed 09/28/08
50	Limestone R.	M	2	Lotek	165.555	no	12/6/2006	9/26/2008	9/26/2008		Collar removed 09/26/08
51	Lime Peak	F	5	Telonics	166.270	yes	9/28/2006	8/20/2008	9/28/2008		Unknown - slipped collar 08/20/
54	Lime Peak	F	3	Lotek	165.255	yes/group	9/28/2006	9/10/2008	9/29/2008		Unknown 09/29/08
56	Victoria	M	2	Lotek	165.370	no	2/3/2007	11/25/2007	9/26/2008		Collar removed 09/26/08
58	Schwatka	F	4	Telonics	166.306	no	2/3/2007	8/20/2008	9/24/2008		Unknown - slipped collar 09/24/
59	Limestone R.	F	7	Lotek	165.432	unk	12/6/2006	12/11/2006	2/3/2007		Dead - myopathy, pred related
61	Schwatka	F	6	Lotek	165.355	yes	2/3/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
62	Limestone R.	M	5	Lotek	165.631	no	12/6/2006	9/26/2008	9/26/2008		Collar removed 09/26/08
63	Limestone R.	F	5	Telonics	166.257	yes	12/6/2006	8/19/2008	9/28/2008		Unknown - slipped collar 08/19/
64	Schwatka	F	5	Telonics	166.119	no	2/3/2007	8/24/2008	9/29/2008		Unknown - slipped collar 09/29/
65	Schwatka	F	7	Telonics	166.106	unk	2/3/2007	8/24/2008	9/24/2008		Unknown - slipped collar 09/24/
66	Schwatka	F	5	Lotek	165.295	unk	2/3/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
67	Victoria	F	6	Lotek	165.245	no	2/4/2007	2/13/2007	2/13/2007		Dead - capture myopathy 02/13
68	Schwatka	M	3	Telonics	166.319	no	2/3/2007	12/11/2007	no recovery		Unknown - collar malfunction
71	Prindle	F	5	Lotek	165.345	yes	2/4/2007	9/28/2008	9/28/2008		Collar removed 09/28/08
72	Schwatka	F	5	Lotek	165.432	no	2/4/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
73	Limestone R.	F	5	Lotek	165.305	yes	2/4/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
74	Victoria	M	2	Lotek	165.530	no	9/28/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
75	Victoria	F	0	Lotek	165.520		9/28/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
82	Prindle	M	4	none			9/28/2007	n/a	n/a		Dead - capture myopathy 09/28
83	Victoria	M	3	Lotek	165.245	no	9/28/2007	9/26/2008	9/26/2008		Collar removed 09/26/08
100	Victoria	F	0	none			2/3/2007	n/a	n/a		Unknown-not collared
167	Prindle	F	5	Lotek	165.333	yes	10/9/2007	9/28/2008	9/28/2008		Collar removed 09/28/08
172	Lime Peak	M	3	Lotek	165.395		10/9/2007	9/28/2008	9/28/2008		Collar removed 09/28/08
178	Prindle	M	3	Lotek	165.570		10/9/2007	unk	no recovery		Unknown

Table 4. Regional distribution of collared sheep by sex and collar type, White Mountains, 2004-2008 (capture myopathy in parentheses).

	Cache/Rocky Mountain		Limestone Ridge		Mount Prindle		Mount Schwatka		Victoria Mountain		
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Total
Lotek	8 (2)	4	3 (2)	3	3 (2)	2 (1)	7	1 (1)	1 (1)	4	44
Telonics	2		3		3		11 (1)	4	3	1	19
All collars	10 (2)	4	6 (2)	3	6 (2)	2 (1)	18 (1)	5 (1)	4 (1)	5	63
% F/region	0.227		0.136		0.136		0.409		0.09		
%M/Region		0.21		0.157		0.105		0.263		0.263	
% /All/Region	0.22		0.142		0.126		0.365		0.142		

Table 5. Corrected estimates of observed Dall's sheep, White Mountains, Alaska, USA, 2005.

Region	# collars observed	# collars present	SCF[1]
Schwatka and Victoria mountains	15	18	0.83
Limestone Ridge, Lime Peak, Prindle Mtn, and Cache Mtn	10	14	0.71
Total	25	32	0.78

[1] Sightability Correction Factor

Table 6. Summary of capture related deaths of Dall's sheep, White Mountains-Tanana Hills, Alaska, 2004-2008.

Sheep ID	Location	Mort Date	Capture[1] sequence	Sex	Age	Capture Notes	Cause of death/necropsy notes
2	Rocky Mountain	03/22/04	2nd	Female	7	Captured with young ram extending handling time, ewe unable to stand upon release	Capture related death, Dr. K Beckmen, ADFG, conducted necropsy: broken bac myopathy
3	Rocky Mountain	03/22/04	3rd	Female	4	Ewe unable to stand upon release	Capture related death, Dr. K. Beckmen, ADFG, conducted necropsy: broken bac myopathy
5	Mount Prindle	09/23/04	4th	Female	6	Old wound on left front hip, small fissure crack in horns	Capture related death, necropsy not conducted, telemetry indicated movemer stopped within 24 hrs of capture
17	Limestone Ridge	09/25/04	16th	Female	7	Struggled with head pulled back, xylazine administered late	Peracute capture myopathy,Dr K. Beckmen, ADF&G, conducted necropsy: low parasite load, acute edema in lungs, organ congestion, acute bruising
24	Schwatka	11/01/04	23rd	Male	3	Black tail, teeth: center 2 permanent, next 2 partially erupted, outside 4 deciduous. Left horn tip broken.	Died about 10/31/04, possible predation related to capture myopathy, picked up b JH on 11/19/04.
59	Limestone Ridge	12/11/06	53rd	Female	7	Although animal got up fine, activity of animal stopped 5 days following capture	Likely capture myopathy or predisposed predation. Body not recovered, bloody snow near collar
67	Victoria Mountain	02/13/07	72nd	Female	6	Constant struggling, never calmed down, heavy panting, walked off slow but steady, ewe unable to walk 9 days after initial capture and dispatched for necropsy	Capture myopathy, Dr. K Beckmen, ADFG, conducted necropsy: body condition avg to poor
82	Mount Prindle	09/28/07	78th	Male	4	Struggled constantly, difficult hobbling, caught two rams initially, let younger one go, older ram administered xylazine and blindfolded. Excellent body condition noted at necropsy and kidney covered in fat	Peracute capture myopathy, Dr. K. Beckmen, ADF&G conducted necropsy: mild to moderate levels of parasites in th skeletal muscle, liver, and small intestine and lungs, severe hemorrhaging in the lungs, cause of death is severe, acute pulmonary edema. Marrow filled with fat and kidney covered in fat
42	Mount Prindle	09/28/07	79th	Female	9	Recaptured ewe broke horn and neck upon capture, appeared fit (121 lb body weight, body fat noticeable)	Capture related death, Dr. K. Beckmen, ADF&G, conducted necropsy: broken neck, rhabdomyolysis or damaged skeletal muscle present likely due to capture. Protozoan sarcocsysts present, but no other parasites, lung congested w edema and possibly related to capture, marrow filled with fat
39	Mount Schwatka	09/29/08	101st	Female	4	Recaptured ewe caught in net with young ram (by horns only), ewe's head pulled back which likely contributed to stress and eventual death, no time to drug animal. Ewe died 5-7 minutes after capture	Peracute capture myopathy, Dr. K. Beckmen, ADFG, conducted necropsy 3 hours post mortem, telemetry indicated movement stopped within 24 hrs of capture

[1] Capture sequence is the placement in capture order of the 102 animals captured

Table 7. Annual survival estimates for Dall's sheep monitored in the White Mountains-Tanana Hills, Alaska, USA, 2004-2009.

	2004/2005			2005/2006			2006/2007			2007/2008			2008/2009		
Parameter	n	mean	95% CL	n	mean	95% CL	n	mean	95% CL	n	mean	95% CL	n	mean	95% CL
Males	10	*	*	14	0.93	0.79-1.06	14	1.00	1.0-1.0	2	**	**	1	**	**
Females	28	0.92	0.83-1.02	28	0.85	0.71-0.99	34	0.82	0.68-0.96	25	1.00	1.0-1.0	22	*	*
All sheep	35	0.94	0.86-1.02	35	0.85	0.73-0.97	44	0.85	0.73-0.97	34	1.00	1.0-1.0	30	*	*

*partial year, survival not estimated
** low sample size, survival not estimated

Table 8. Summary of percent occurrence by forage group in microhistological samples of fecal pellets from Dall's sheep, by region, month and year in the White Mountains-Tanana Hills, Alaska.

	Limestone Ridge				Rocky Mountain[2]					Prindle Mountain				Mount Schwatka				Victoria Mountain		
Forage Group	Feb 2007	June/July 2006	July 2005	Sept/Oct[1] 2004	Feb 2007	Mar 2004	June/July 2006	July 2005	Sept/Oct[1] 2004	Feb 2007	June/July 2006	July 2005	Sept/Oct[1] 2004	Feb 2007	June/July 2006	July 2005	Sept/Oct[1] 2004	Feb 2007	June/July 2006	July 2005
Grasses	32.6	18.4	22.8	27.2	45.3	53.6	20.5	26.7	27.2	48.8	19.3	18.8	27.2	11.5	17.5	24.1	27.2	32.7	22.1	20.5
Sedge/Rushes	17.4	26.9	32.1	16.9	14.1	8.5	41.4	52.6	16.9	9.3	60.7	61.9	16.9	34.4	38.7	29.2	16.9	12.8	56.7	42.8
Forbs	10.8	15.6	18.7	9.1	8.6	11.7	5.8	3.0	9.1	1.7	4.8	5.5	9.1	22.0	21.0	20.8	9.1	22.5	10.0	16.8
Mosses	16.4	15.3	6.9	4.0	16.6	12.1	5.5	1.4	4.0	19.1	3.0	4.1	4.0	11.7	6.1	5.7	4.0	18.4	1.8	3.1
Lichens	19.1	15.7	13.6	36.5	12.5	10.7	17.9	8.7	36.5	12.1	5.1	7.6	36.5	12.9	4.8	4.2	36.5	9.0	3.6	0.8
Shrub	3.7	8.1	5.5	6.3	2.4	3.4	8.9	7.6	6.3	9.0	7.1	1.6	6.3	6.8	11.8	16.0	6.3	4.5	5.6	8.4
Conifers			0.4		0.5							0.5		0.9						0.5
Ferns							0.2								0.1			0.1	0.2	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] September/October measures represents a mean value derived from a composite sample collected from all regions except Victoria Mountain

[2] Includes Cache Mountain

Table 9. Percent nitrogen in fecal pellets for Dall's sheep by region, month and year in the White Mountains-Tanana Hills, Alaska.

	2004	2005					2006					2007				
Month	All Regions[1]	Limestone Ridge	Rocky Mountain[3]	Prindle Mountain	Mount Schwatka	Victoria Mountain	Limestone Ridge	Rocky Mountain[3]	Prindle Mountain	Mount Schwatka	Victoria Mountain	Limestone Ridge	Rocky Mountain[3]	Prindle Mountain	Mount Schwatka	Victoria Mountain
February												1.96	2.11	2.05	1.9[2]	1.65
June							2.30	3.22	3.45	2.97	2.82			3.26		
June/July								3.41								
July		2.71	2.76	3.17	2.56	2.86[2]				2.99[2]						
Sept/Oct[1]	1.82															

[1] September/October measures represents a mean value derived from a composite sample collected from all regions except Victoria Mountain

[2] Mean value from two samples

[3] Includes Cache Mountain

Table 10. Lungworm (Protostrongylus stilesi) larvae per gram of feces in captured Dall's sheep by region, sex and age in the White Mountains, Alaska, 2004.

Parameter	n	Mean LPG	Median LPG	Minimum	Maximum	Standard Deviation	Variance
Limestone Ridge	6	1706.57	1047.27	76.07	4435.20	1769.92	3132625.12
Lime Peak[1]	10	12046.86	1386.50	53.67	90395.62	27930.24	780098448.93
Mount Prindle	2	8550.32	8550.32	8454.94	8645.71	134.90	18198.25
Mount Schwatka	13	5123.65	4901.67	0.00	13752.73	4477.63	20049130.40
Victoria Mountain	2	146.12	146.12	102.50	189.74	61.69	3805.72
Females	27	7443.72	1566.67	0.00	90395.62	17225.56	296719918.51
Males	7	4378.11	1770.00	318.42	15273.27	5396.71	29124474.22
Ages 1-3	6	3708.21	2280.93	318.42	8645.71	3598.89	12951993.15
Ages 4-6	9	15378.16	7642.40	0.00	90395.62	28721.21	824908033.30
Ages 7-9	10	2525.36	1434.77	53.67	8306.67	3099.73	9608304.48
Age > 10	2	9007.90	9007.90	1097.02	16918.79	11187.68	125164208.27
Total	34	6812.57	1593.21	0.00	90395.62	15513.15	240657763.71

[1] includes Cache Mountain

Table 11. Lungworm (Prostrongylus stilesi) larvae per gram of feces in Dall's sheep by region in the White Mountains, Alaska, June, 2006.

Region	Sample Date	Larvae per gram	Comments
Victoria	6/20/2006	6	
Schwatka	6/20/2006	8	South side lick-Schwatka
Schwatka	6/20/2006	16	South side lick-Schwatka
Schwatka	6/20/2006	0	South side lick-Schwatka
Schwatka	6/20/2006	19	East of Schwatka
Schwatka	6/20/2006	2	East of Schwatka
Schwatka	6/20/2006	135	East of Schwatka
Schwatka	6/20/2006	4	East of Schwatka
Schwatka	6/20/2006	13	Top of Schwatka
Schwatka	6/20/2006	34	Top of Schwatka
Schwatka	6/20/2006	2	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Schwatka	6/20/2006	6	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Schwatka	6/20/2006	11	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Schwatka	6/20/2006	8	Top of Schwatka
Schwatka	6/20/2006	9	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Schwatka	6/20/2006	0	Top of Schwatka
Rocky Mountain[1]	6/19/2006	1	Mascot Lick
Rocky Mountain[1]	6/19/2006	0	Mascot Lick
Rocky Mountain[1]	6/19/2006	2	Mascot Lick
Rocky Mountain[1]	6/19/2006	20	Mascot Lick
Rocky Mountain[1]	6/19/2006	1	Mascot Lick
Rocky Mountain[1]	6/19/2006	0	Mascot Lick
Rocky Mountain[1]	6/19/2006	0	Mascot Lick
Rocky Mountain[1]	6/19/2006	0	Mascot Lick

[1] includes Cache Mountain

Table 12. Range and mean of trace minerals in serum (n=28) and whole blood (n=24) samples from Dall's Sheep, White Mountains, Alask

Element (PPM)	Serum/whole blood concentration Range	Mean (SD)	Range of normal values Puls (1994) Serum	Whole Blood	Assessment of range of WMH values Lemke and Schwantje (2005)
Copper	0.84-2.23	1.37 (±0.27)	0.70-2.00	1.17-2.56	normal to slightly high
Iron	5.29-28.71	9.54 (±4.76)	1.66-2.22	169-312	high
Selenium[1]	0.08-0.39	0.17 (±0.08)	0.080-0.400	0.130-0.203	deficient to normal
Zinc	0.291-1.149	0.62 (±0.17)	0.80-1.20	0.90-1.84	deficient to normal

[1] Selenium measures are whole blood, all other elements are serum

Table 13. Summary of sheep stream crossing by year and age, White Mountains, Alaska, USA, 2004-2008.

ID	Sex	Age	Collar Type	Capture Location	Capture Date	Total Crossings	Beaver Creek	Victoria Creek	2004	2005	2006	2007	2008
0	F	7	Telonics	Victoria	10/16/2004	28	0	28		12	8	4	4
13	F	9	Lotek	Limestone Ridge	9/25/2004	10	10	0		8	2		
14	F	8	Telonics	Limestone Ridge	9/25/2004	2	2	0		2			
15	F	7	Lotek	Limestone Ridge	9/25/2004	28	28	0		24	4		
19	F	6	Telonics	Victoria	10/16/2004	22	0	22	2	12	8		
22	F		Lotek	Victoria	10/16/2004	22	0	22	4	18	8		
25	F	8	Telonics	Limestone Ridge	10/17/2004	19	19	0	2	4	1	4	8
34	F	8	Telonics	Schwatka	10/18/2004	0							
35	F	6	Lotek	Schwatka	10/18/2004	13	0	13		13			
36	F	9	Telonics	Schwatka	10/18/2004	11	0	11	1	10			
50	M	2	Lotek	Limestone Ridge	12/6/2006	2	2	0				2	0
56	M	2	Lotek	Victoria	2/3/2007	6	0	6				6	
62	M	5	Lotek	Limestone Ridge	12/6/2006	8	8	0				4	4
63	F	5	Telonics	Limestone Ridge	2/3/2007	6	6	0				4	2
64	F	5	Telonics	Schwatka	2/3/2007	12	0	12				7	5
65	F	7	Telonics	Schwatka	2/3/2007	6	0	6				2	4
66	F	5	Lotek	Schwatka	2/3/2007	15	0	15				3	12
73	F	5	Lotek	Limestone Ridge	2/4/2007	14	14	0				0	14
74	M	2	Lotek	Victoria	9/28/2007	10	4	6					10
75	F		Lotek	Victoria	9/28/2007	6	0	6					6
83	M	3	Lotek	Victoria	9/28/2007	6	4	2					6
Totals						246	97	149					

Table 14. Merged minimum convex polygon data for ewe annual movements between 2004 and 2008.

Annual Analysis (Sum of seasons by year)	Sheep in Summary*	50 Percentile Area (km2)	95 Percentile Area (km2)	Area of Merged MCPs (km2) (Sheep)
Nov04-Oct05	23-26	43.427	419.741	1457.533 (29)
Nov05-Oct06	18-26	48.107	375.961	1201.156 (29)
Nov06-Oct07	18-25	23.858	274.71	1431.78 (28)
Nov07-Sep08	14-21	44.983	354.335	1428.972 (21)
Mean				1379.86 (107)

* Number of sheep varied from season to season and included seasonal data from all sheep.

Appendix A. Radio collar specifications for Telonics model TGW-3580 with store on board GPS, Argos uplink, and temperature and activity sensor.

	GPS Tranmission		Argos Transmission		
Period	Schedule	Time (GMT)	Schedule	Days	Time (GMT)
01/01 to 04/30 (120 days) 61 locations/animal	1 position/2 days	1600	4 hours/12 days	10	2000-2300
05/01 to 05/31 (31 days) 31 locations/animal	1 position/day	1600	4 hours/6 days	31	2000-2300
06/01 to 07/31 (61 days) 122 locations/animal	2 positions/day	1600 0400	4 hours/3 days	21	2000-2300
08/01 to 12/31 (153 days) 153 locations/animal	1 position/day	1600	4 hours/6 days	31	2000-2300

01/01 to 12/31
365 days
367 total locations/animal
306 total locations/animal collected at same time of day annually

VHF Beacon

Pulse rate: 50 bpm = successful transmission, 35 bpm = unsuccessful transmission, 100 bpm = mortality
Duty cycle: On 7 hours, 1900 GMT; Off 17 hours, 0201 GMT

Theoretical battery life (based on mean annual temp of -20°C)

VHF beacon = 4.37 years, effective till 02/01/09
GPS = 4.1 years, effective until 10/22/08
Radio collar release = 5.0 years, effective until 10/22/09
Estimated 5.5 months of battery life left on VHF beacon when radio collar release deploys.
Estimated 2 months of battery life left on GPS when radio collar release deploys
Deployment date for radio collars = 09/21/04, Deployment date for radio collar release = 08/19/08, 1400 GMT

Other: Delay time for mortality sensor = 12 hours, Activity collection sensor interval = 5 minutes
Activity switch position = level, Adjustment range for the radio collar = Females 15" on center, Males 18" on center

Note: estimate that VHF beacon battery good for 52.5 months or until 02/01/09. Drop off date of 08/19/09 would be 5.5 months short of expiration of beacon battery

Appendix B. Bootstrap code used for estimating home ranges.

```
datalocation <- file.choose()    ##command tells R to look for your data file on your computer and name it
"data" #R:\GIS_Projects\YukonFlats\Biological\Wildlife\Dall_Sheep\2015\SheepUDs
\WM_DallSheep_HomeRange.csv HR<-read.table(datalocation,header=TRUE,sep=",")

head (HR)

Female<- subset(HR, Sex=="Female")
Male<-  subset(HR, Sex=="Male")

Lotek1hr<-                          subset(HR,                Collar=="Lotek-1hr")
Lotek2hr<-                          subset(HR,                Collar=="Lotek-2hr")
Telonics<- subset(HR, Collar=="Telonics")

###Set Parameters
DATA  <- Telonics$BB_ContPoly

NumbSimulations <- length(Telonics$BB_ContPoly)


BootstrapData=rep(NA,100000)    ##create an empty(filled with NA) vector of data that will later be filled with
bootstrapped samples




for(i in 1:100000){        ##here "i" is a variable in a vector that has a hundred thousand elements, the "for" command
executes the group of of expressions within the braces{}, once for each element in the vector
resample= sample(DATA, size=NumbSimulations,replace=T)  ##Sample the NDiff vector n times
BootstrapData[i]=mean(resample,na.rm=TRUE)   ##take the mean of the NDiff Vector of resampled data
}


Mean=mean(BootstrapData,na.rm=TRUE)
lowerCI=quantile(BootstrapData,.025,na.rm=TRUE)########lower 95%CI for bootstrapped difference in means (here
"quantile" produces samples corresponding the probability =.025)
upperCI=quantile(BootstrapData,.975,na.rm=TRUE)
sd=sd(BootstrapData,na.rm=TRUE)


Mean
lowerCI
upperCI
sd
```

Appendix B. cont. Results from bootstrap code used for estimating home ranges.

```
## Results ##
#MCP All Sheep      Mean =  213.729     lowerCI 2.5% = 174.4433  upperCI 97.5% = 257.0128   sd =  21.07397
#MCP Female         Mean =  183.5977    lowerCI 2.5% = 146.942   upperCI 97.5% = 224.3039   sd =  19.74881
#MCP Male           Mean =  313.0938    lowerCI 2.5% = 212.843   upperCI 97.5% = 426.8123   sd =  54.80199
#MCP Lotek-1hr      Mean =  308.6024    lowerCI 2.5% = 222.1436  upperCI 97.5% = 405.3854   sd =  46.908
#MCP Lotek-2hr      Mean =  185.6947    lowerCI 2.5% = 133.8056  upperCI 97.5% = 241.7372   sd =  27.50269
#MCP Telonics       Mean =  179.461     lowerCI 2.5% = 129.088   upperCI 97.5% = 241.5099   sd =  28.83017

#BB_50 All Sheep    Mean =  7.707398    lowerCI 2.5% = 6.190892  upperCI 97.5% = 9.343323  sd =  0.8086065
#BB_50 Female       Mean =  8.266824    lowerCI 2.5% = 6.360669  upperCI 97.5% = 10.31548  sd =  1.015971
#BB_50 Male         Mean =  5.858553    lowerCI 2.5% = 4.556462  upperCI 97.5% = 7.236467  sd =  0.6866436
#BB_50 Lotek-1hr    Mean =  4.30548     lowerCI 2.5% = 3.452937  upperCI 97.5% = 5.17875   sd =  0.4423423
#BB_50 Lotek-2hr    Mean =  4.537136    lowerCI 2.5% = 3.290058  upperCI 97.5% = 6.069562  sd =  0.7129871
#BB_50 Telonics     Mean =  12.77076    lowerCI 2.5% = 10.07091  upperCI 97.5% = 15.45932  sd =  1.37727

#BB_95 All Sheep    Mean =  53.07074    lowerCI 2.5% = 44.04195  upperCI 97.5% = 63.02113  sd =  4.844967
#BB_95 Female       Mean =  56.18314    lowerCI 2.5% = 44.76796  upperCI 97.5% = 68.76354  sd =  6.136135
#BB_95 Male         Mean =  42.82743    lowerCI 2.5% = 35.77469  upperCI 97.5% = 49.83159  sd =  3.590998
#BB_95 Lotek-1hr    Mean =  34.30953    lowerCI 2.5% = 28.67137  upperCI 97.5% = 39.65975  sd =  2.815754
#BB_95 Lotek-2hr    Mean =  34.89236    lowerCI 2.5% = 27.24771  upperCI 97.5% = 42.87136  sd =  3.977491
#BB_95 Telonics     Mean =  82.63258    lowerCI 2.5% = 66.67789  upperCI 97.5% = 100.0765  sd =  8.553973

#BB_CP All Sheep    Mean =  117.6712    lowerCI 2.5% = 98.26478  upperCI 97.5% = 140.0697  sd =  10.65719
#BB_CP Female       Mean =  114.9271    lowerCI 2.5% = 91.27691  upperCI 97.5% = 142.7184  sd =  13.1799
#BB_CP Male         Mean =  126.6854    lowerCI 2.5% = 100.6141  upperCI 97.5% = 156.4904  sd =  14.28938
#BB_CP Lotek-1hr    Mean =  116.383     lowerCI 2.5% = 88.77338  upperCI 97.5% = 145.9397  sd =  14.59673
#BB_CP Lotek-2hr    Mean =  88.38364    lowerCI 2.5% = 66.02767  upperCI 97.5% = 111.879   sd =  11.6803
#BB_CP Telonics     Mean =  147.4685    lowerCI 2.5% = 110.1046  upperCI 97.5% = 193.3402  sd =  21.32809
```

Appendix C. Morphological measurements (cm) for captured Dall's sheep in the White Mountains, Alaska, USA, 2004-2008.

						Horn Length		Horn Base		Annuli							Condtion (1-5)				
ID	Date	Location	Wt (lb)	Sex	Age	Right	Left	Right	Left	Right	Left	Body length	Chest girth	Neck	Meta-tarsus	Jaw	Withers	Ribs	Hips	Tooth[1] wear	Lamb
0	10/16/04	Victoria		F	7					7	7						3	3	3		unk
1	03/22/04	Lime Pk	135	F	6	23	23	13	13	6	6	159	113	37	28	20.5	3.5	3.5	2.5	M	yes
2	03/22/04	Lime Pk	113	F	7	25.5	28	12	12	5	7	151	103	37.5	30	20	3	3.5	2.5	M	yes
3	03/22/04	Lime Pk	118	F	4	20	19	12	12	3	4	160	103.5	40	28	20	2.5	2.5	2.5	M	yes
4	10/18/04	Schwatka		M	6	64.5	65.5	32.5	33	6	6	167	117		30.1	21.8	3	3	3	L	no
5	09/22/04	Prindle	118	F	6	23	23.5	12	11	6	5				26.5		2.5	2.5	2	M	no
6	09/22/04	Prindle	150	F	6	29	28	13	13	6	6	151		40.1	28.9	20.2	3	2	2	M	no
7	09/22/04	Lime Pk	156	F	10	22.5	25	13	13	10	9	146		41	27.7	19.9	3	2.5	2.5	H	no
8	09/22/04	Lime Pk	91	M	1	0	18	14.5	0	1	1	133	94.5	35	26	22	3	2.5	2	L	no
9	09/22/04	Lime Pk	144	F	7	27.2	27.3	13.5	13.5	7	7	155	107	43.5	28.6	20.3	3	3	3	M	unk
10	09/22/04	Lime Pk		F	11	31.4	25.7	12.6	12.4	11	9	142	107.5	39.5	27.7	20.6	2	2	2	M	yes
11	09/22/04	Lime Pk	142	M	3	46.4	46.4	23.5	23.5	3	3	159	107	45	29.5	25.1	2	2.5	2.5	L	no
12	09/22/04	Lime Pk	154	F	9	23.5	23	12.8	12.7	9	9	166	117	40.5	28.5	21.9	2	2	2	M	no
13	09/25/04	Limestone	132	F	9	24	27	14	14.5	8	9	155	112	43	27.5	21	3	2.5	3	L	no
14	09/25/04	Limestone		F	8	31.7	29	13.5	13.5	8	8	160	112	39	29	22.1	3.5	3	3	L	no
15	09/25/04	Limestone	139	F	7	30.5	31.2	13	13.5	7	7	157	115	45	27.1	21	2.5	2.5	2.5	L	no
16	09/25/04	Limestone	109	M	2	29	29	17.5	17.5	2	2	145	101.5	43	28.7	20	2	2	2	L	no
17	09/25/04	Limestone	169	F	7	23	27.5	13.9	13.8	6	7	156	107	41	29.9	22.6	3	3.5	3	M	yes
18	10/16/04	Victoria	136	M	2	41	38	24	23	2	2						2.5	2.5	2.5	L	no
19	10/16/04	Victoria		F	6					6	6						2.5	2.5	2.5	M	yes
20	10/16/04	Victoria		F	4	25	27.5			4	4						2	2	2		unk
21	10/17/04	Schwatka	126	F	3	18	18	12	12.5	3	3	152	10?		27	20.5	3	3	3	L	yes
22	10/16/04	Victoria		F													3	3	3		unk
23	10/17/04	Schwatka	146	F	12	32	23	13	12.5	12	10	152	119		28.6	20.6	2	2	2	L	yes
24	10/17/04	Schwatka	113	M	3	28.5	23			3	3	155	127		29.2	19.3	2	2	2	L	no

[1] L = light (1mm), M = medium (2mm), H=high (3mm)

Appendix C cont. Morphological measurements (cm) for captured Dall's sheep in the White Mountains, Alaska, USA, 2004-2008.

						Horn Length		Horn Base		Annuli							Condtion (1-5)				
ID	Date	Location	Wt (lb)	Sex	Age	Right	Left	Right	Left	Right	Left	Body length	Chest girth	Neck	Meta-tarsus	Jaw	Withers	Ribs	Hips	Tooth[1] wear	Lamb
25	10/17/04	Limestone	125	F	8	29	32	12	12	8	8	156	119		28.4	21.5	3	3.5	3	L	yes
26	10/20/04	Prindle		F	6	23	23	13	13	6	6	157	110		27.1	21	2.5	2.5	2.5	H	no
29	11/08/04	Prindle	127	F	5	Broke	26	Broke	13	Broke	5	162	103	42	27.4	20.3	2	2.5	2	M	yes
30	11/08/04	Prindle	148	M	5	54	53.5	27	26.5	5	5	174	117	54	28.5	21.7	2.5	3	2	M	no
31	10/18/04	Schwatka		M	stump					stump	stump										no
32	10/18/04	Schwatka		F	8	27.5	26	13	13.5	8	7	157	110		27.5	19.9	2.5	2	2	M	yes
33	10/18/04	Schwatka		F	10					9	10	160	124		28.6	21.7	2	2	2	L	yes
34	10/18/04	Schwatka		F	8	29.5	27	12.5	12	8	6	151	108		27.3	21.4	2	2	2.5	M	yes
35	10/18/04	Schwatka		F	6					5	6						3	2.5	2.5		unk
36	10/18/04	Schwatka	142	F	9	31	33	13	13	9	9	151	111		28.5	20.8	3	2.5	3	M	yes
37	10/18/04	Schwatka	137	F	9	27	28	13	13.5	9	9	160	108		28.7	21.5	2	2	2	M	yes
38	10/18/04	Schwatka	139	F	7	29	29	14	14	7	7	158	107		27.8	19.9	2	2	2	M	unk
39	10/18/04	Schwatka	127	F	4	21	22.5	12.5	12.5	3	4	150	101		27.1	20	2	2.5	2.5	L	yes
40	10/18/04	Schwatka	136	F	8	24	25.5			8	8	161	112		27.5	21.1	2	2	2	M	yes
41	10/18/04	Schwatka	138	F	6					5	6	156			28	20.5	2.5	2.5	2.5	L	yes
42	10/06/05	Prindle	112	F	9	27	28	13	13	8	9	142	99	39	27.7	19.9	2	2	2	M	no
43	10/06/05	Lime Peak	152	F	11	30	33	14.5	14	11	11	139	110	38	27.5	20.6	3	3.5	3.5	H	no
44	10/06/05	Lime Peak		F	5	20.5	22.5	13	12.5	5	5	134	113.5	43	27.4	19.4	2.5	2.5	2	M	no
45	09/28/06	Lime Peak	135	M	5	38	39	23.5	23.5	5	5	147	105	39.5	29.5	20.7	2.5	3	3	L	no
48	02/03/07	Schwatka		M	3					3	3				29	24.8					unk
49	09/28/06	Lime Peak		F	4	29.5	28	13.5	13.5	4	4	163	114	43	27.6	20.5	3	3.5	3.5	M	no
50	12/06/06	Limestone		M	2	22	24			2	2				18.8	20.3	2	2	2		unk
51	09/28/06	Lime Peak		F	5	28.5	27			5	4	146	113.5	39	27.5	21.2	2.5	2	2.5		yes
54	09/28/06	Lime Peak		F	3	27	28	14.5	14.5	3	3	151	116	44	28.5	20.5	3	3	3	M	yes
56	02/03/07	Victoria		M	2					2	2										no

[1] L = light (1mm), M = medium (2mm), H=high (3mm)

Appendix C cont. Morphological measurements (cm) for captured Dall's sheep in the White Mountains, Alaska, USA, 2004-2008.

						Horn Length		Horn Base		Annuli							Condtion (1-5)				
ID	Date	Location	Wt (lb)	Sex	Age	Right	Left	Right	Left	Right	Left	Body length	Chest girth	Neck	Meta-tarsus	Jaw	Withers	Ribs	Hips	Tooth[1] wear	Lamb
58	02/03/07	Schwatka	100	F	4	20	19	12	13	4	4	131	96	41	27.5	18.3	2.5	2.5	3		no
59	12/06/06	Limestone		F	7					7	7				27.4	21.2					unk
61	02/03/07	Schwatka	115	F	6	Broke	27	Brok	13	Broke	6	130	101	39.5	27.9	21.2	2	2	2		yes
62	12/06/06	Limestone		M	5					5	5				30	20.7					unk
63	12/06/06	Limestone		F	5					5	5				27.4	21.1					yes
64	02/03/07	Schwatka	129	F	5	22	24	13.5	14	5	5	142	115	44	28	19.6	2.5	2.5	2		no
65	02/03/07	Schwatka	110	F	7	24.5	25	12.5	12	7	6	141	104	42.5	26.2	19.6	2	2	2	M	unk
66	02/03/07	Schwatka	140	F	5	21.3	22.5	13	13.3	5	5	157.5	114	46	28.5	21.3	3	2.5	2.5	L	unk
67	02/04/07	Victoria		F	6					6	6										n
68	02/03/07	Schwatka		M	3	53	52	29	28	3	3	148	113	47	28.9	21.7	3	3	3	L	n
71	02/04/07	Prindle	95	F	5	0	25.2	12.5	13	broke	5	139	104	38.5	26.2	19.3	unk	unk	unk	L	y
72	02/04/07	Schwatka	135	F	5	25	22.5			5	5	158	124	43	28.5	20.3	2.5	2	2	L	n
73	02/04/07	Limestone	140	F	5	26.5	0	13	0	5	broke	149	110	43	27.7	20.4	2.5	2	2.5	L	y
74	09/28/07	Victoria		M	2					2	2				30						n
75	09/28/07	Victoria	135	F																	unk
82	09/28/07	Prindle	156	M	4					4	4	143			29	21					unk
83	09/28/07	Victoria	170	M	3	54.5	56	31	30	3	3	169	118	53	30	17.5	2.5	2.5	3	L	n
100	02/03/07	Victoria		yrl F																	unk
167	09/28/08	Prindle		F	5	21.5	23.5	12.5	12.5	5	5	156	116	45	26.9	20.2	3	3.5	3.5	L	unk
172	10/09/07	Lime Peak	160	M	3					3	3										unk
178	10/09/07	Prindle	135	M	3	34	34			3	3										unk

[1] L = light (1mm), M = medium (2mm), H=high (3mm)

Appendix D-1. Minimum convex polygon (MCP) and BBMM isopleth (BB_isopoly) home range estimates and movement statistics for individual Dall's sheep in the White Mountains, Alaska, USA, 2004-2008.

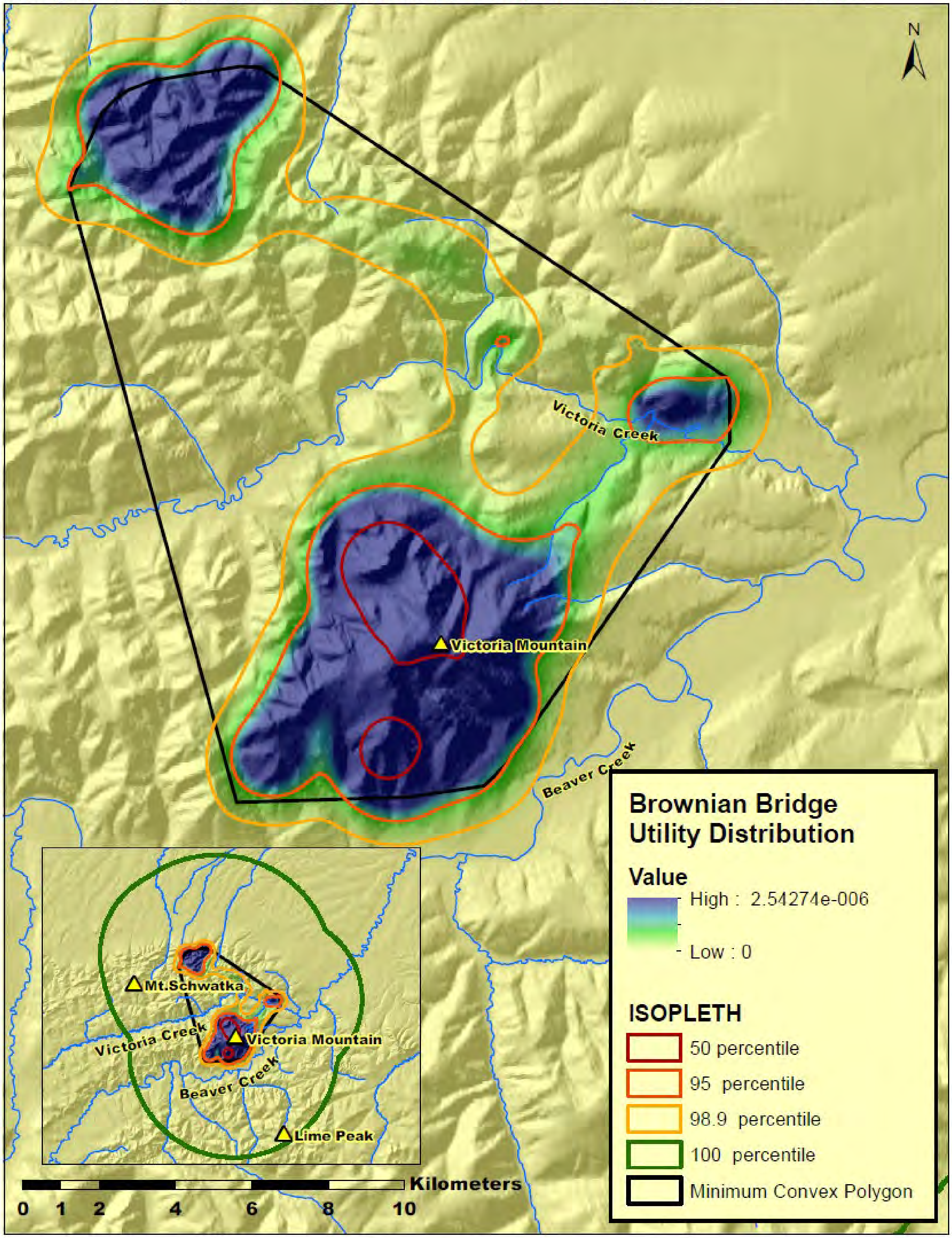
Sheep_ID	Sex	Max_Annuli	Location	Collar	Collar Days	Number of GPS Locations	MCP Area_KM2	BB_Isopoly 50 percentile Area_KM2	BB_Isopoly 95 percentile Area_KM2	BB_Isopoly Continuous Polygon		BB_Isopoly 100 percentile Area_KM2
										Area_KM2	Percentile	
S000	Female	7	Victoria	Telonics	1441	1383	212.477	10.458	75.959	147.596	98.9000%	1705.027
S001	Female	6	Lime Peak	Lotek-2hr	920	10947	281.763	13.266	69.923	136.491	99.5100%	425.453
S007	Female	10	Lime Peak	Lotek-2hr	180	2123	104.501	1.147	14.318	36.704	98.1000%	202.853
S009	Female	7	Lime Peak	Telonics	1468	1397	172.806	21.212	91.560	144.393	99.0000%	2377.938
S010	Female	11	Lime Peak	Lotek-2hr	732	8724	100.535	6.102	37.997	67.448	99.2000%	173.733
S012	Female	9	Lime Peak	Lotek-2hr	96	1141	35.352	2.000	13.213	19.950	98.0000%	83.770
S013	Female	9	Limestone R.	Lotek-2hr	733	8542	215.262	5.665	42.486	116.349	99.3000%	351.480
S014	Female	8	Limestone R.	Telonics	527	399	186.891	22.998	102.339	212.711	99.5000%	1874.665
S015	Female	7	Limestone R.	Lotek-2hr	799	9395	231.764	3.286	50.001	110.457	98.0000%	591.080
S019	Female	6	Victoria	Telonics	672	576	197.055	16.560	115.341	184.961	99.0000%	3446.888
S021	Female	3	Schwatka	Telonics	1440	1203	50.739	3.074	30.842	49.662	99.0000%	640.705
S022	Female	0	Victoria	Lotek-1hr	840	19985	164.092	2.263	23.878	58.214	98.8000%	175.655
S023	Female	12	Schwatka	Lotek-1&2	535	7453	31.631	2.105	11.743	17.786	98.0000%	66.493
S025	Female	8	Limestone R.	Telonics	1440	1337	207.446	17.610	93.540	184.643	99.1000%	2343.833
S026	Female	6	Prindle	Telonics	938	761	651.203	19.035	161.939	505.946	99.8000%	3849.098
S029	Female	5	Prindle	Telonics	1380	1158	376.756	18.164	150.250	271.032	99.0000%	5227.698
S032	Female	8	Schwatka	Telonics	390	366	38.700	2.804	24.556	46.832	99.0000%	459.750
S033	Female	10	Schwatka	Telonics	423	419	81.817	9.532	50.052	85.585	99.2000%	985.518
S034	Female	8	Schwatka	Telonics	221	143	56.832	4.998	54.205	75.503	98.0000%	830.758
S035	Female	6	Schwatka	Lotek-2hr	433	5119	227.579	2.669	31.473	86.411	98.4200%	280.403
S036	Female	9	Schwatka	Telonics	435	399	176.112	14.457	102.050	136.412	98.0000%	1488.085
S037	Female	9	Schwatka	Lotek-2hr	464	5190	44.924	1.913	14.559	27.913	97.8100%	90.625
S038	Female	7	Schwatka	Lotek-2hr	838	9952	104.435	2.733	25.532	50.353	98.6000%	176.688
S039	Female	4	Schwatka	Telonics	1442	1327	95.252	3.686	48.047	107.559	99.5000%	948.200
S040	Female	8	Schwatka	Telonics	837	2978	111.001	5.839	52.774	79.615	98.0000%	1587.578
S041	Female	6	Schwatka	Telonics	1407	1289	89.718	11.277	56.685	67.489	97.0000%	854.663
S042	Female	9	Prindle	Lotek-2hr	722	8591	153.767	3.951	31.262	76.728	99.3000%	260.473
S043	Female	11	Lime Peak	Lotek-2hr	205	2414	50.041	2.123	14.435	36.048	98.8000%	94.393
S044	Female	5	Lime Peak	Lotek-2hr	722	8530	233.512	6.115	38.893	105.142	99.5600%	372.168
S049	Female	4	Lime Peak	Lotek-1hr	732	16859	408.249	3.073	34.398	156.566	98.8126%	364.858
S051	Female	5	Lime Peak	Telonics	692	650	264.965	21.124	94.693	173.723	99.2000%	1719.308
S054	Female	3	Lime Peak	Lotek-1&2	713	7249	73.408	6.989	34.975	52.298	99.0000%	165.470
S058	Female	4	Schwatka	Telonics	564	545	62.204	8.015	41.597	44.859	96.0000%	468.288
S061	Female	6	Schwatka	Lotek-1hr	601	14076	87.804	3.098	23.871	51.799	98.4230%	141.120
S063	Female	5	Limestone R.	Telonics	622	565	322.898	22.106	170.707	241.788	98.0000%	4171.735
S064	Female	5	Schwatka	Telonics	568	562	225.630	18.236	112.481	180.725	99.0000%	1567.493
S065	Female	7	Schwatka	Telonics	568	538	178.140	9.082	62.293	124.192	99.0000%	2195.843
S066	Female	5	Schwatka	Lotek-1hr	601	13532	288.327	5.505	45.018	159.352	99.4900%	846.040
S071	Female	5	Prindle	Lotek-2hr	602	6938	456.397	6.398	51.117	197.851	99.5190%	483.095
S072	Female	5	Schwatka	Lotek-1hr	600	13427	53.893	2.337	12.649	29.114	99.2000%	115.685
S073	Female	5	Limestone R.	Lotek-1hr	600	13567	231.412	4.719	40.528	87.430	99.2000%	325.730
S075	Female	?	Victoria	Lotek-1hr	364	8354	192.063	2.395	21.270	78.211	98.3154%	205.440
S167	Female	5	Prindle	Lotek-1hr	355	8132	364.188	5.300	40.321	119.265	99.3000%	348.983
S004	Male	6	Schwatka	Telonics	655	510	93.138	10.548	61.170	93.188	99.0000%	1708.045
S008	Male	1	Lime Peak	Lotek-2hr	520	6173	245.825	4.999	54.546	119.669	99.2000%	413.505
S011	Male	3	Lime Peak	Lotek-1hr	805	19027	342.262	8.013	49.053	152.317	99.4460%	313.703
S016	Male	2	Limestone R.	Lotek-2hr	799	9245	166.222	6.249	37.272	90.678	99.3600%	324.620
S030	Male	5	Prindle	Lotek-2hr	642	7267	320.106	3.964	31.174	135.785	99.3900%	373.193
S031	Male	?	Schwatka	Telonics	660	560	97.402	10.179	65.361	85.225	98.0000%	992.455
S045	Male	5	Lime Peak	Lotek-1hr	731	17228	384.356	5.951	48.672	128.977	99.4000%	335.065
S050	Male	2	Limestone R.	Lotek-1hr	660	15205	639.132	5.993	43.526	219.533	99.3562%	532.755
S056	Male	2	Victoria	Lotek-1hr	295	7012	192.831	3.922	30.276	77.961	99.2200%	298.660
S062	Male	5	Limestone R.	Lotek-1hr	660	15356	260.564	5.885	40.047	113.654	99.0700%	314.900
S074	Male	2	Victoria	Lotek-1hr	364	8503	442.406	3.262	33.265	132.267	99.0050%	356.265
S083	Male	3	Victoria	Lotek-1hr	364	8123	117.573	1.455	16.706	55.691	98.8000%	175.250
S172	Male	3	Lime Peak	Lotek-1hr	355	8033	768.011	5.728	45.442	241.452	99.2881%	534.088

Appendix D-2. Mean BBMM isopleth home range estimates at the 95 percentile, minimum convex polygon home range estimates, and radio collar days by region and sex for Dall's sheep in the White Mountains, Alaska, USA, 2004-2008.

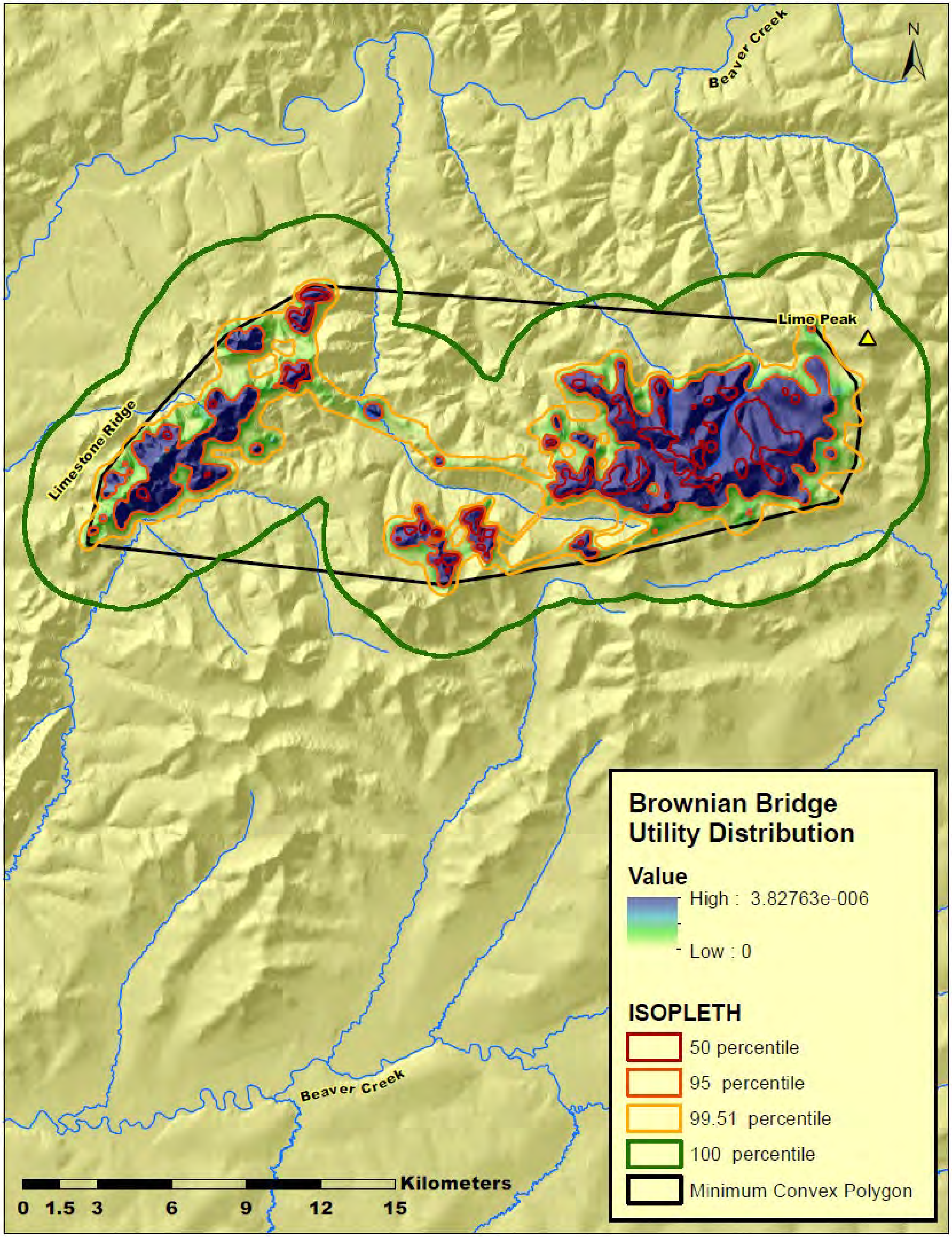
Region	Mean MCP by sex (n)		Mean BBMM 95 Percentile by sex (n)		Mean collar days by sex (n)	
	Male	Female	Male	Female	Male	Female
Victoria	250.9 (3)	191.42 (4)	26.7 (3)	59.1 (4)	341 (3)	829.3 (4)
Lime Peak	435.1 (4)	172.5 (10)	49.4 (4)	44.4 (10)	803.6 (4)	646 (10)
Limestone Ridge	355.3 (3)	232.6 (6)	40.3 (3)	83.3 (6)	706.3 (3)	786.8 (6)
Prindle	320.1 (1)	400.5 (5)	31.2 (1)	87.0 (5)	642 (1)	799.4 (5)
Schwatka	95.3 (2)	111.4 (18)	63.3 (2)	44.5 (18)	657.5 (2)	687.1 (18)
Mean total by sex	313.1 (13)	183.6 (43)	42.8 (13)	56.2 (43)	577.7 (13)	717.7 (43)
Mean total all sheep	213.6 (56)		53.1 (56)		685.2 (56)	

Appendix D-3. (Maps) Minimum convex polygon and BBMM isopleth home range estimates and movement statistics for individual Dall's sheep in the White Mountains, Alaska, USA, 2004-2008.

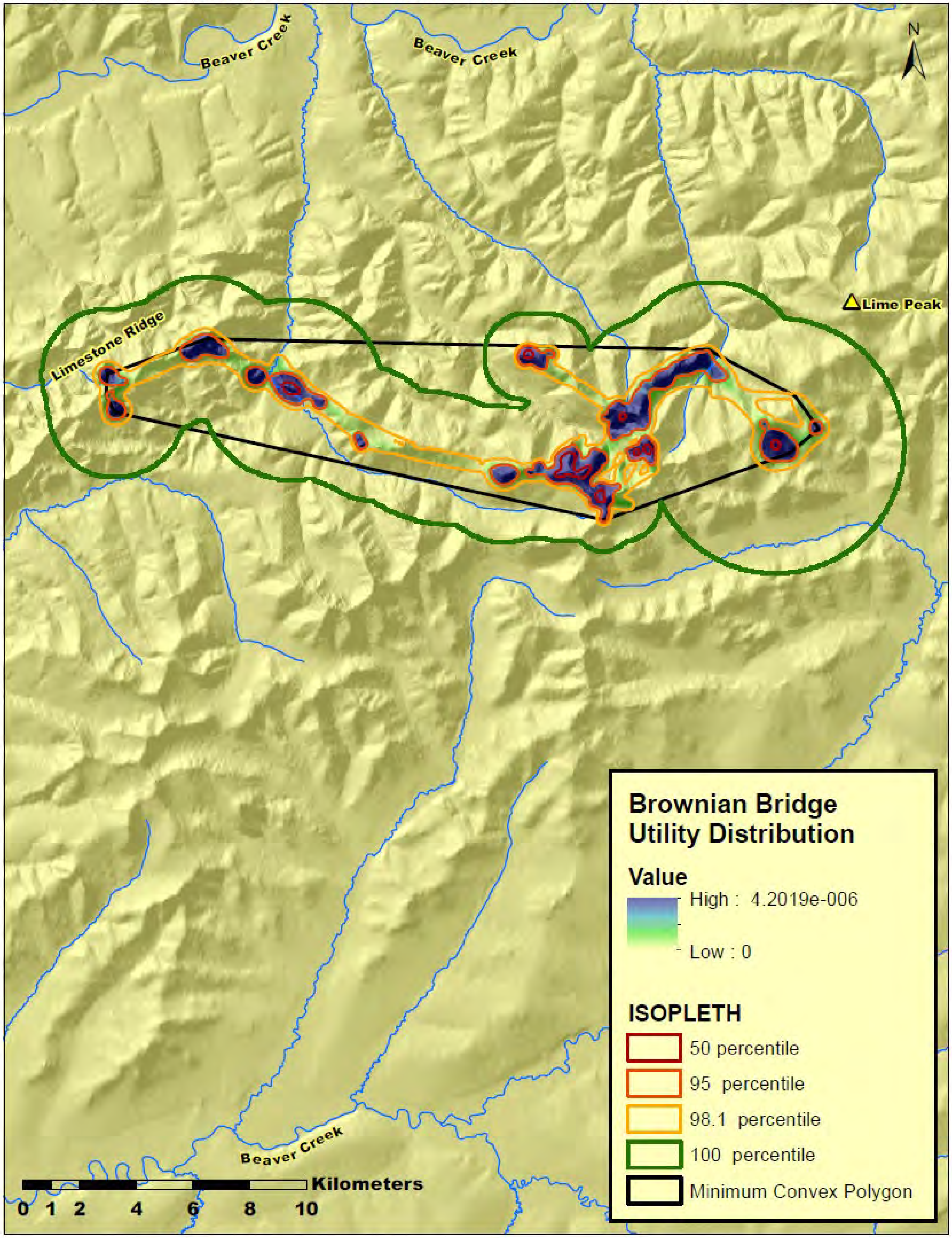
Sheep 0, Ewe, 7 years, Victoria, Telonics, n=1383, 1441 days, 10/16/2004-9/26/2008



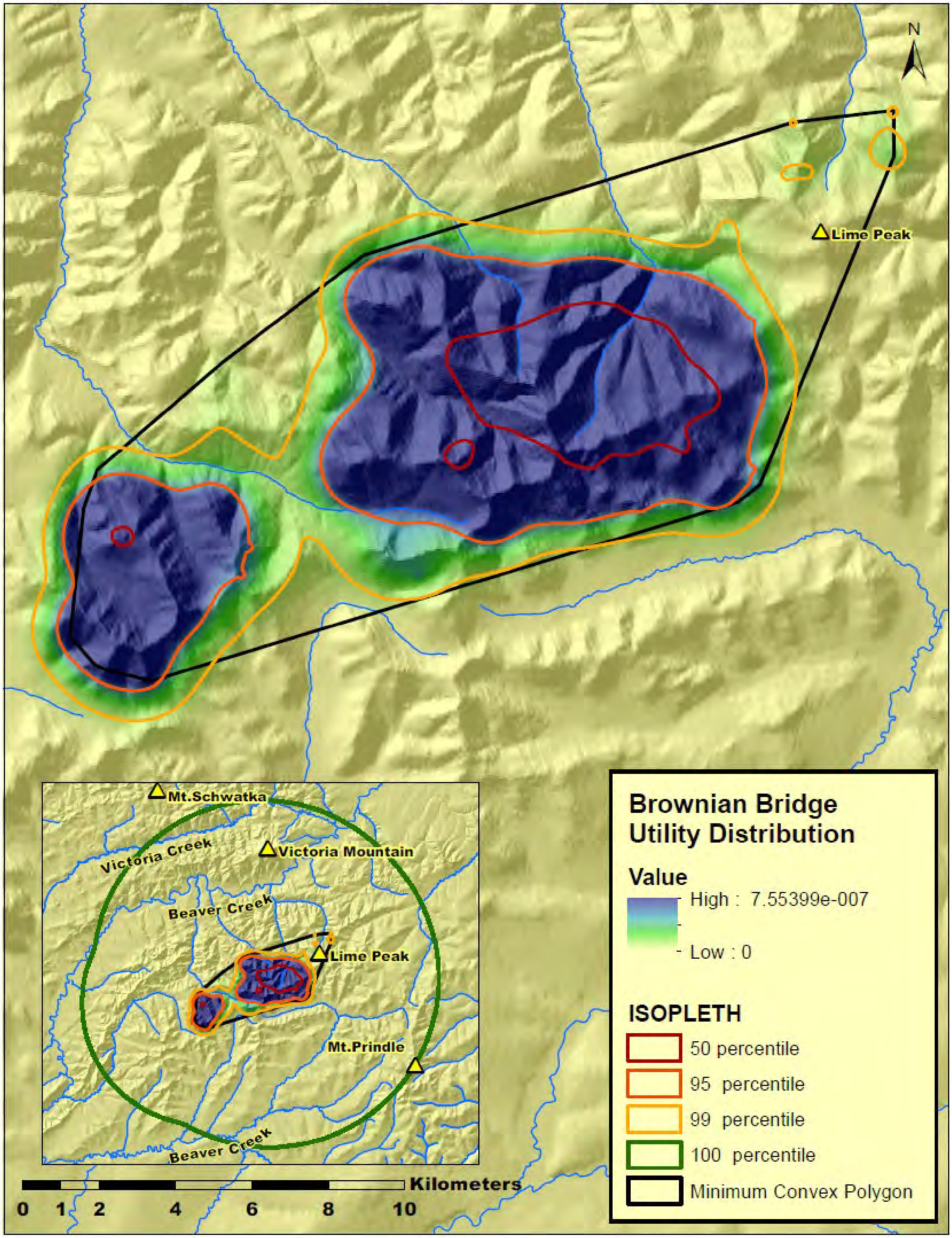
Sheep 1, Ewe, 6 years, Lime Peak, Lotek 2-hr, n=10947, 920 days, 3/22/2004-9/28/2006



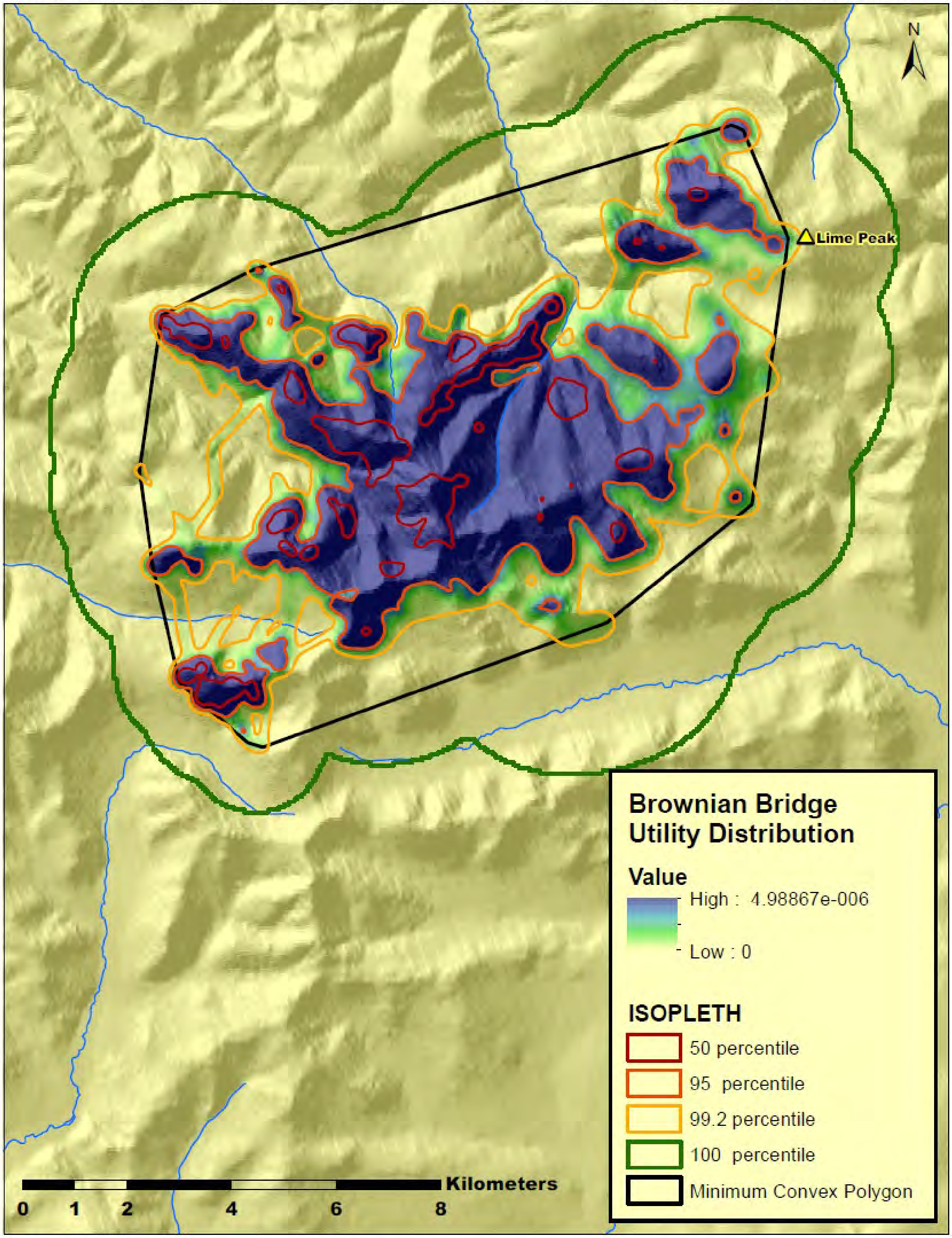
Sheep 7, Ewe, 10 years, Lime Peak, Lotek 2-hr, n=2123, 180 days, 9/22/2004-3/21/2005



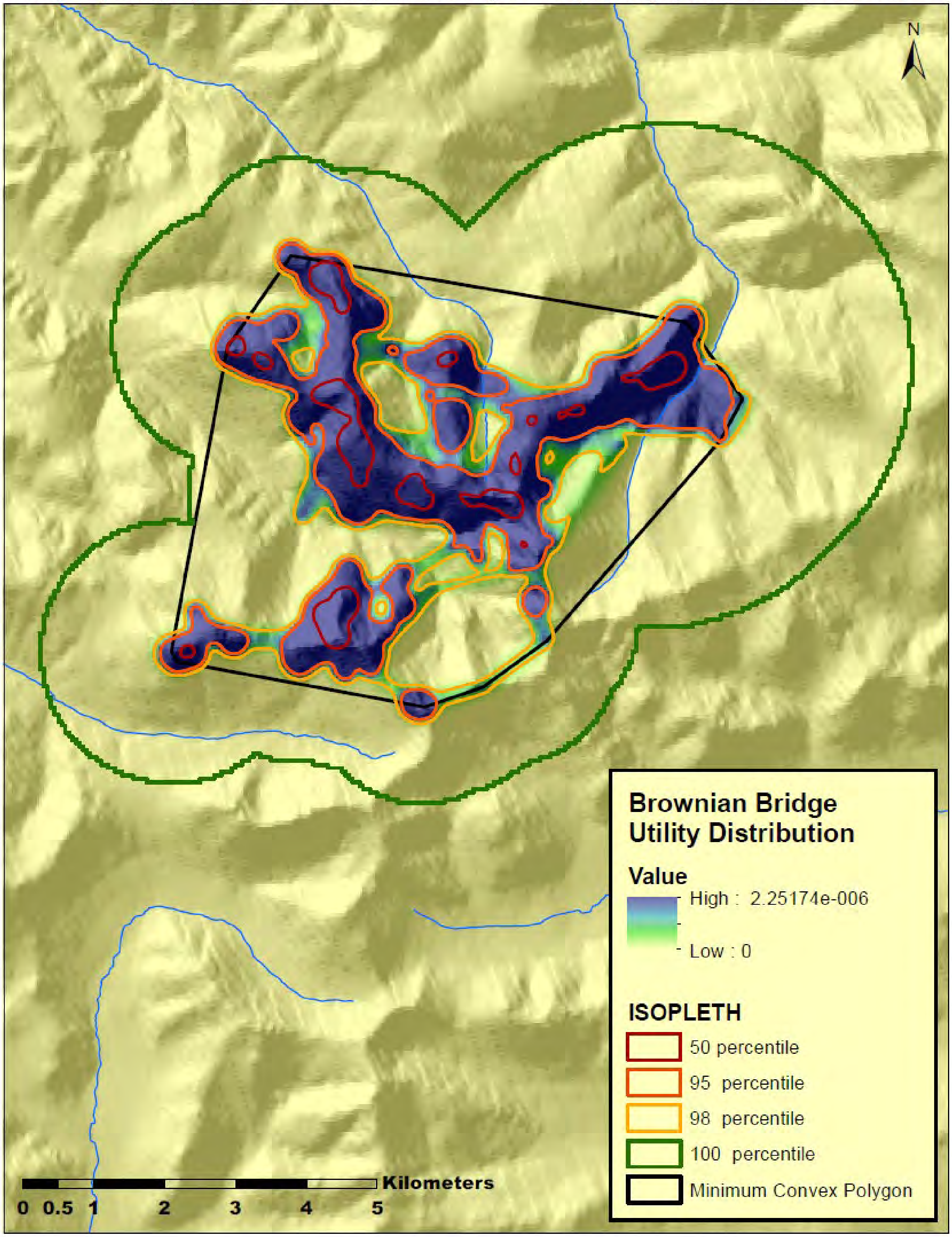
Sheep 9, Ewe, 7 years, Lime Peak, Telonics, n=1397, 1468 days, 9/22/2004-9/29/2008



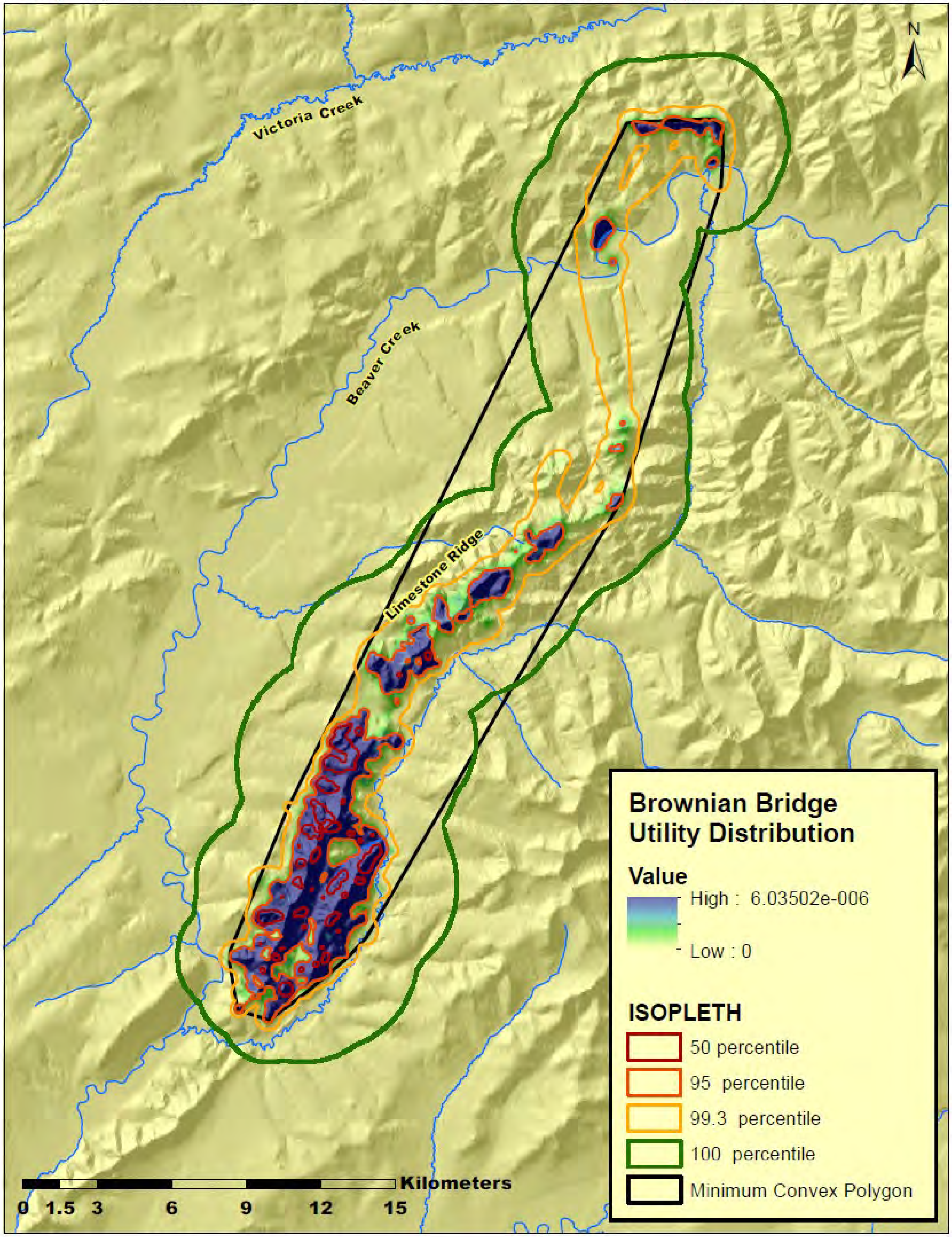
Sheep 10, Ewe, 11 years, Lime Peak, Lotek 2-hr, n=8724, 732 days, 9/22/2004-9/24/2006



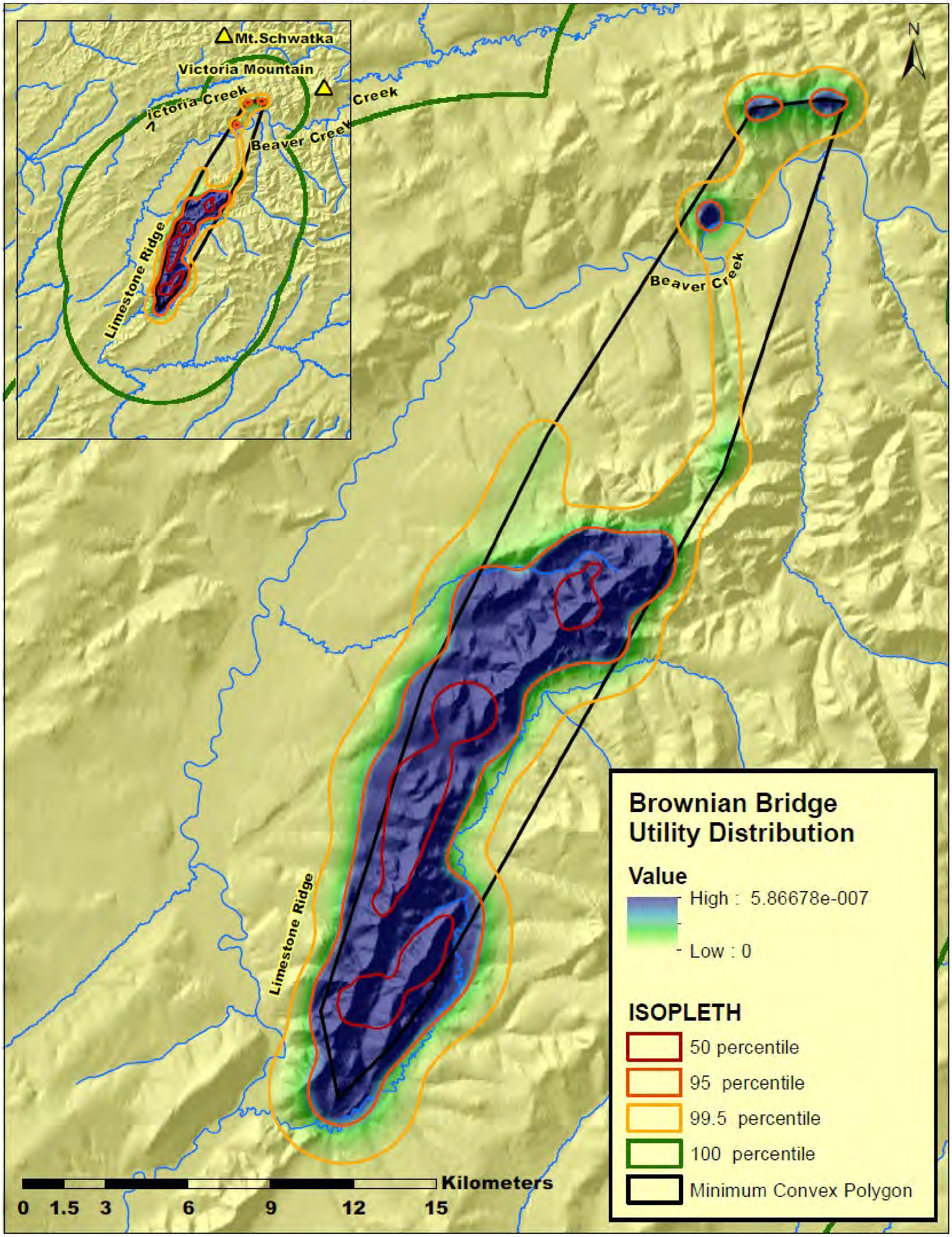
Sheep 12, Ewe, 9 years, Lime Peak, Lotek 2-hr, n=1141, 96 days, 9/22/2004-12/27/2004



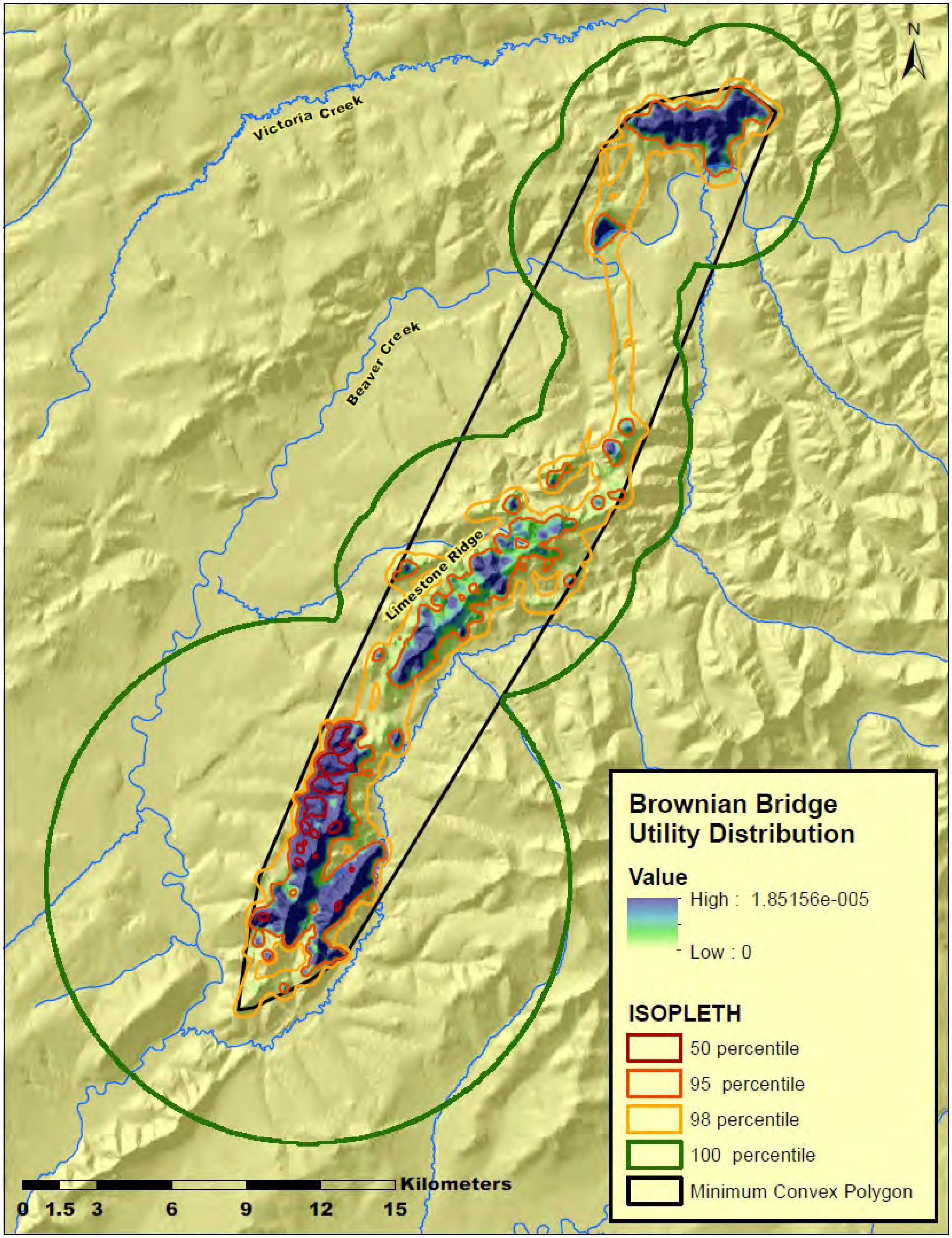
Sheep 13, Ewe, 9 years, Limestone R, Lotek 2-hr, n=8542, 733 days, 9/25/2004-9/28/2006



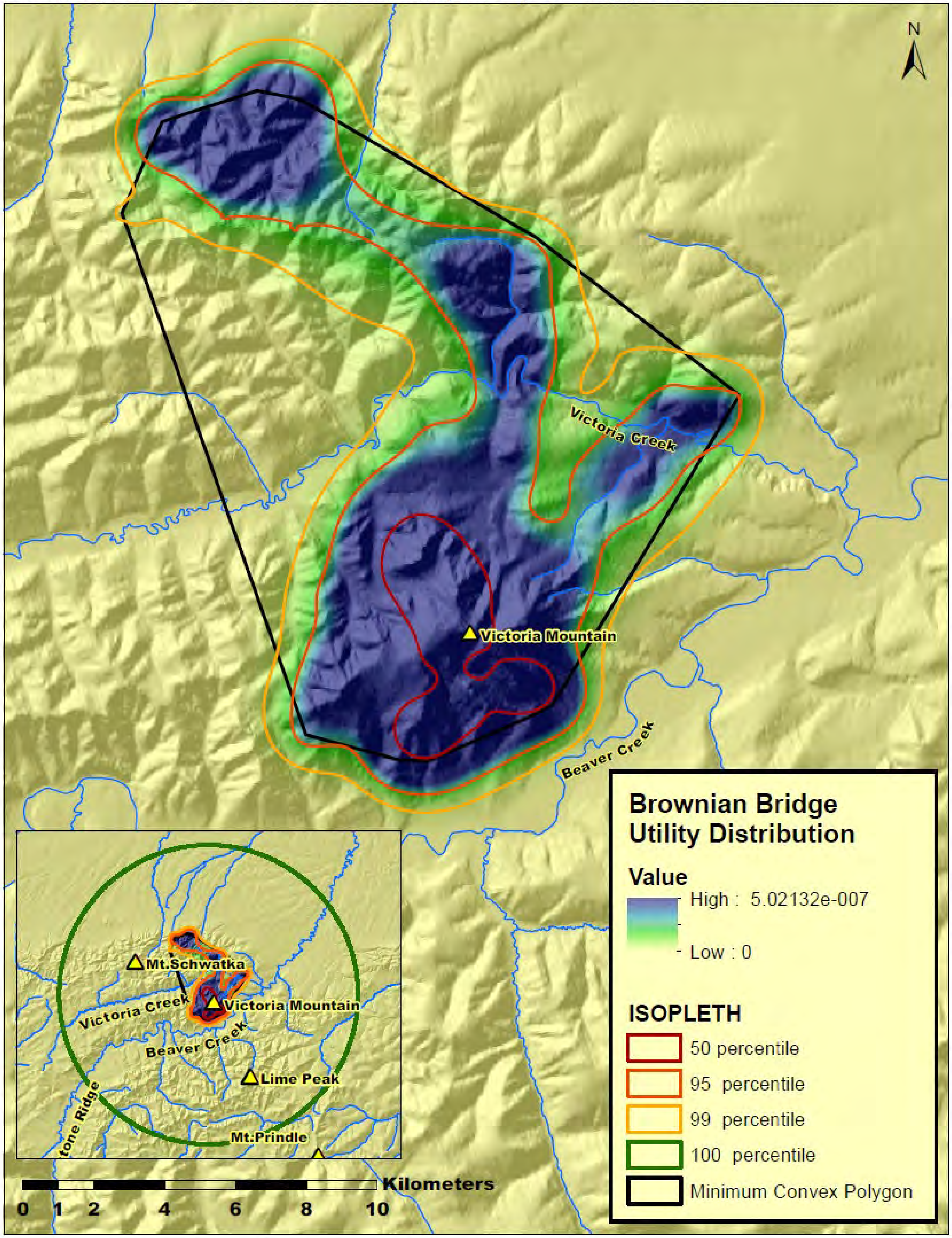
Sheep 14, Ewe, 8 years, Limestone R, Telonics, n=399, 527 days, 9/25/2004-3/06/2006



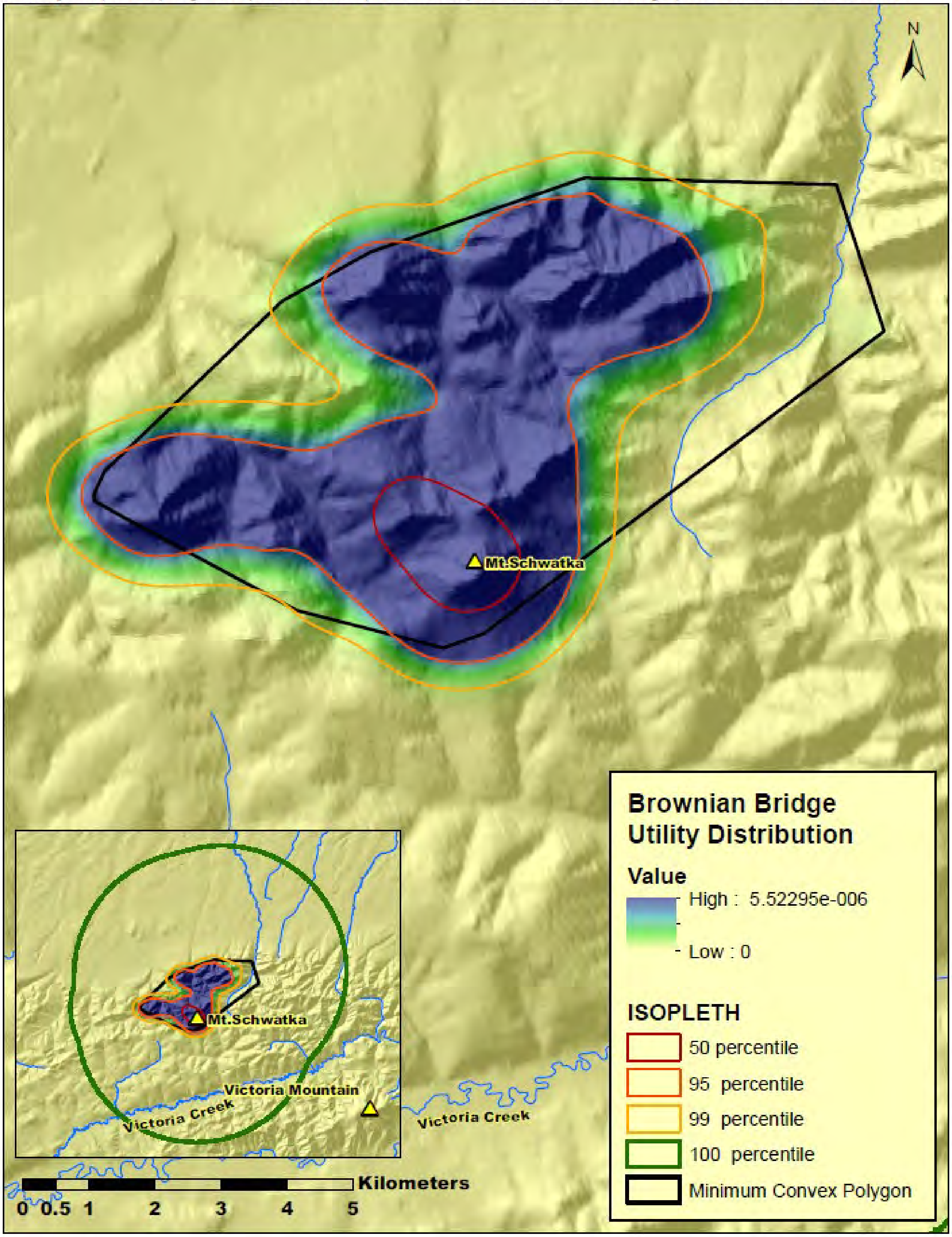
Sheep 15, Ewe, 7 years, Limestone R, Lotek 2-hr, n=9395, 799 days, 9/25/2004-12/3/2006



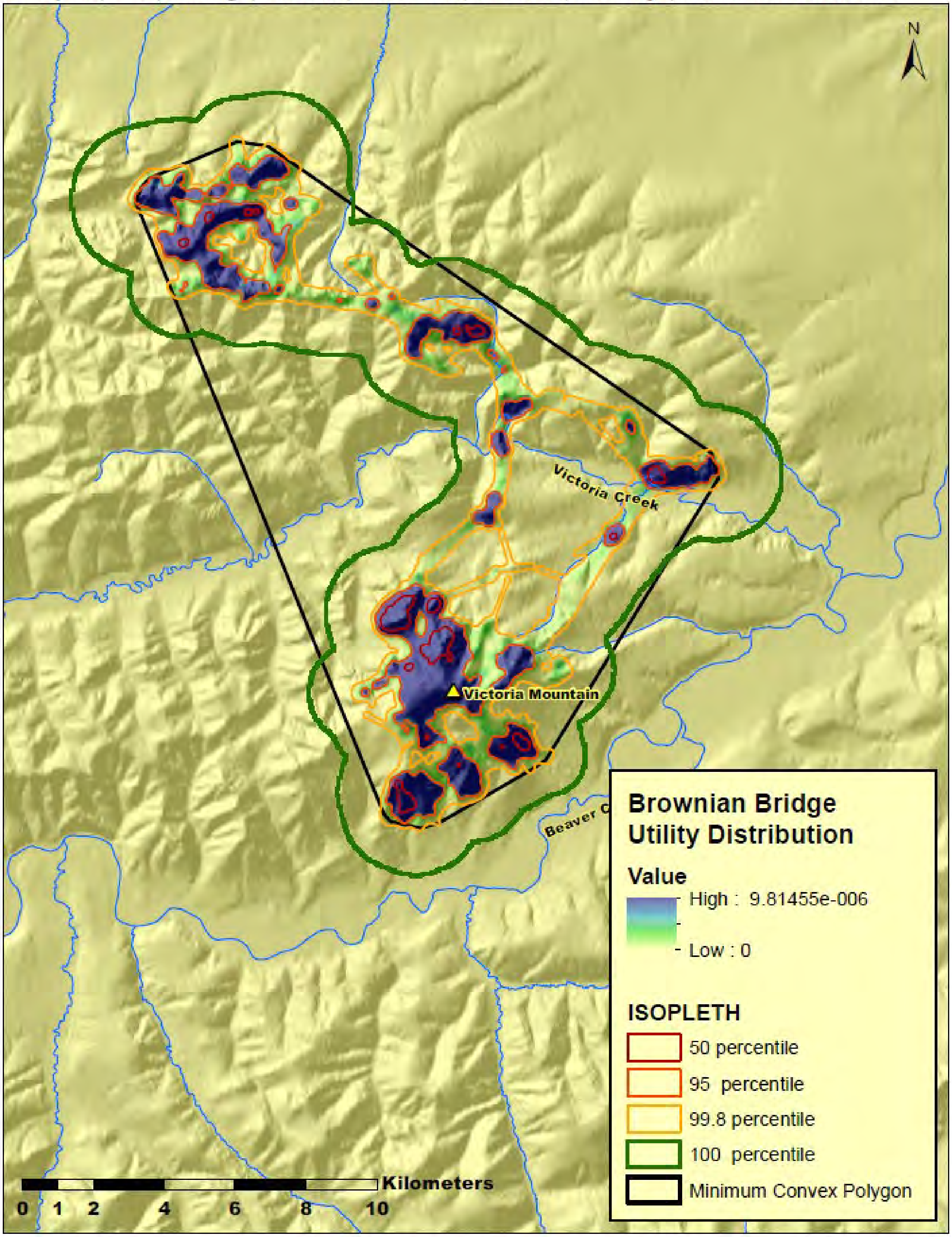
Sheep 19, Ewe, 6 years, Victoria, Telonics, n=576, 672 days, 10/16/2004-8/19/2006



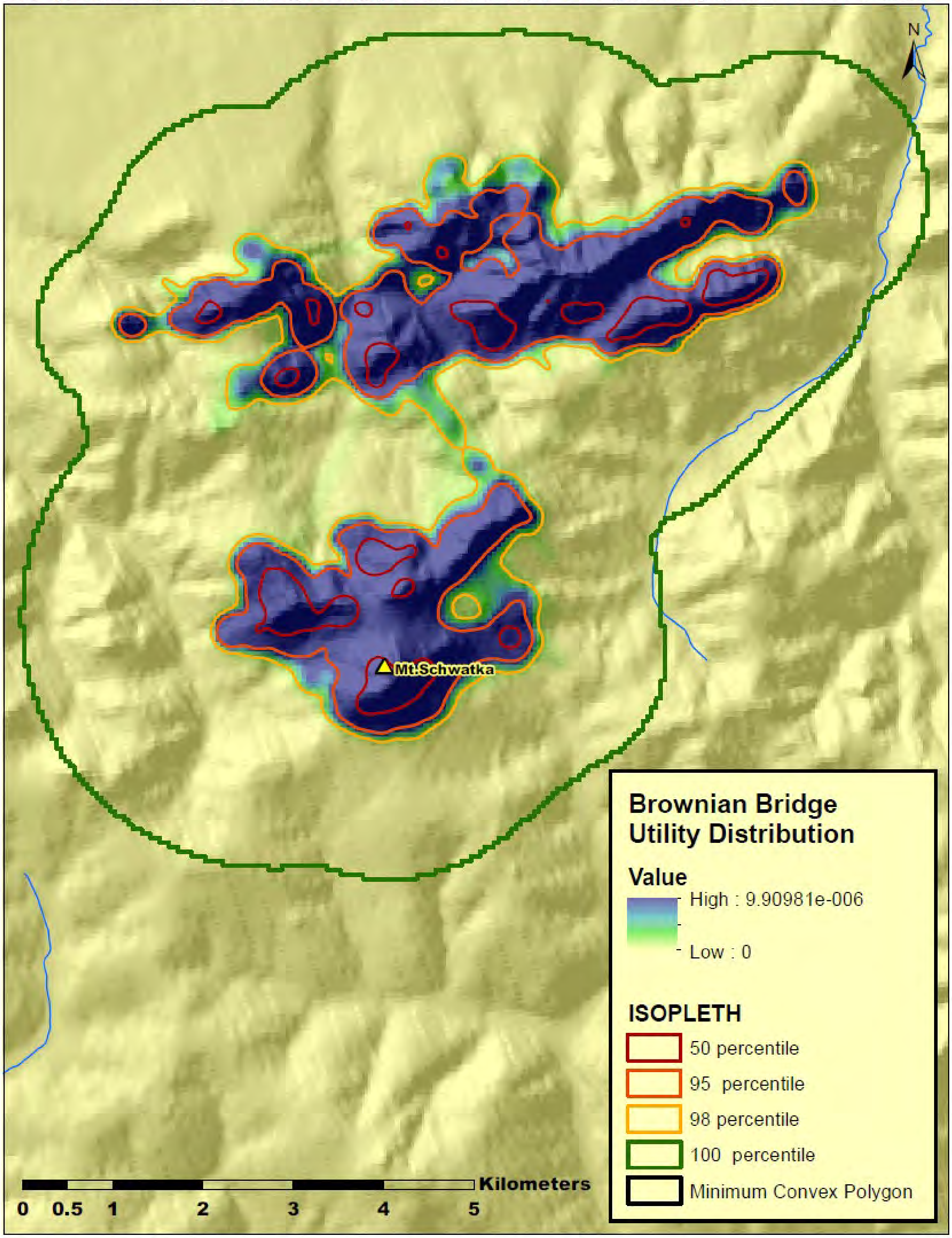
Sheep 21, Ewe, 3 years, Schwatka, Telonics, n=1203, 1440 days, 10/17/2004-9/26/2008



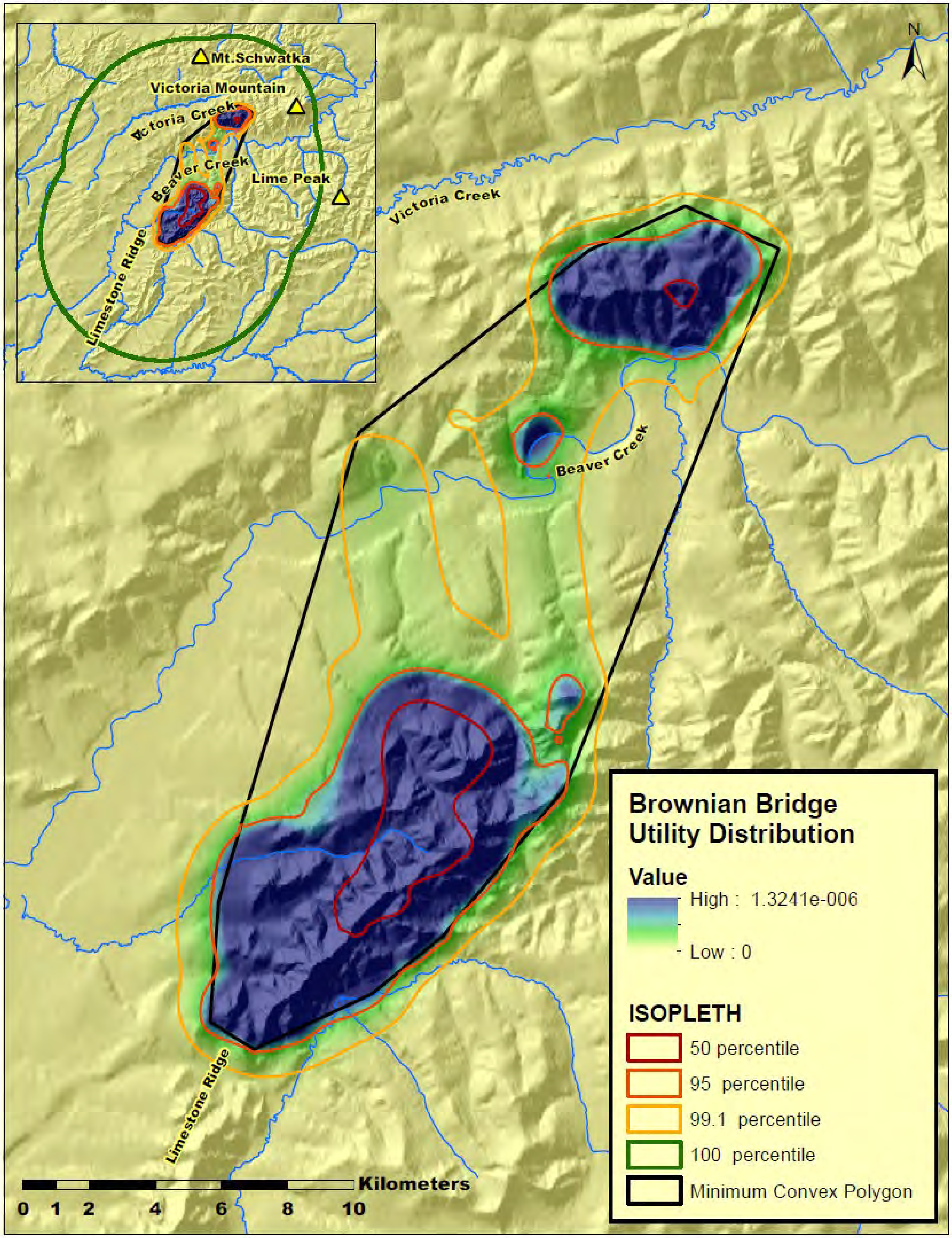
Sheep 22, Ewe, unk age, Victoria, Lotek 1-hr, n=19985, 840 days, 10/16/2004-2/03/2007



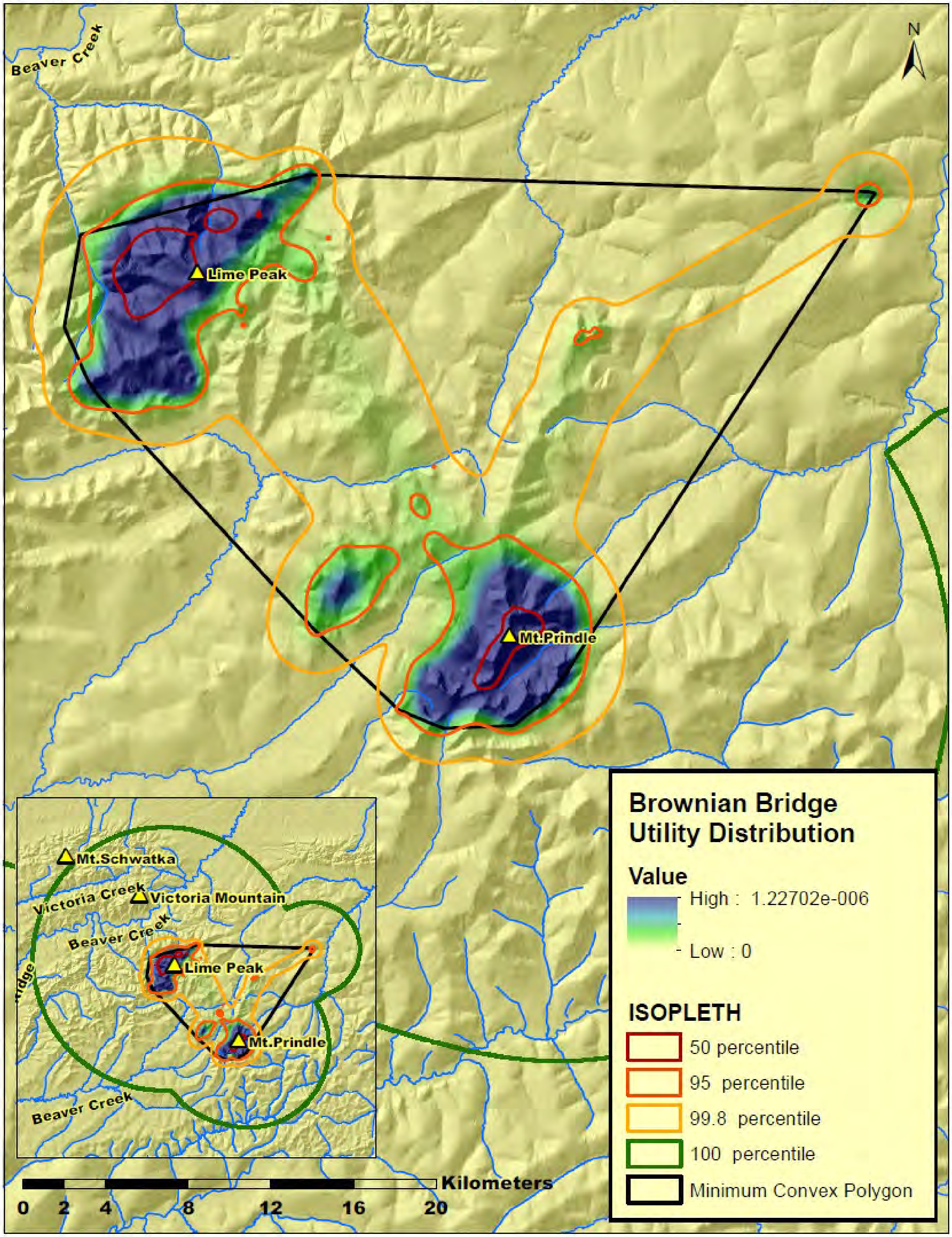
Sheep 23, Ewe, 12 years, Schwatka, Lotek 1&2-hr, n=7453, 535 days, 10/17/2004-4/05/2006



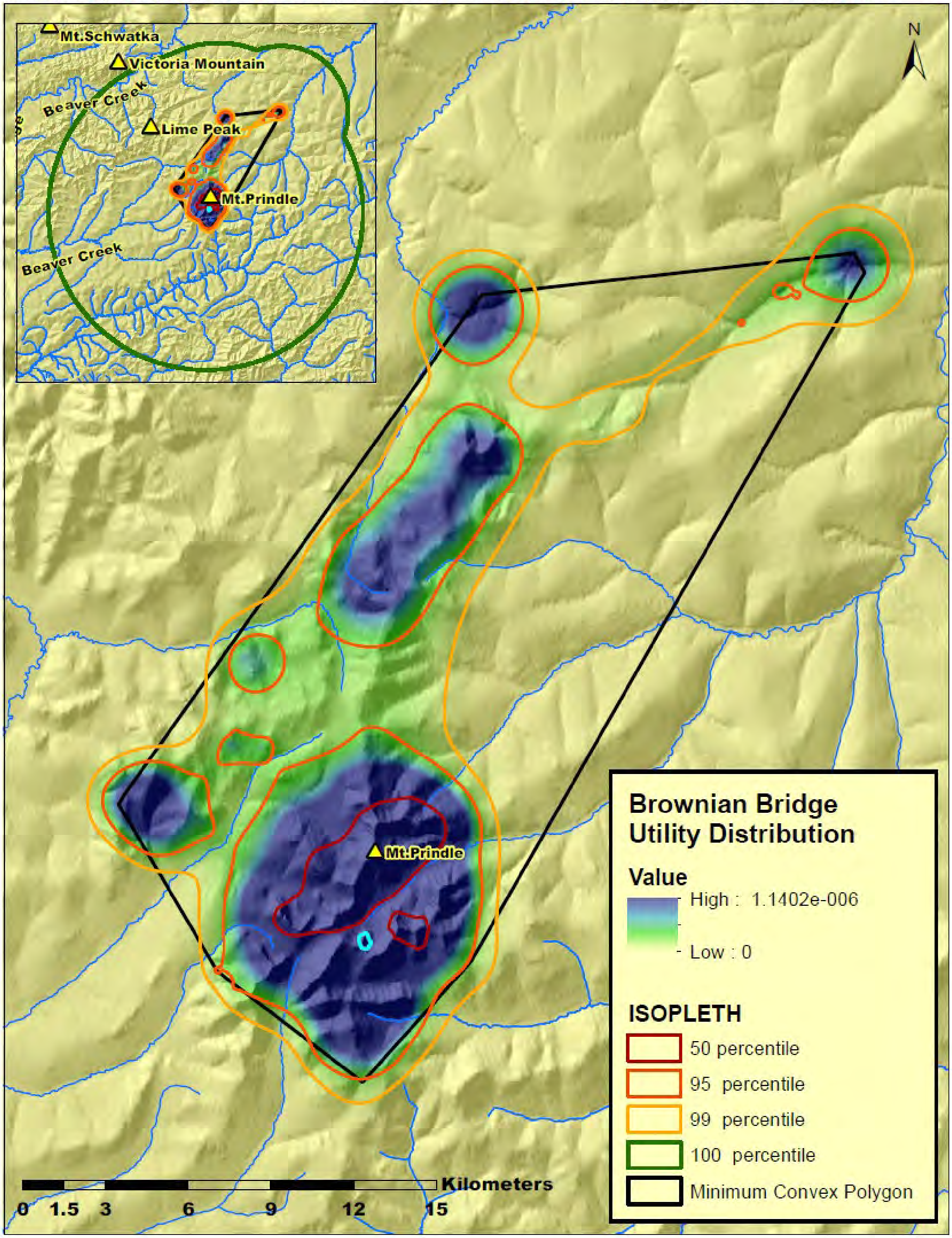
Sheep 25, Ewe, 8 years, Limestone R, Telonics, n=1337, 1440 days, 10/17/2004-9/26/2008



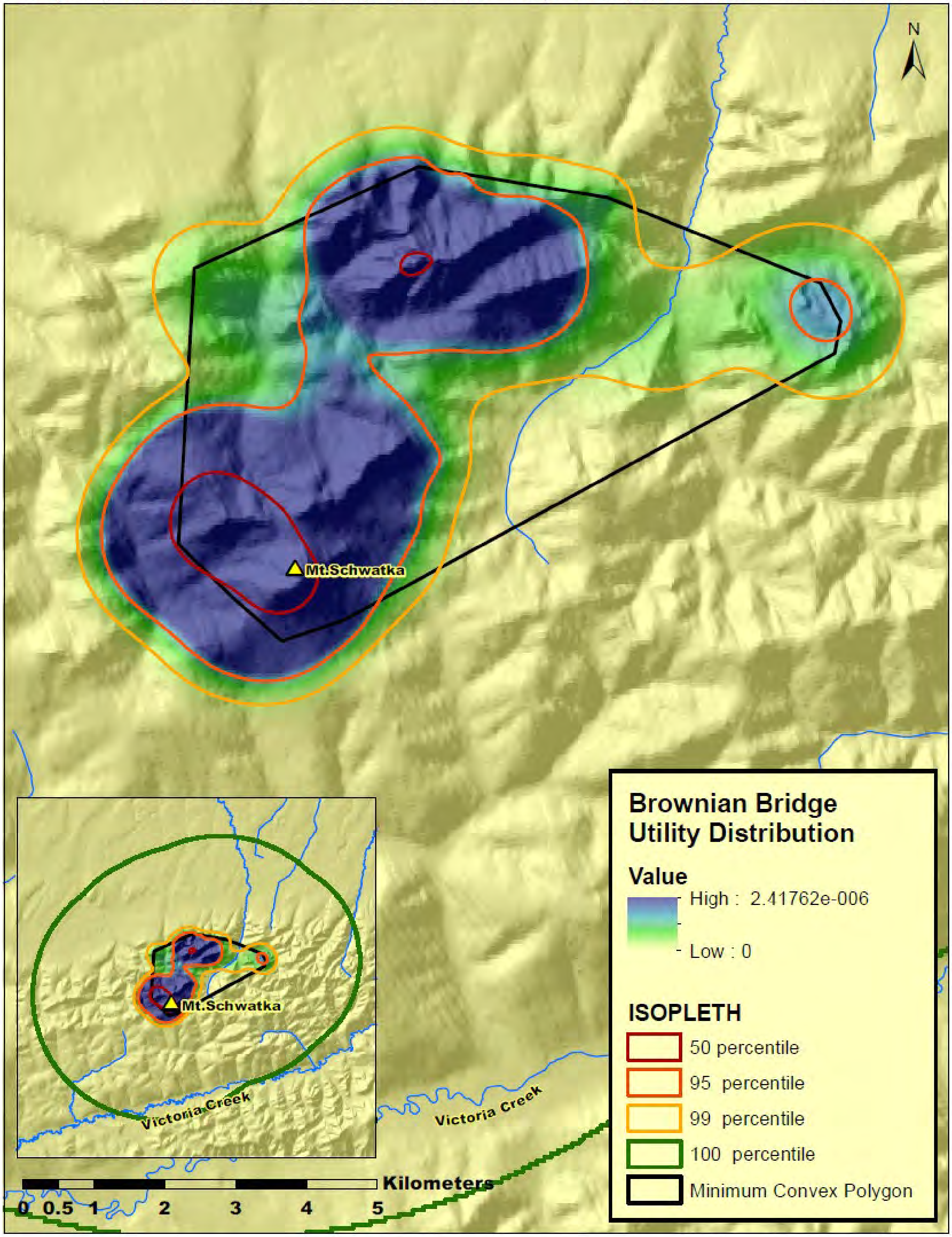
Sheep 26, Ewe, 6 years, Prindle, Telonics, n=761, 938 days, 10/20/2004-5/16/2007



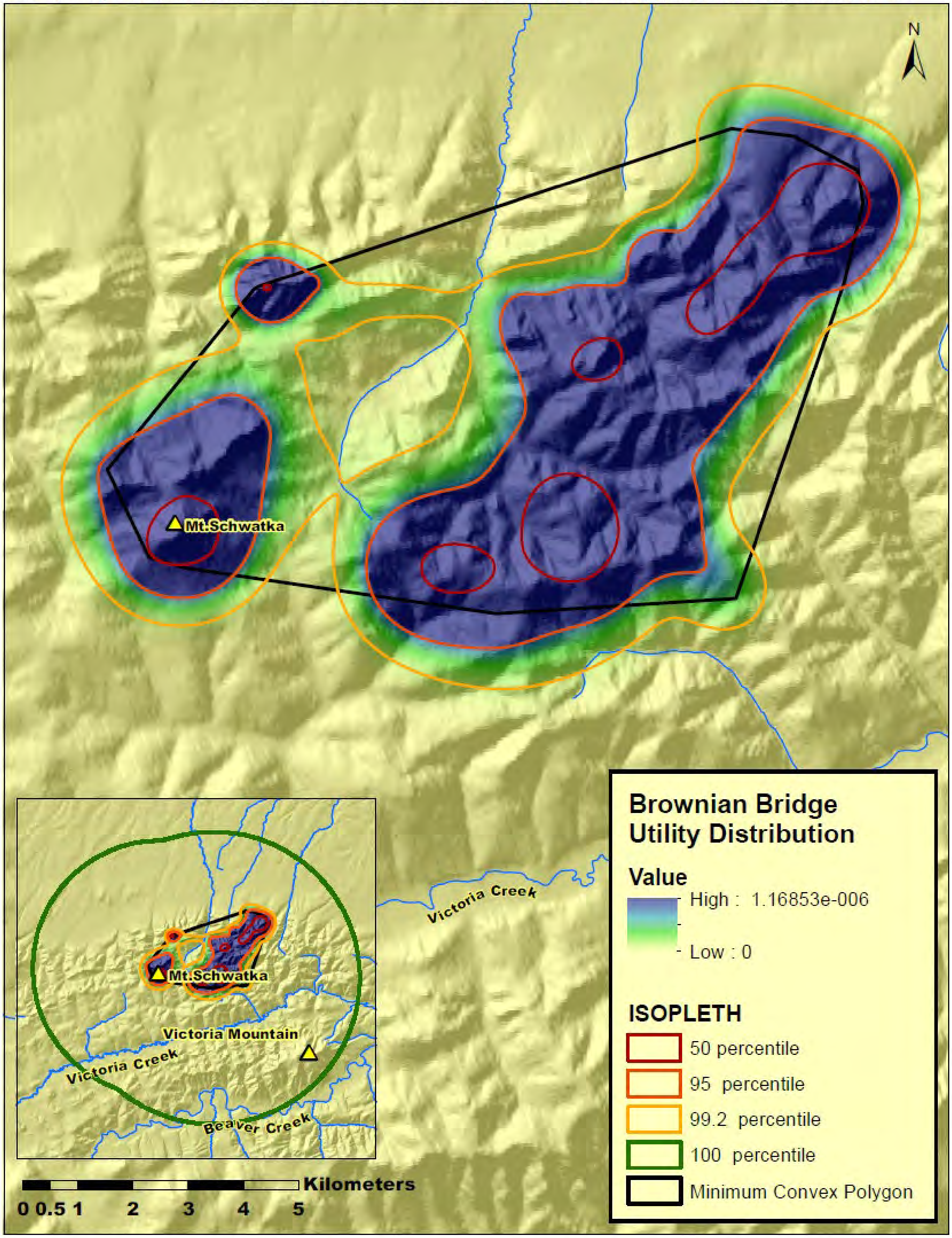
Sheep 29, Ewe, 5 years, Prindle, Telonics, n=1158, 1380 days, 11/08/2004-8/19/2008



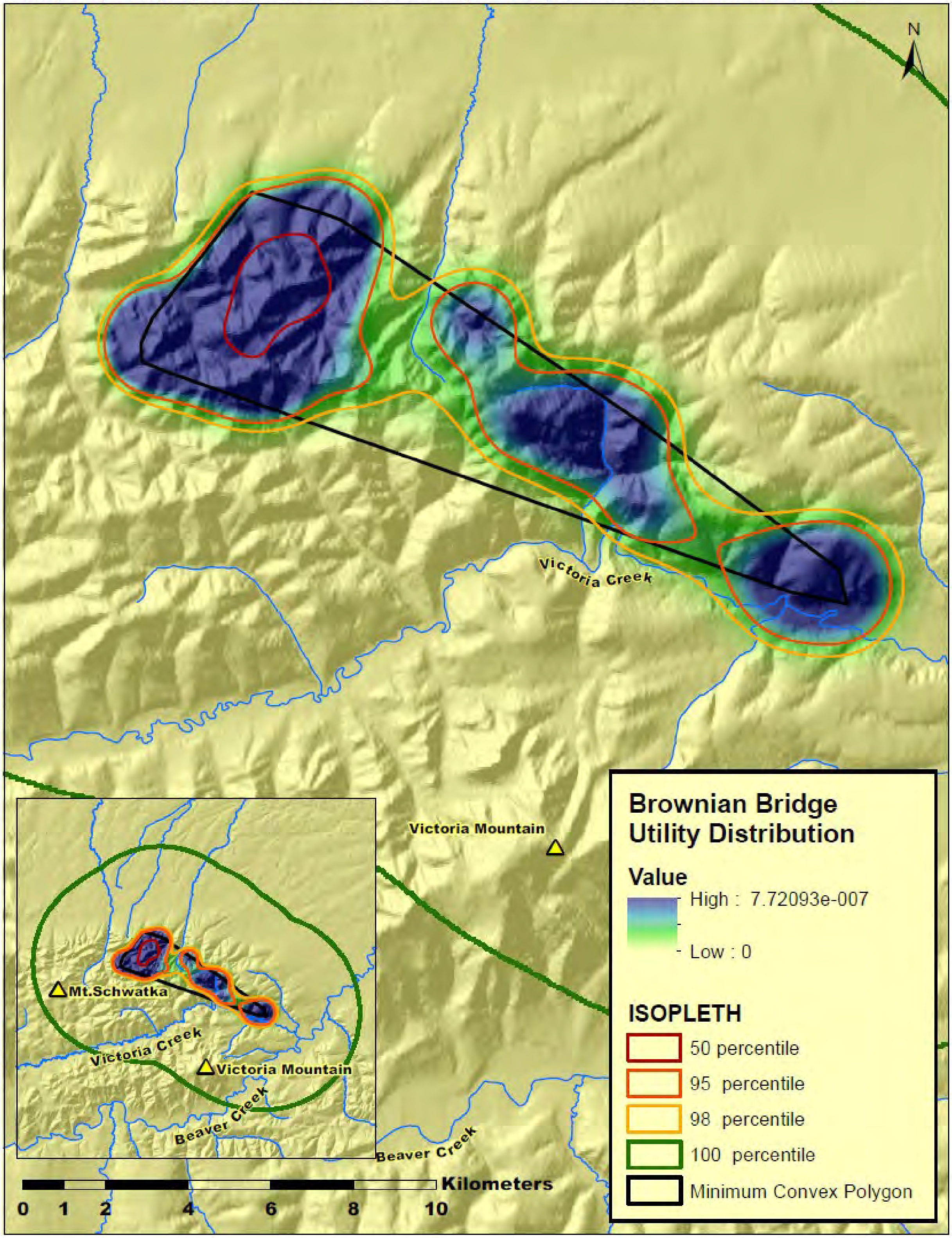
Sheep 32, Ewe, 8 years, Schwatka, Telonics, n=366, 390 days, 10/18/2004-11/12/2005



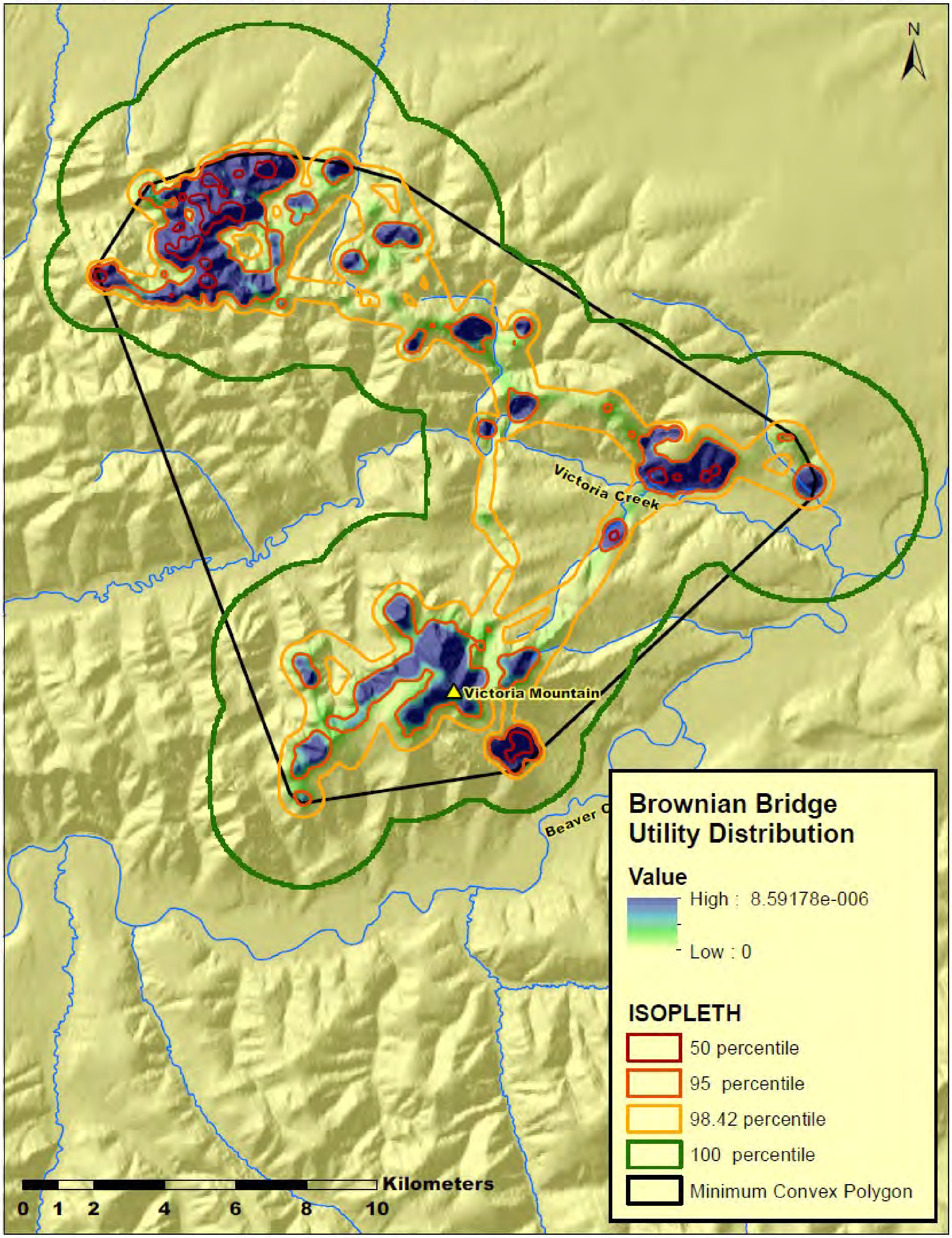
Sheep 33, Ewe, 10 years, Schwatka, Telonics, n=419, 423 days, 10/18/2004-12/15/2005



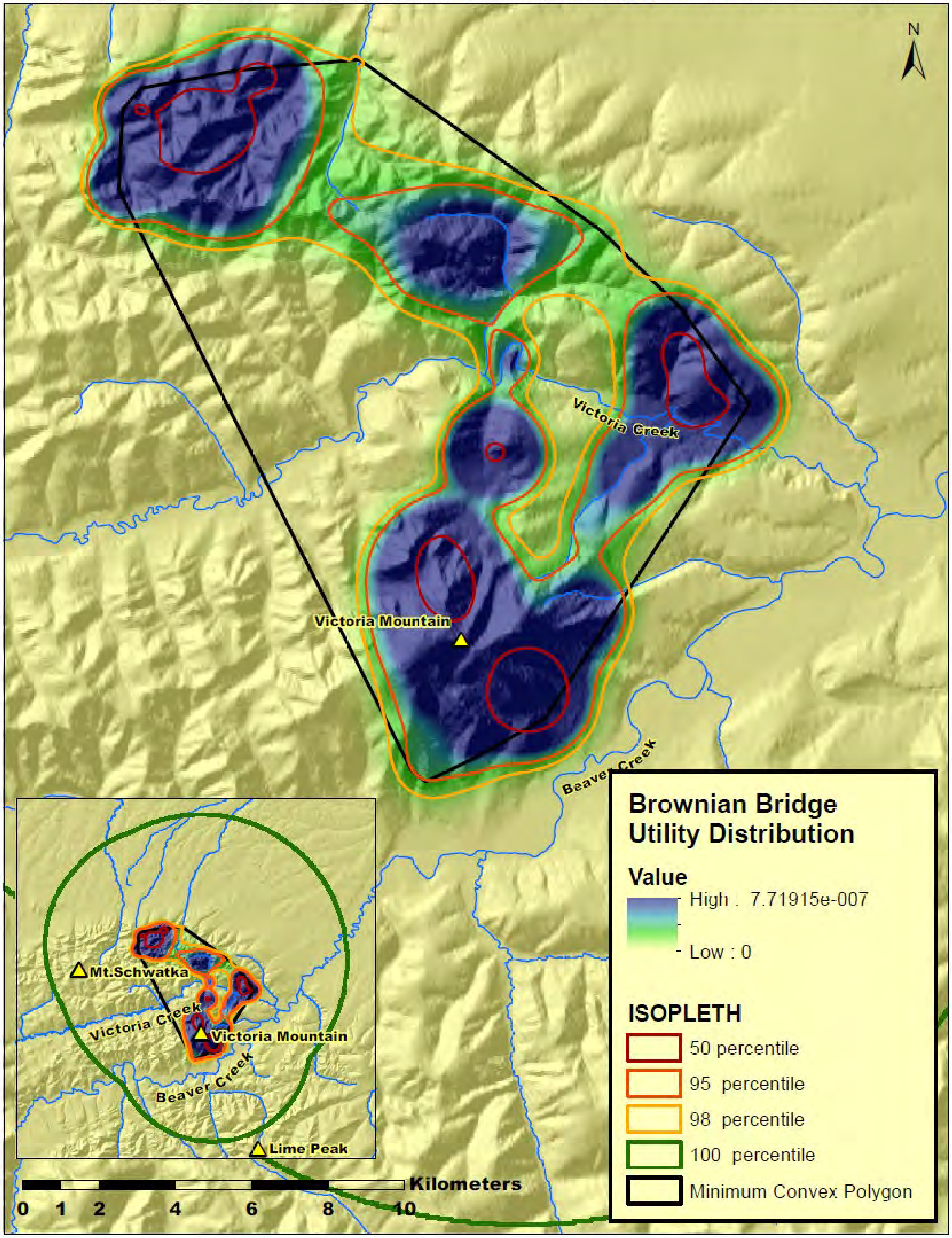
Sheep 34, Ewe, 8 years, Schwatka, Telonics, n=143, 221 days, 10/18/2004-5/27/2005



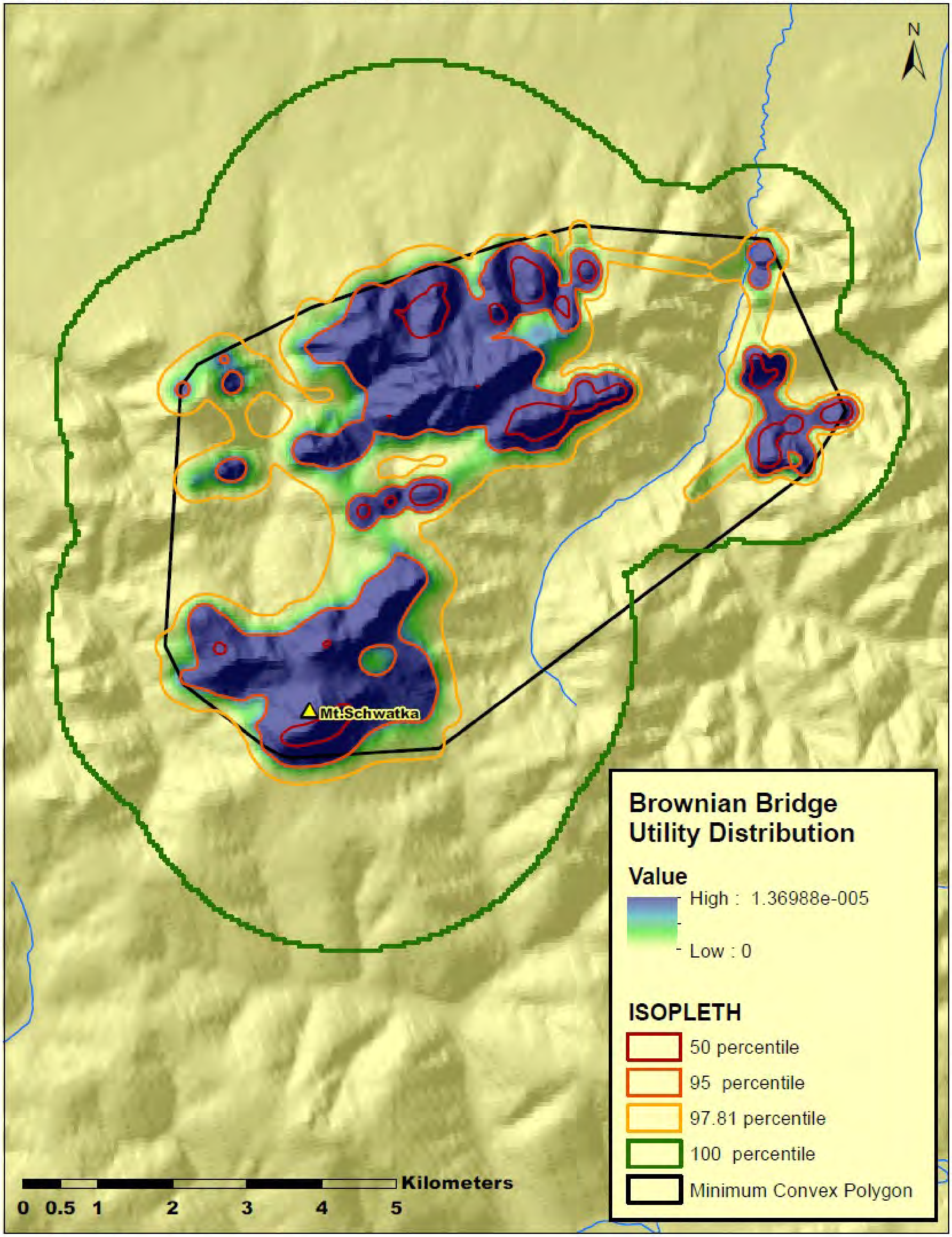
Sheep 35, Ewe, 6 years, Schwatka, Lotek 2-hr, n=5119, 433 days, 10/18/2004-12/25/2005



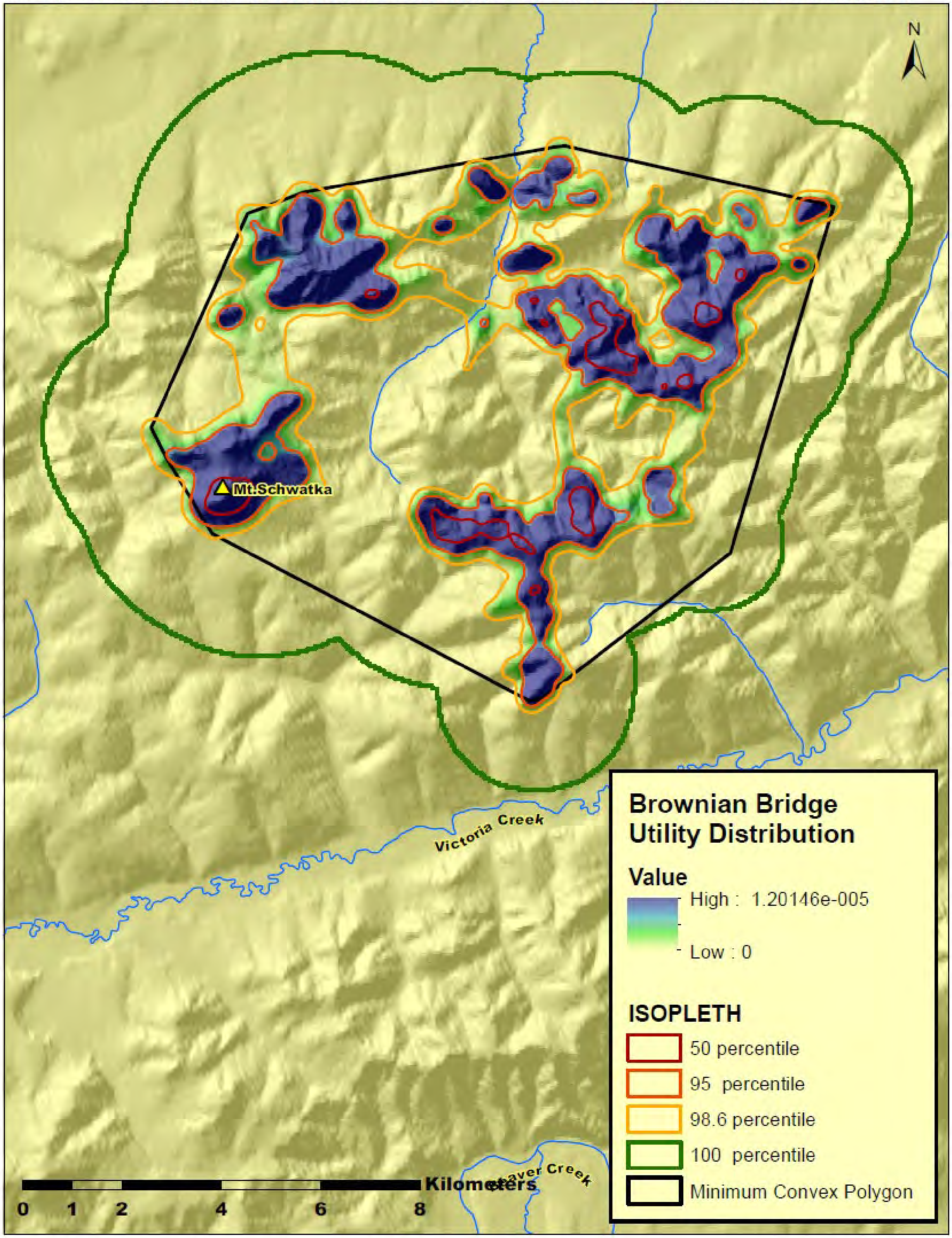
Sheep 36, Ewe, 9 years, Schwatka, Telonics, n=399, 435 days, 10/18/2004-12/27/2005



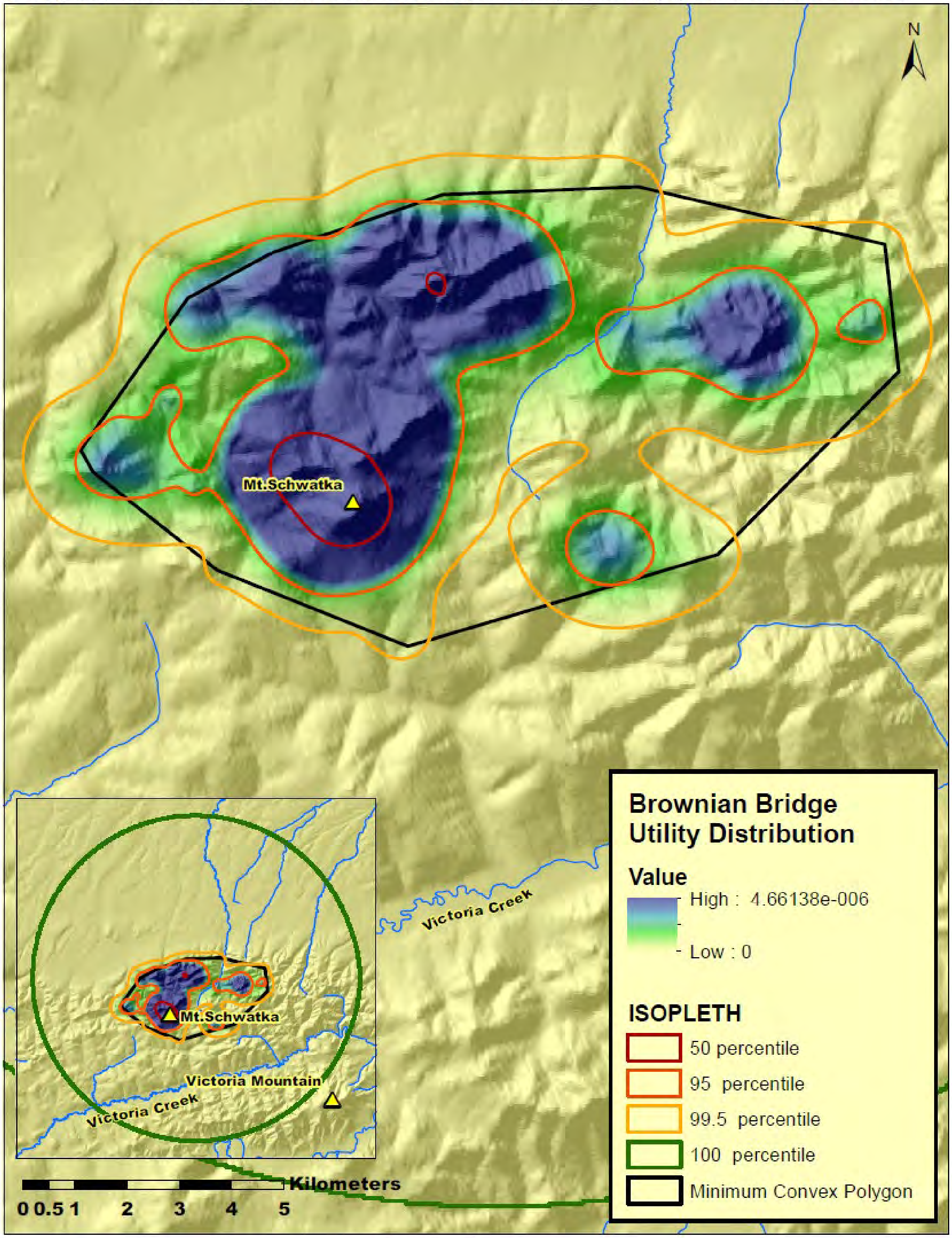
Sheep 37, Ewe, 9 years, Schwatka, Lotek 2-hr, n=5190, 464 days, 10/18/2004-1/25/2006



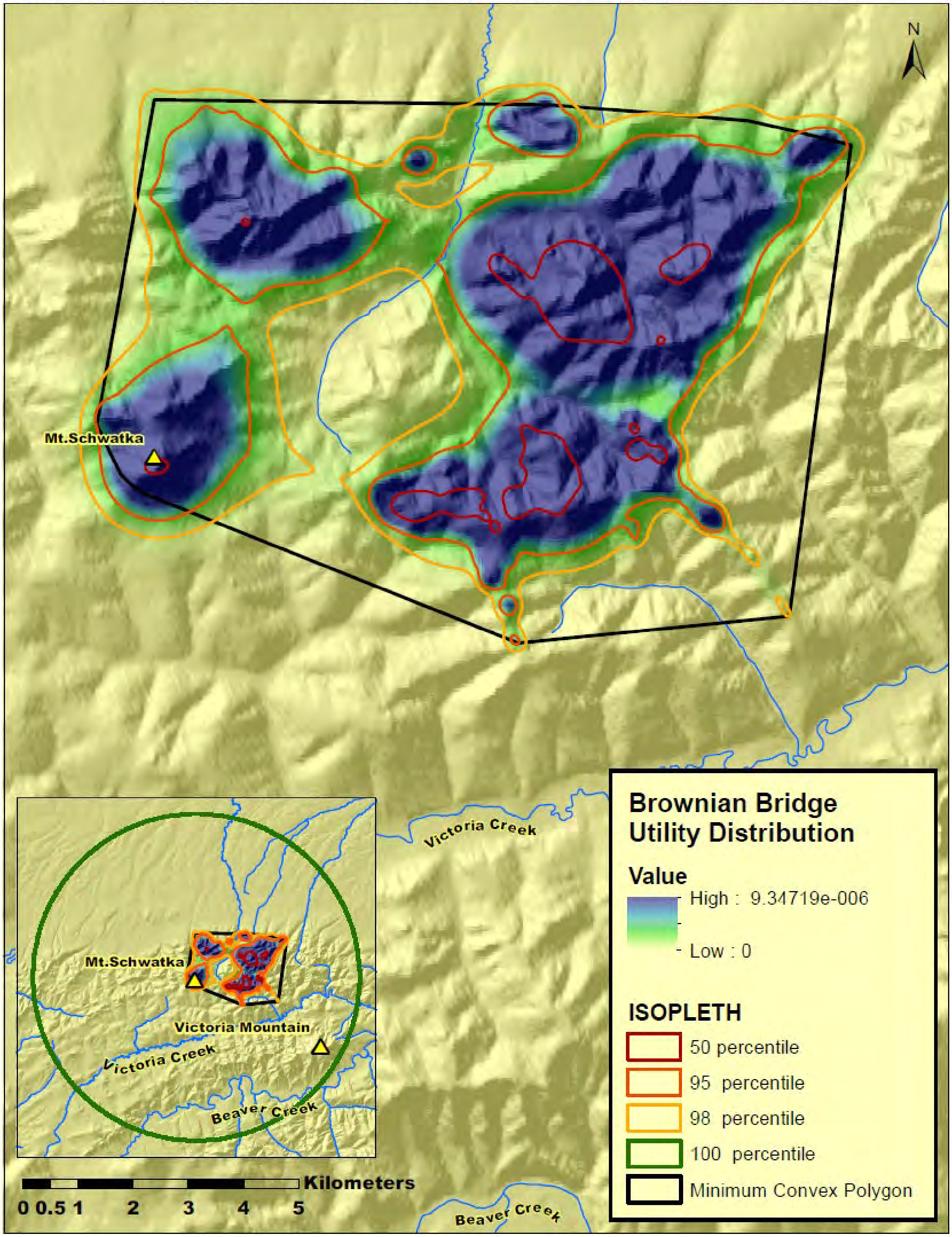
Sheep 38, Ewe, 7 years, Schwatka, Lotek 2-hr, n=9952, 838 days, 10/18/2004-2/03/2007



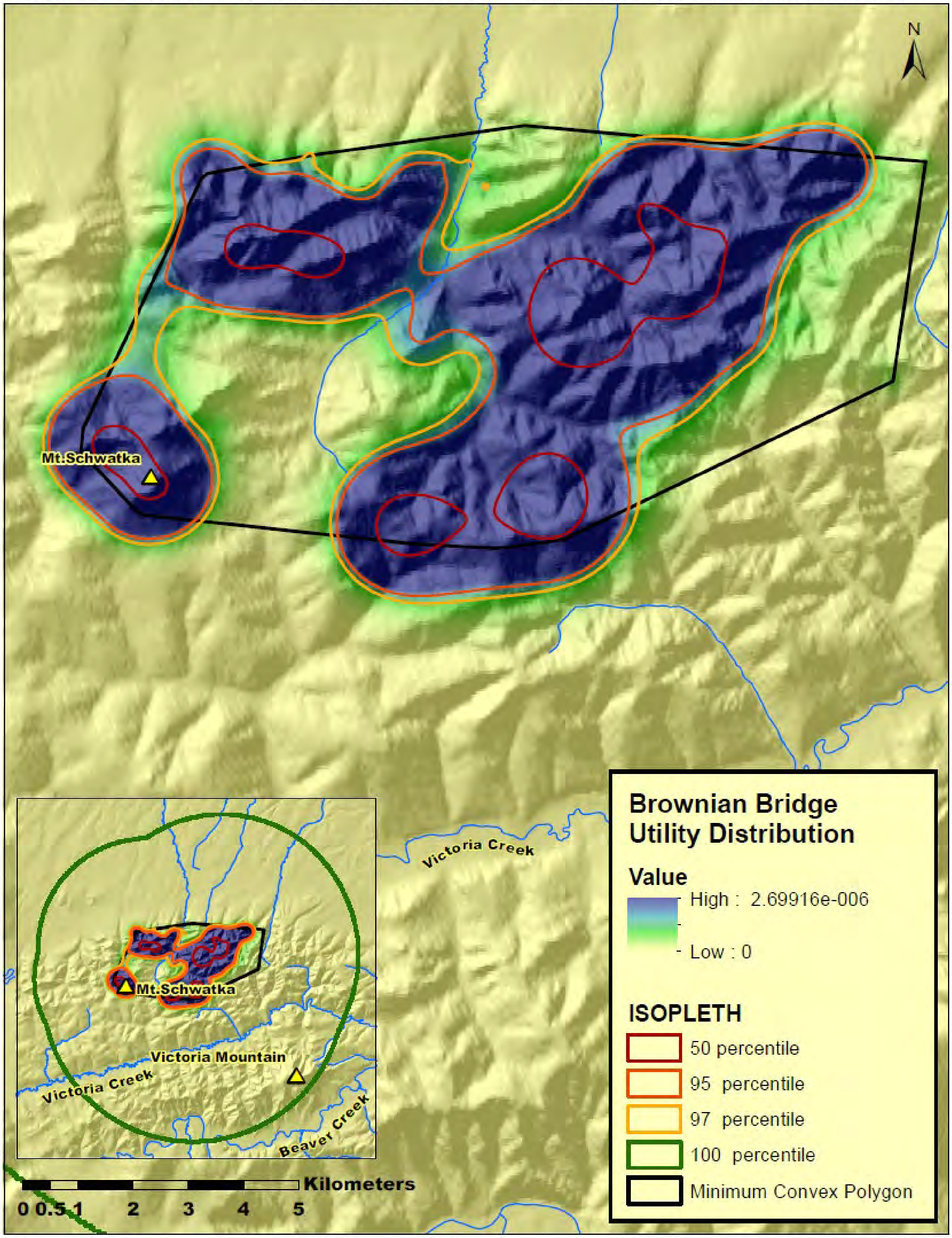
Sheep 39, Ewe, 4 years, Schwatka, Telonics, n=1327, 1442 days, 10/18/2004-9/29/2008



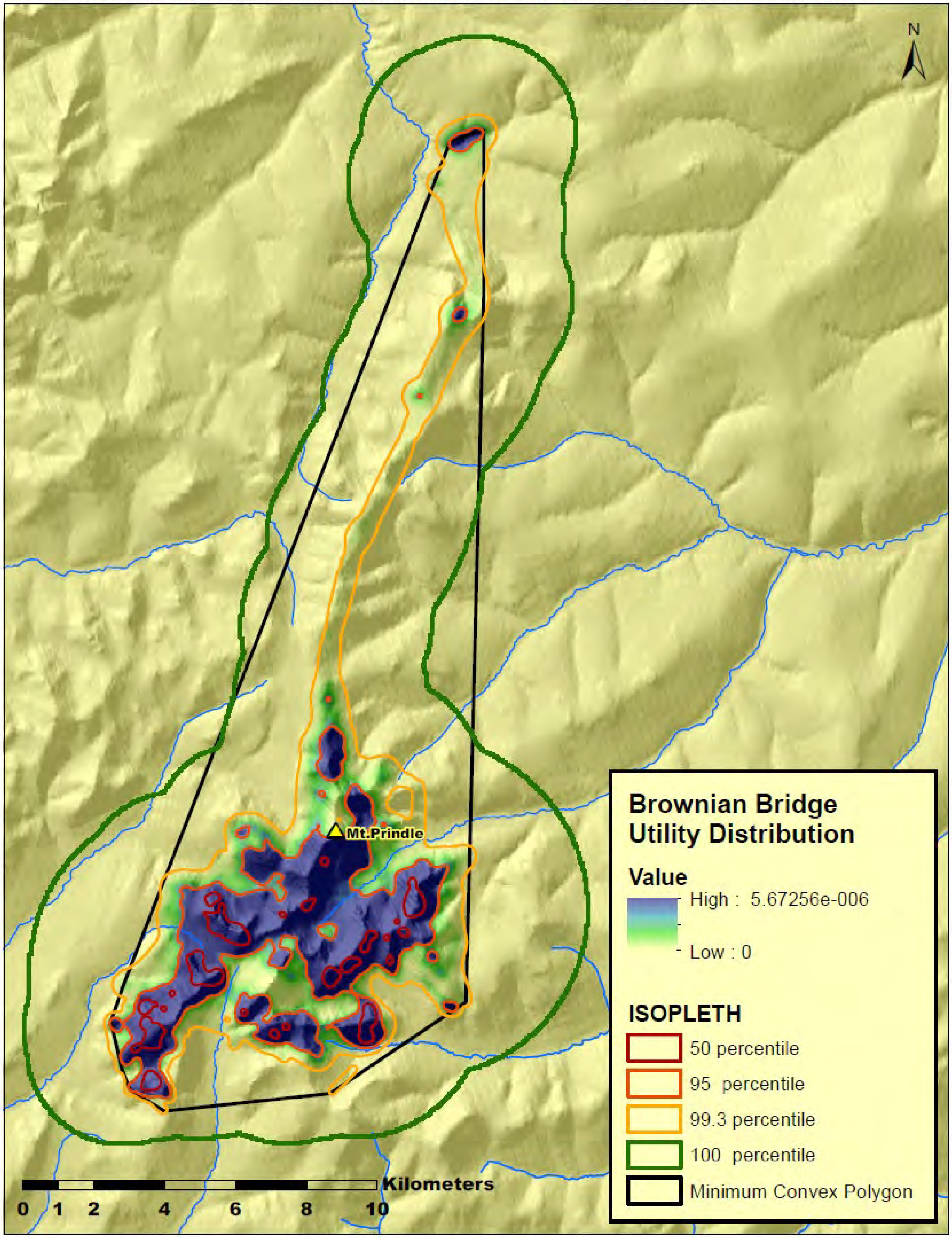
Sheep 40, Ewe, 8 years, Schwatka, Telonics, n=2978, 837 days, 10/18/2004-2/02/2007



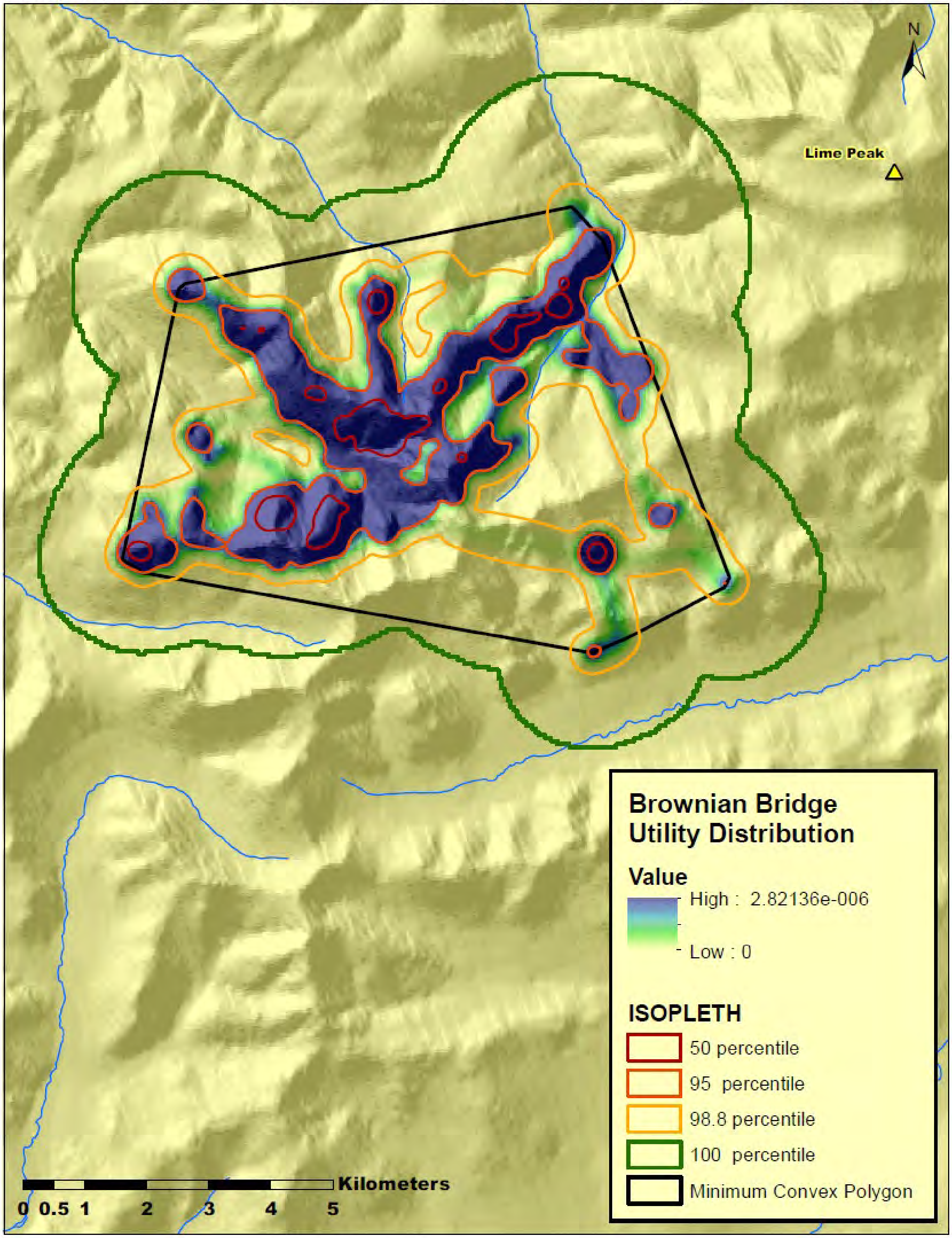
Sheep 41, Ewe, 6 years, Schwatka, Telonics, n=1289, 1407 days, 10/18/2004-8/25/2008



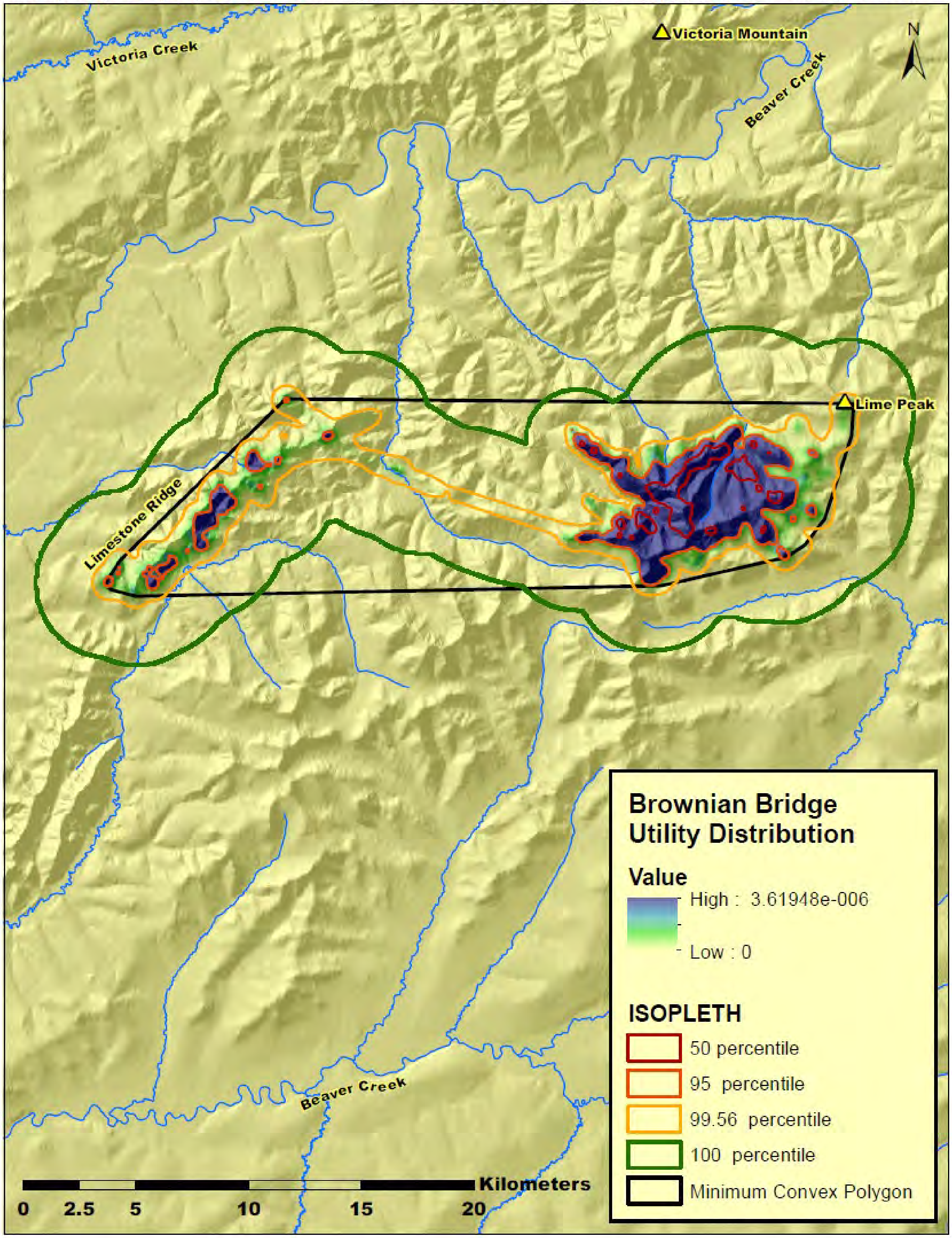
Sheep 42, Ewe, 9 years, Prindle, Lotek 2-hr, n=8591, 722 days, 10/06/2005-9/28/2007



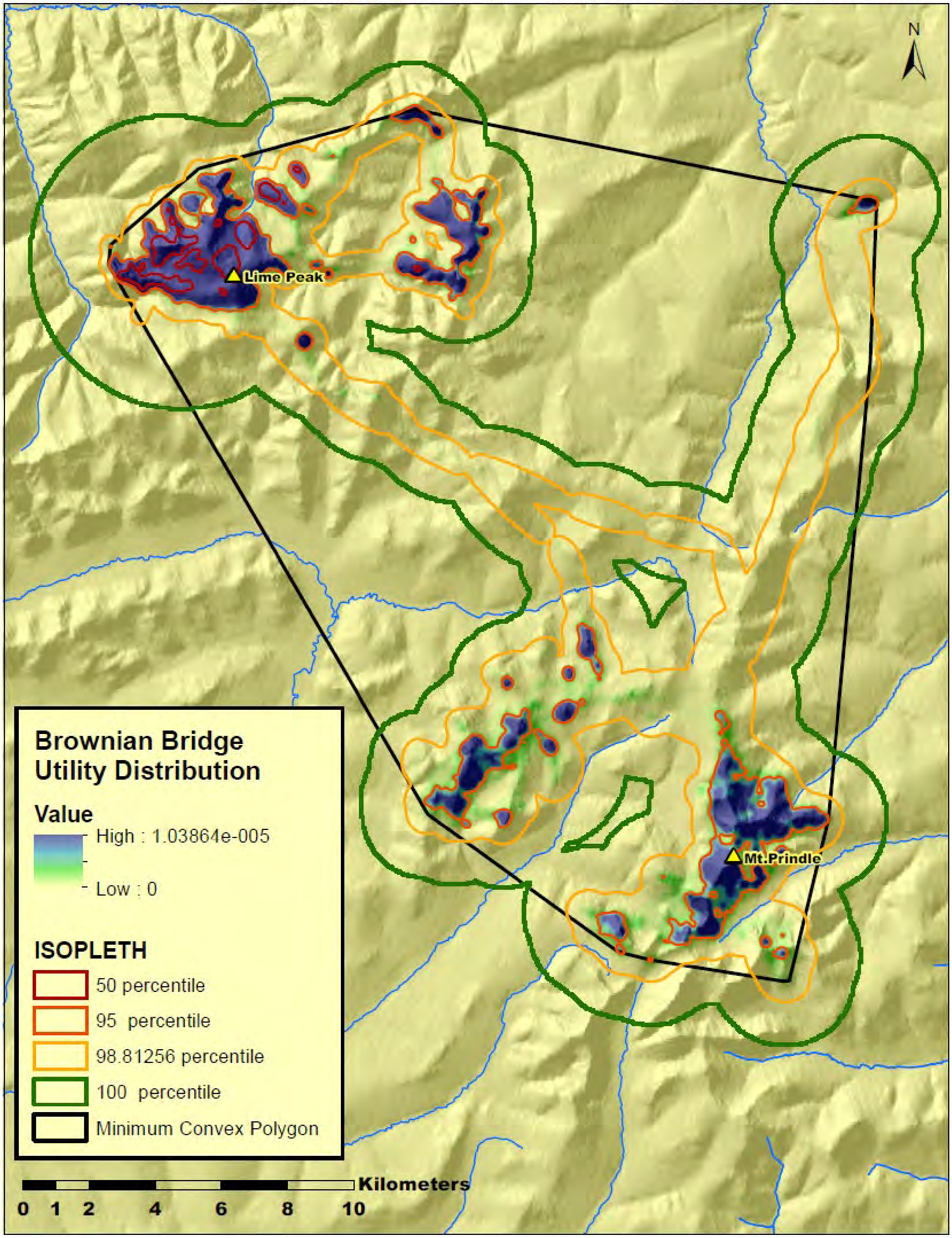
Sheep 43, Ewe, 11 years, Lime Peak, Lotek 2-hr, n=2414, 205 days, 10/06/2005-4/29/2006



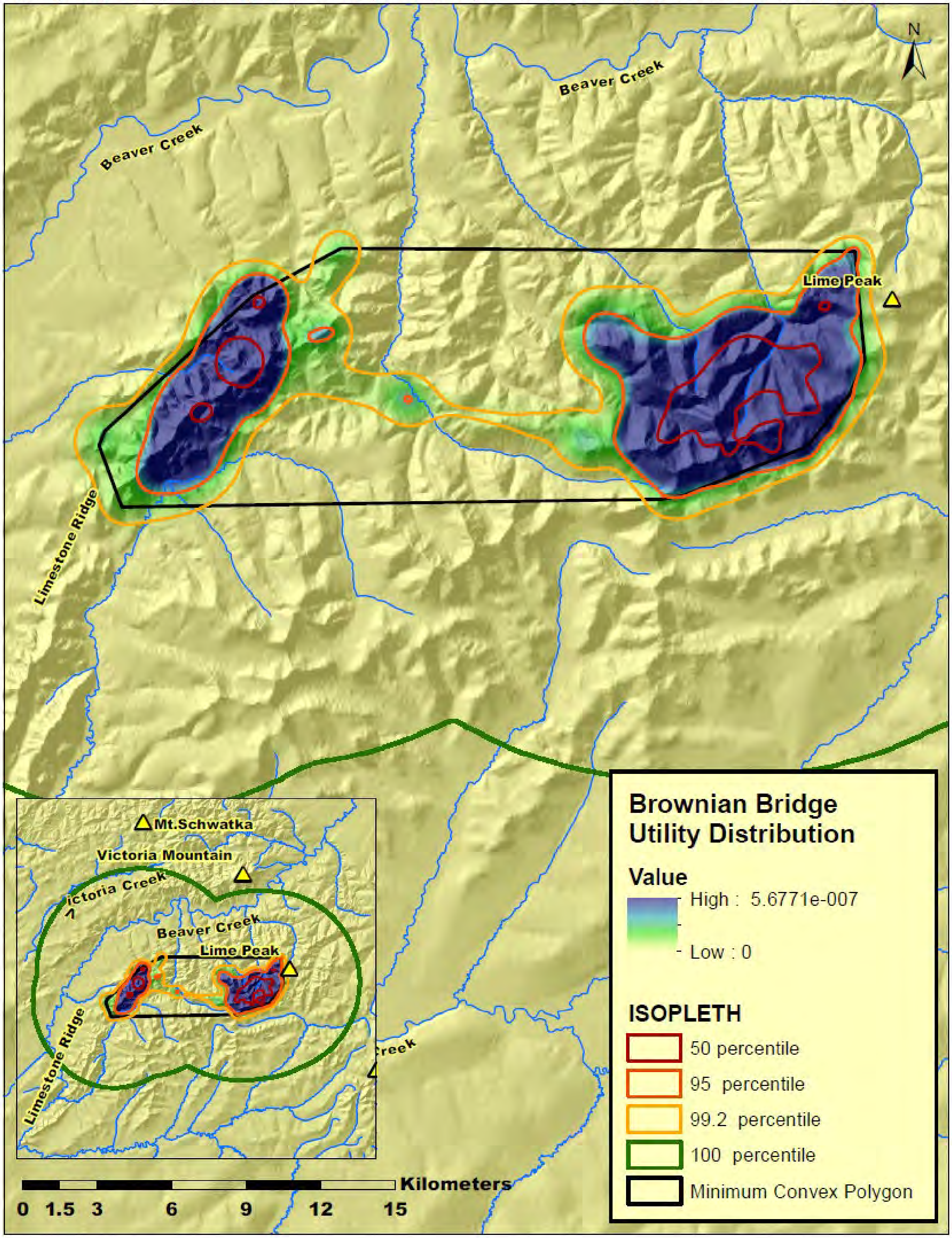
Sheep 44, Ewe, 5 years, Lime Peak, Lotek 2-hr, n=8530, 722 days, 10/06/2005-9/28/2007



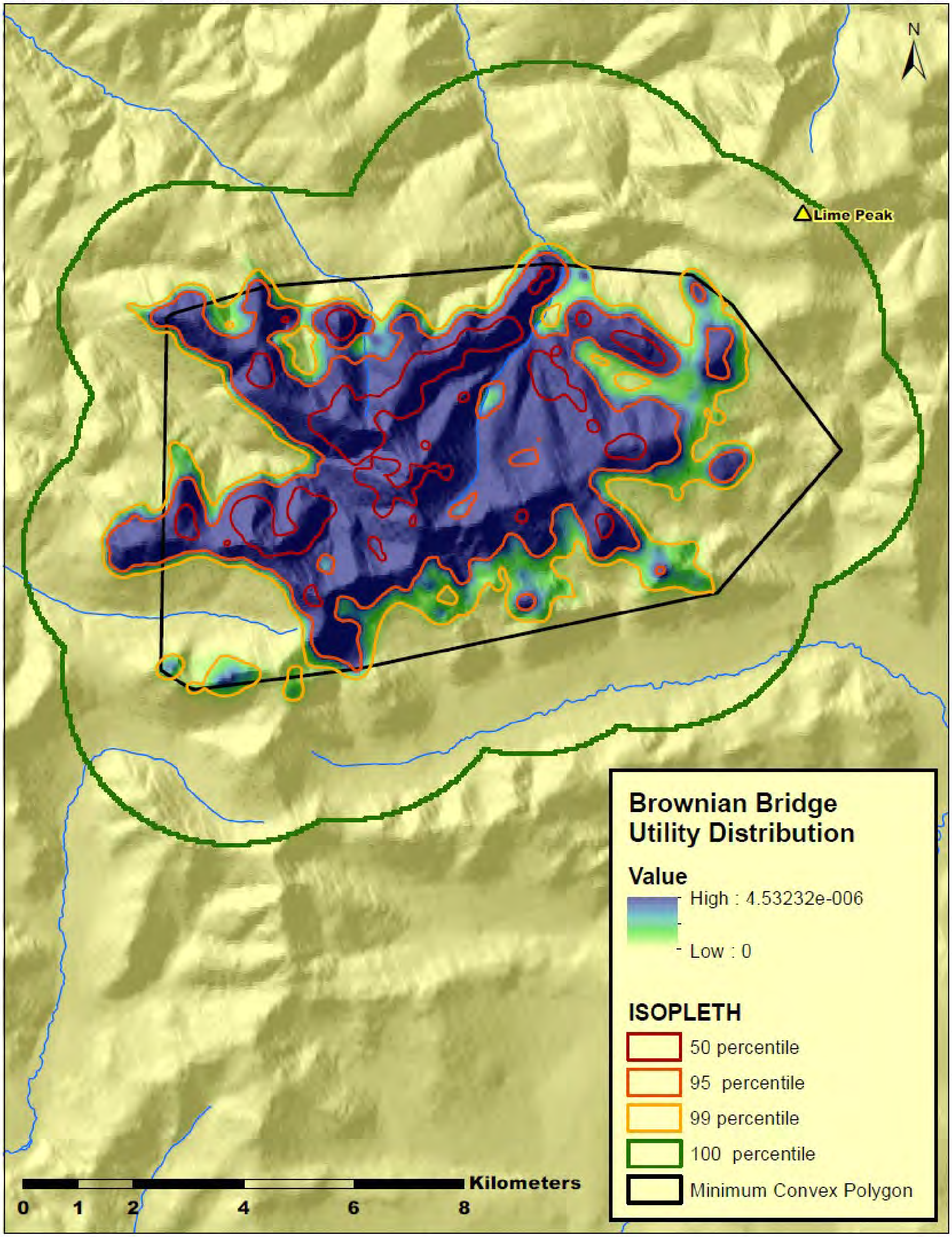
Sheep 49, Ewe, 4 years, Lime Peak, Lotek 1-hr, n=16859, 732 days, 9/28/2006-9/28/2008



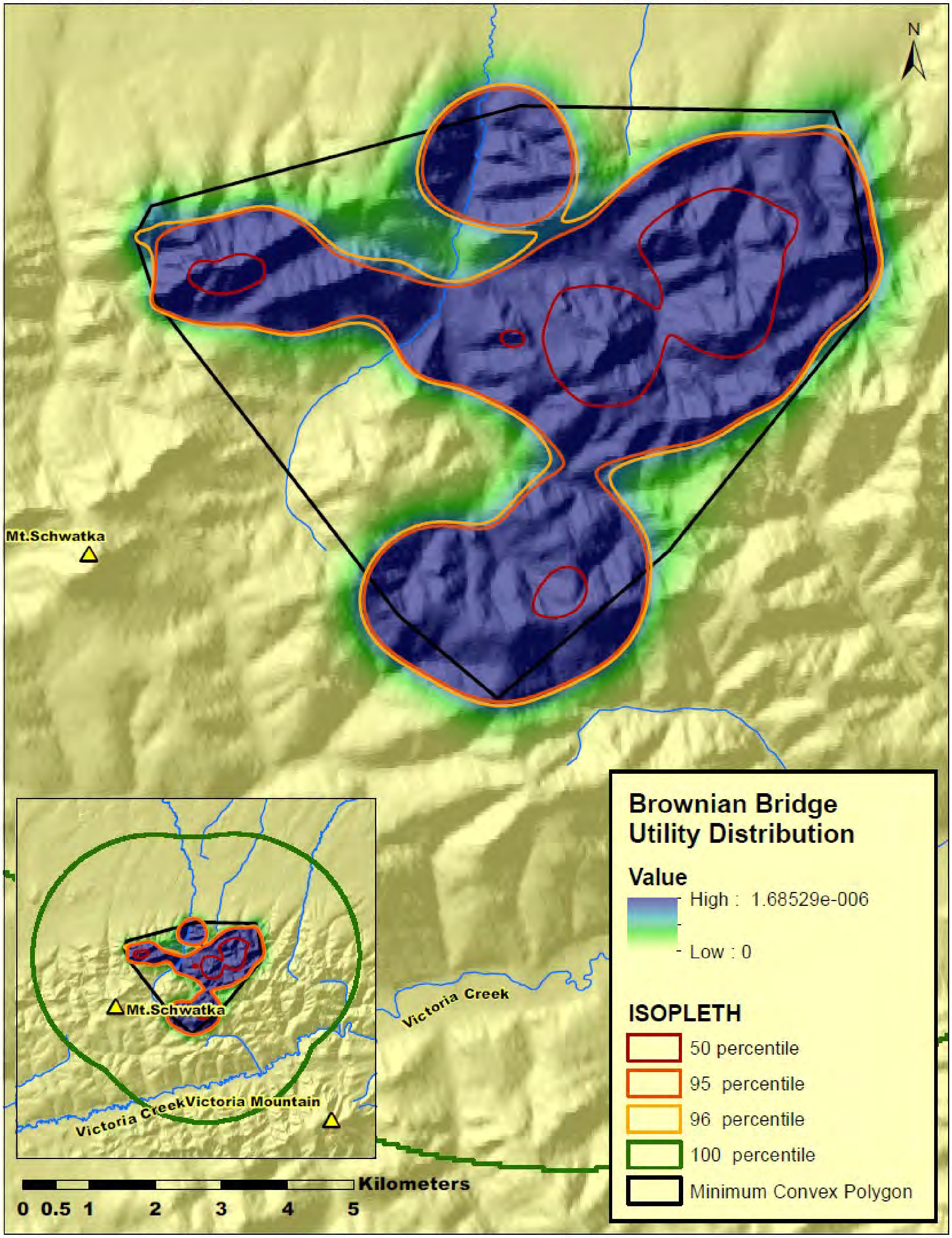
Sheep 51, Ewe, 5 years, Lime Peak, Telonics, n=650, 692 days, 9/28/2006-8/20/2008



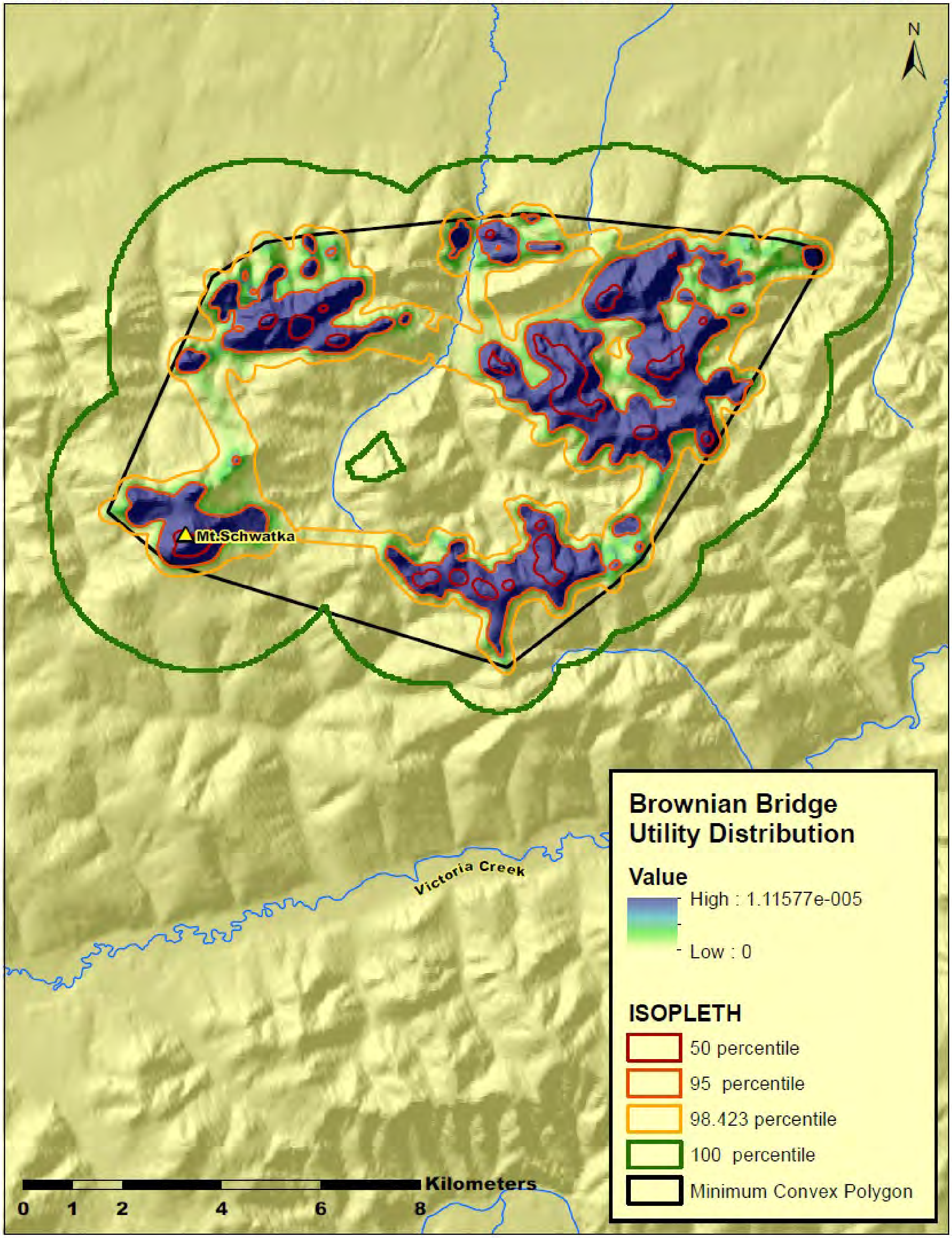
Sheep 54, Ewe, 3 years, Lime Peak, Lotek 1&2-hr, n=7249, 713 days, 9/28/2006-9/10/2008



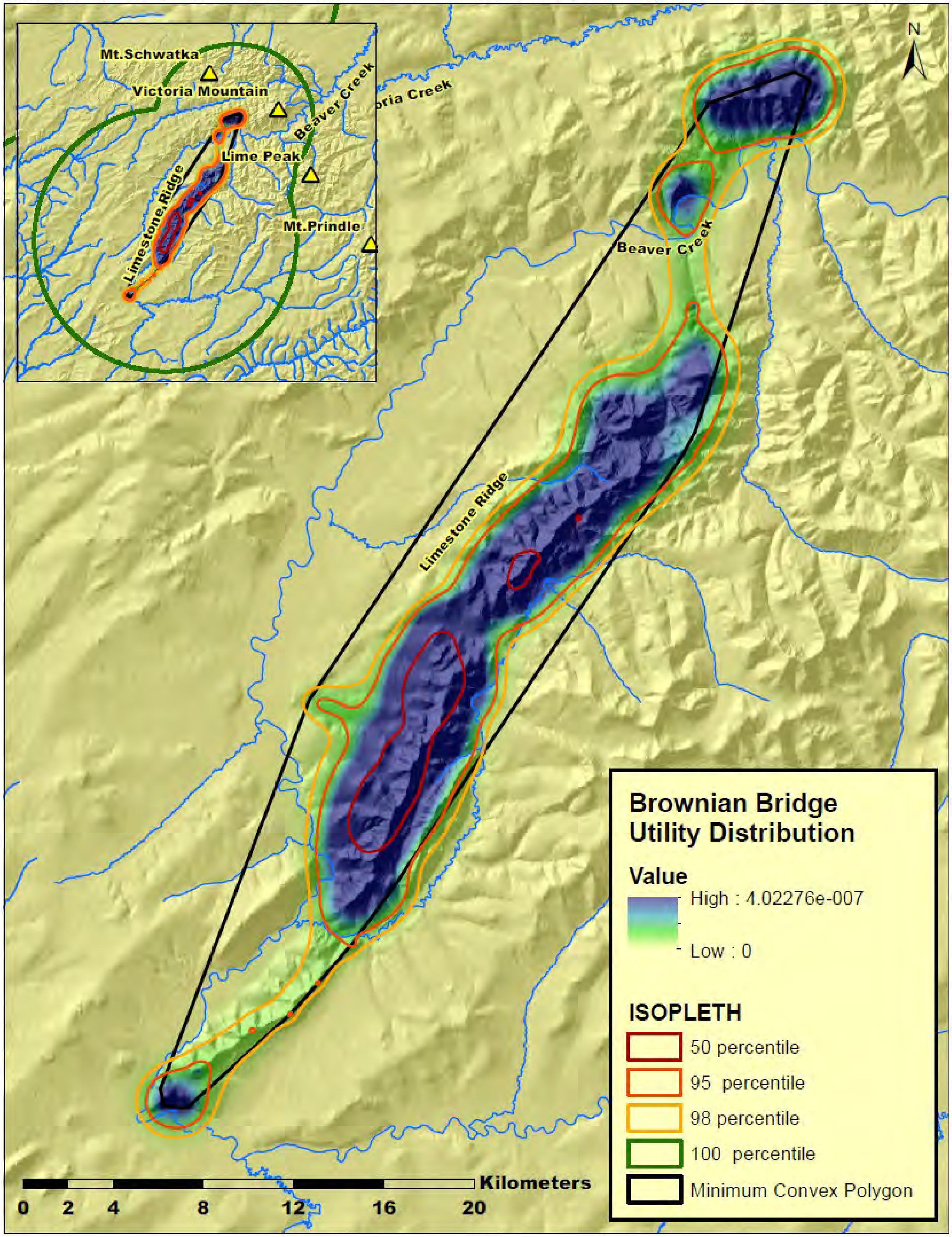
Sheep 58, Ewe, 4 years, Schwatka, Telonics, n=545, 564 days, 2/03/2007-8/20/2008



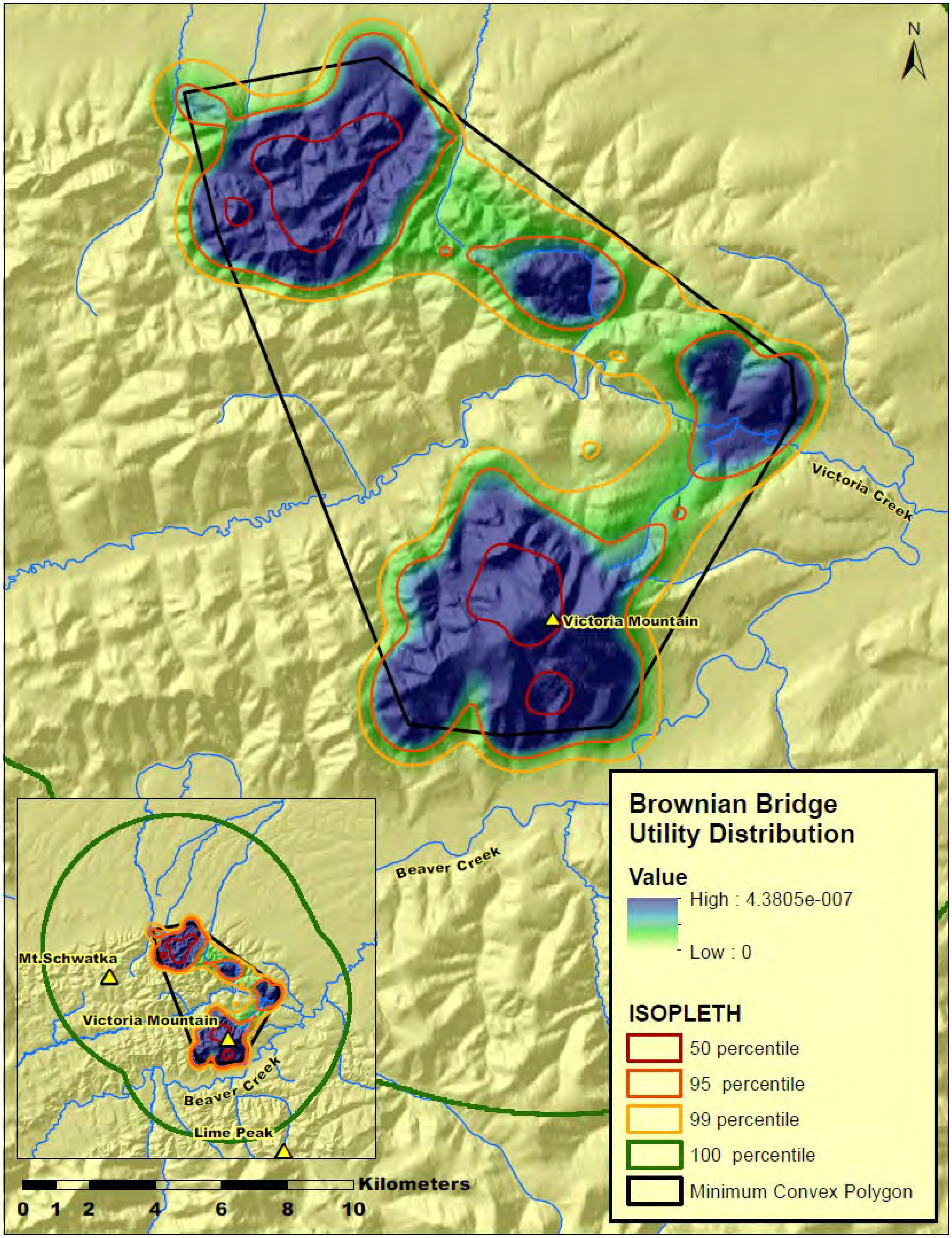
Sheep 61, Ewe, 6 years, Schwatka, Lotek-1hr, n=14076, 601 days, 2/03/2007-9/26/2008



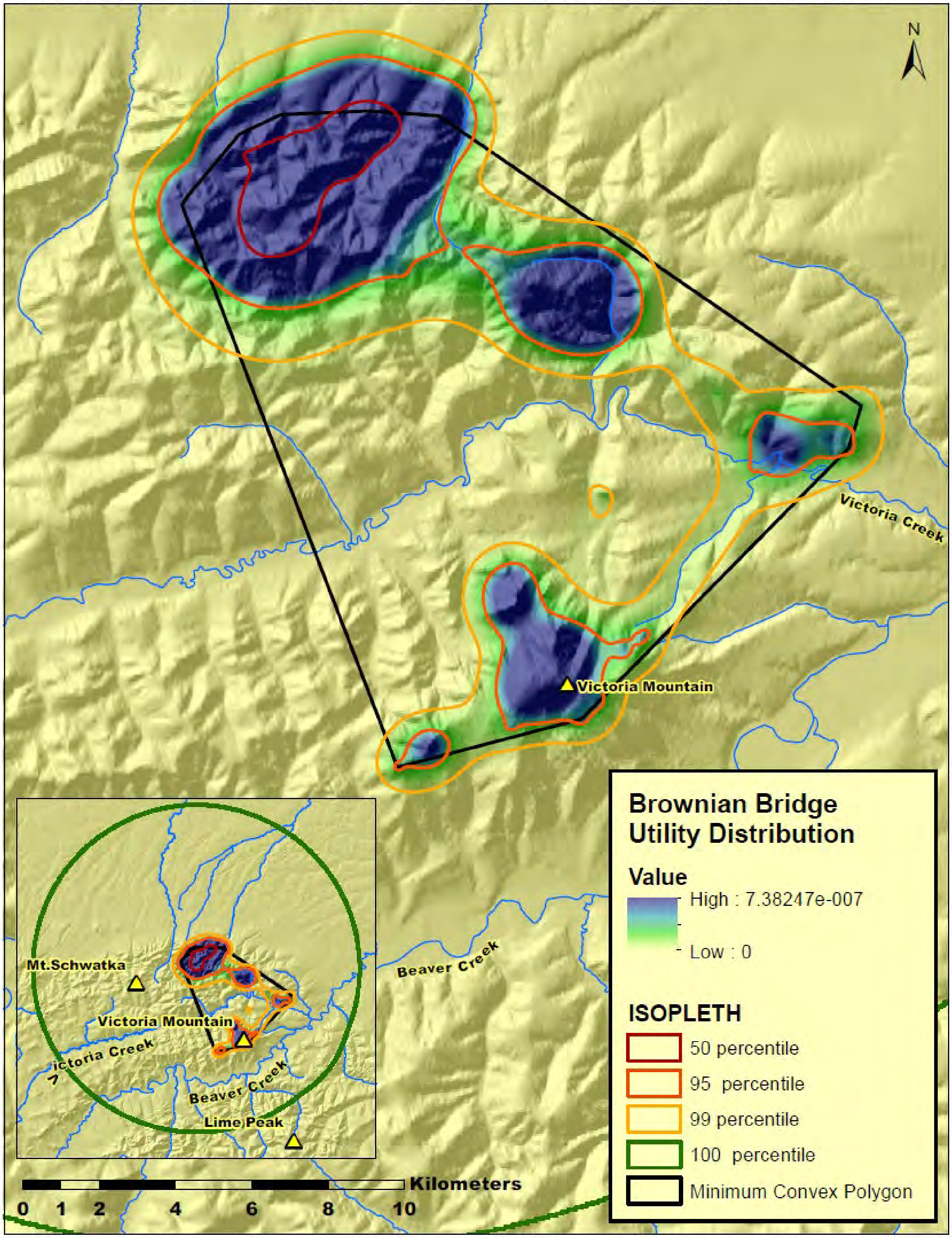
Sheep 63, Ewe, 5 years, Limestone R, Telonics, n=565, 622 days, 12/06/2006-8/19/2008



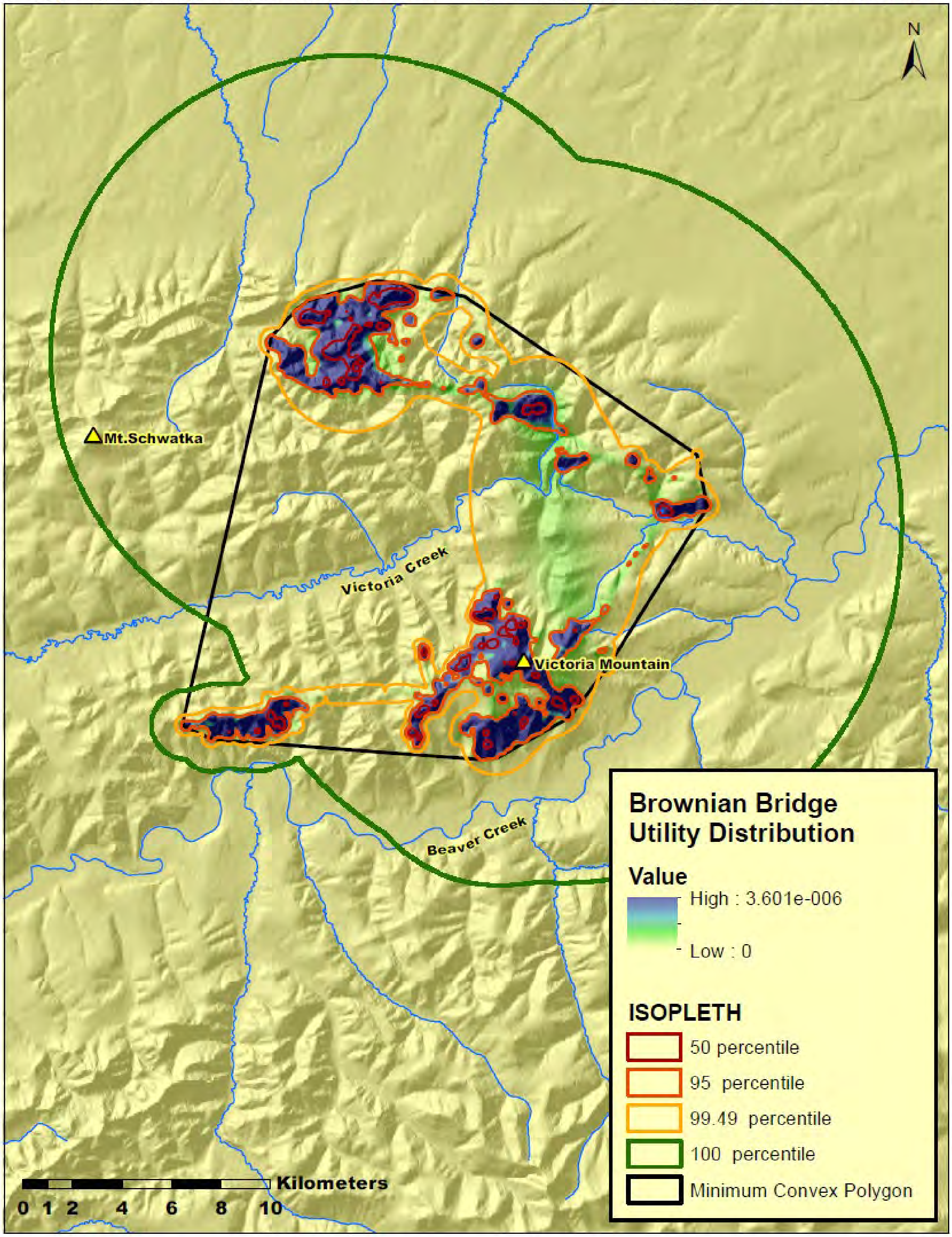
Sheep 64, Ewe, 5 years, Schwatka, Telonics, n=562, 568 days, 02/03/2007-8/24/2008



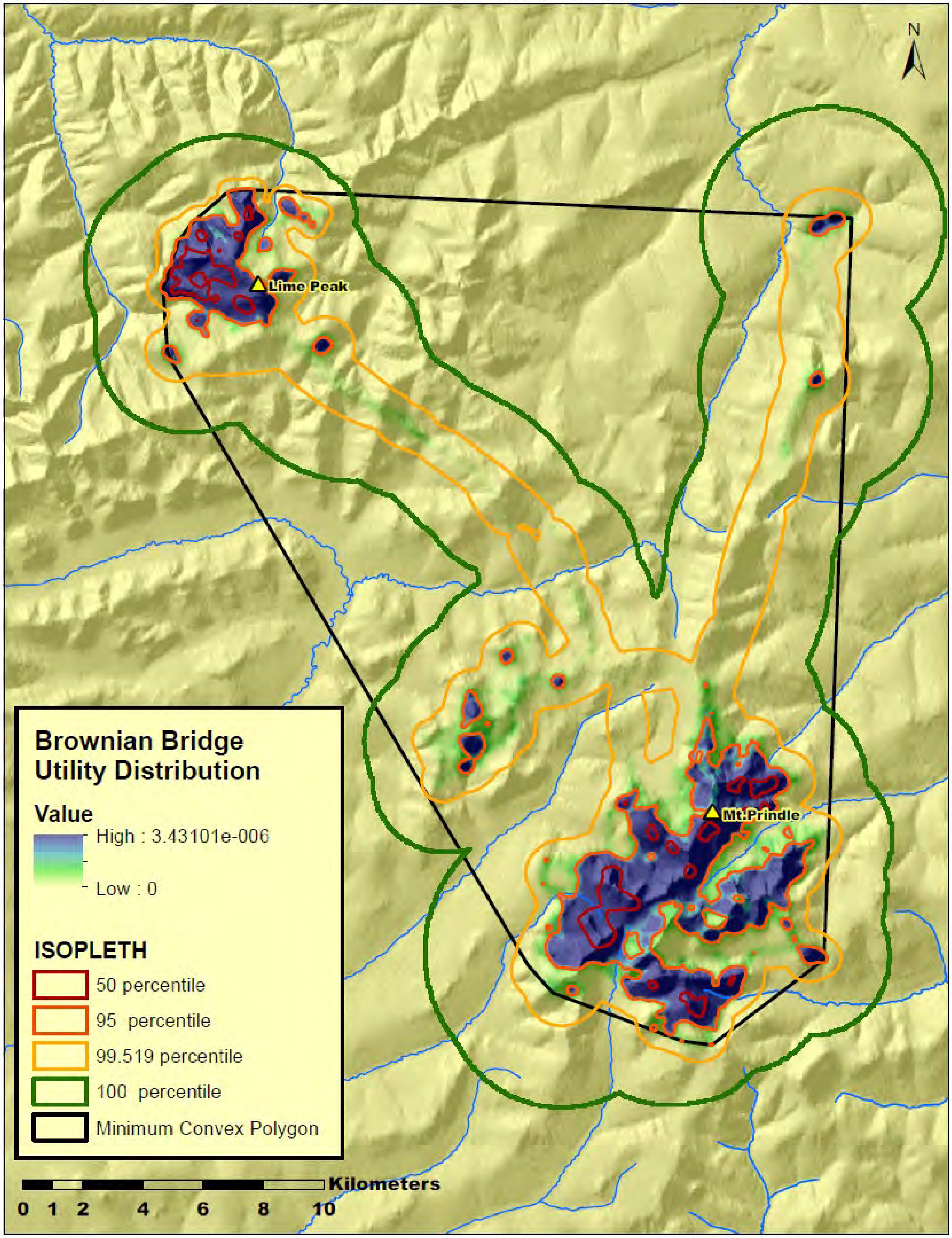
Sheep 65, Ewe, 7 years, Schwatka, Telonics, n=538, 568 days, 02/03/2007-8/24/2008



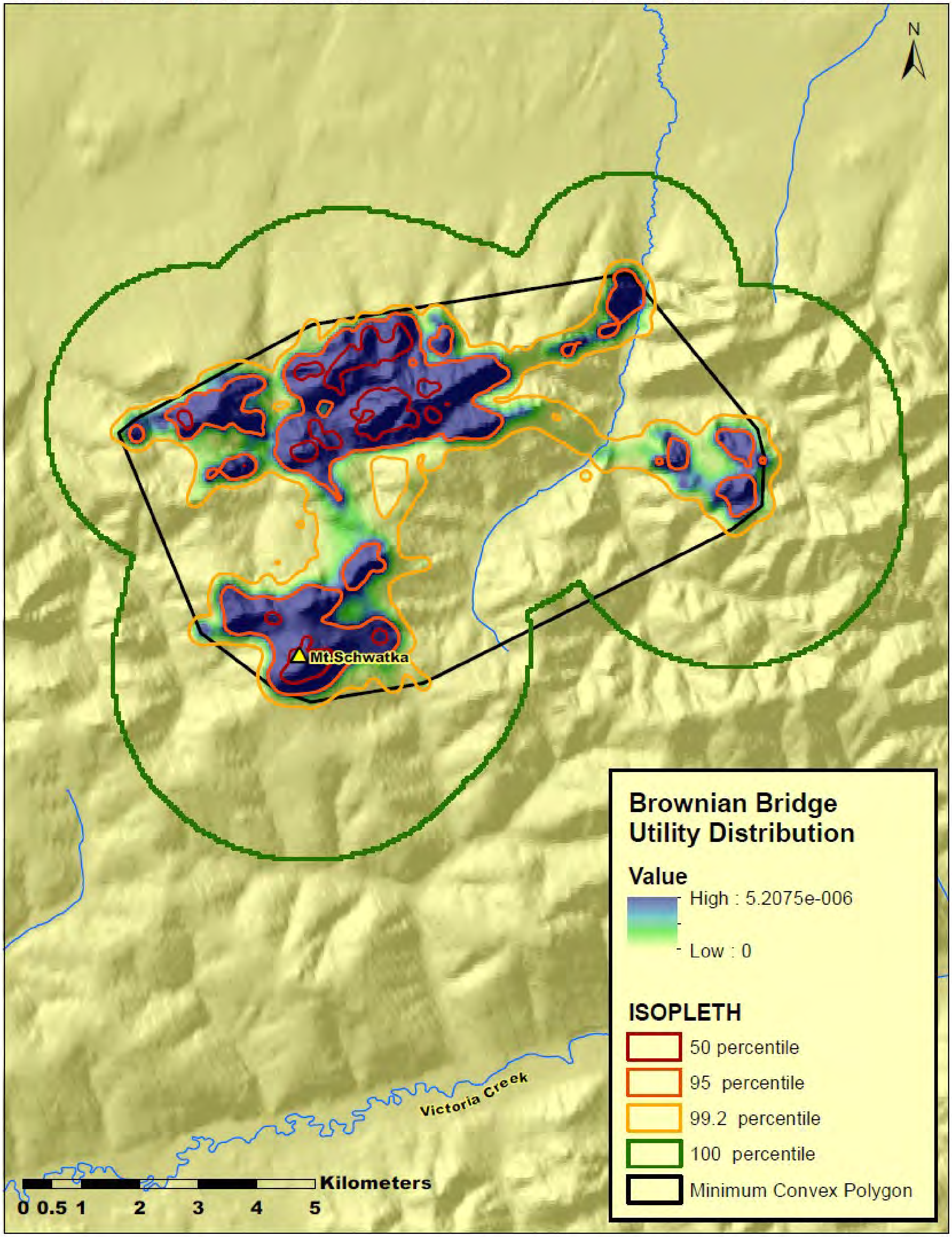
Sheep 66, Ewe, 5 years, Schwatka, Lotek 1-hr, n=13532, 601 days, 02/03/2007-9/26/2008



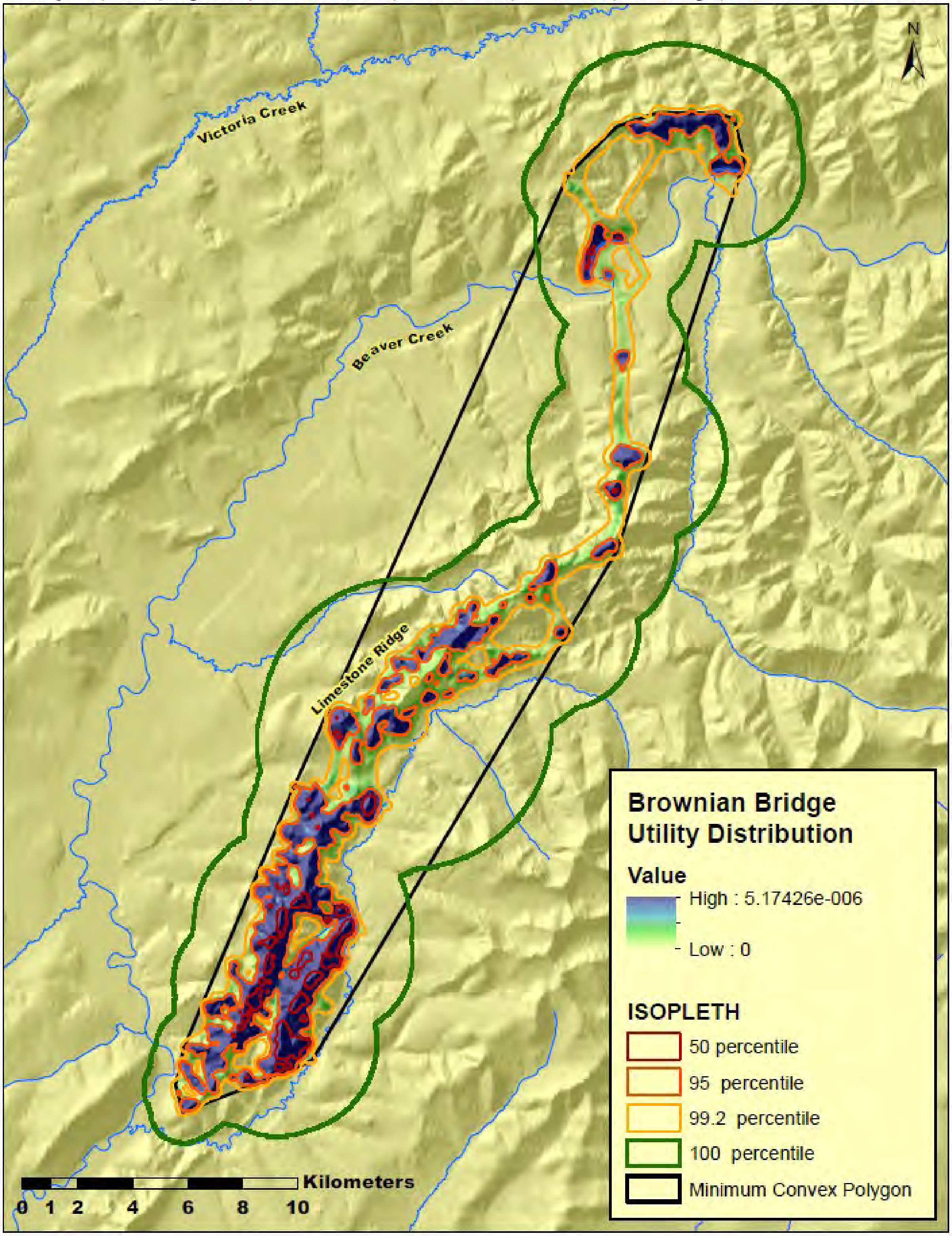
Sheep 71, Ewe, 5 years, Prindle, Lotek 2-hr, n=6938, 602 days, 02/04/2007-9/28/2008



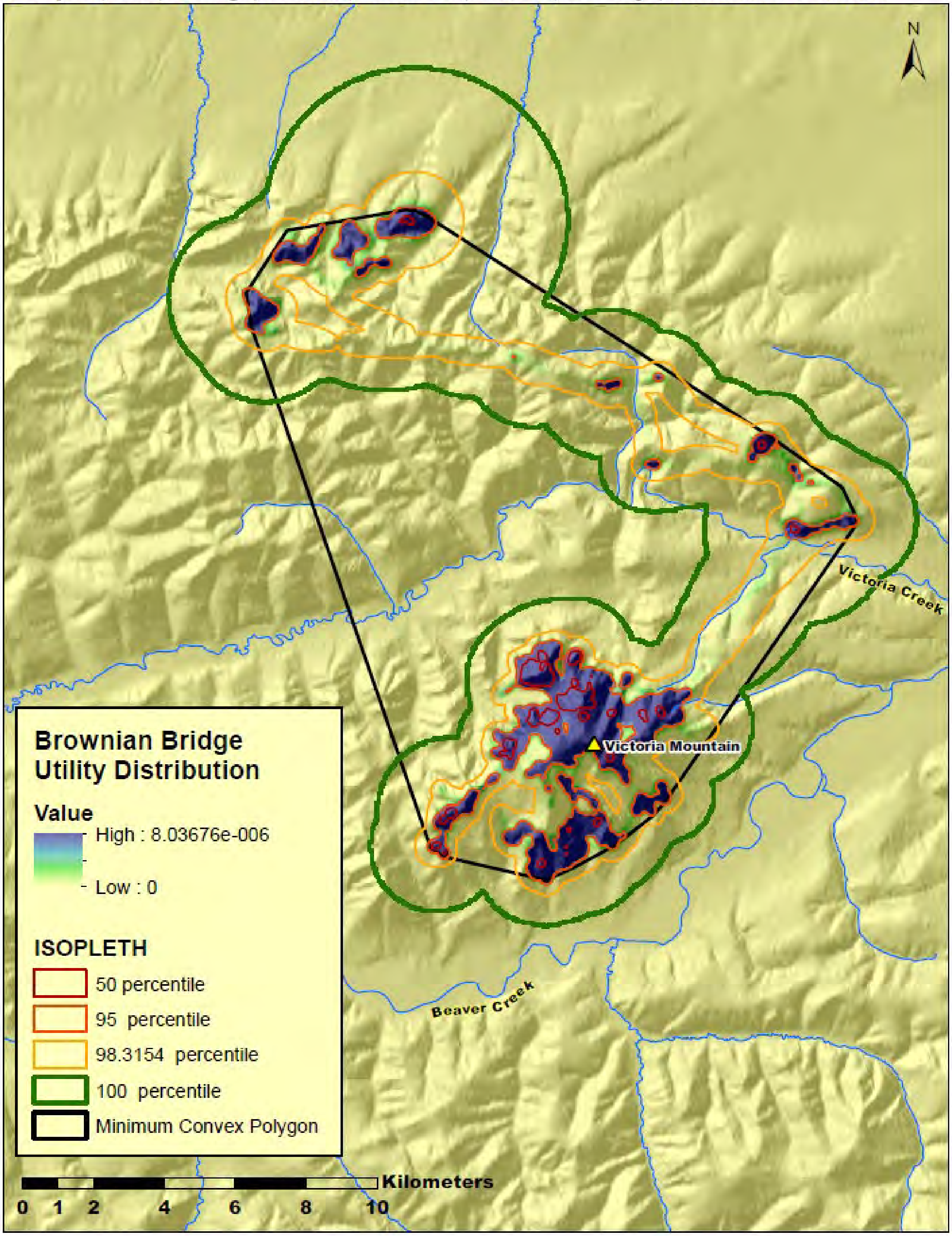
Sheep 72, Ewe, 5 years, Schwatka, Lotek 1-hr, n=13427, 600 days, 02/04/2007-9/26/2008



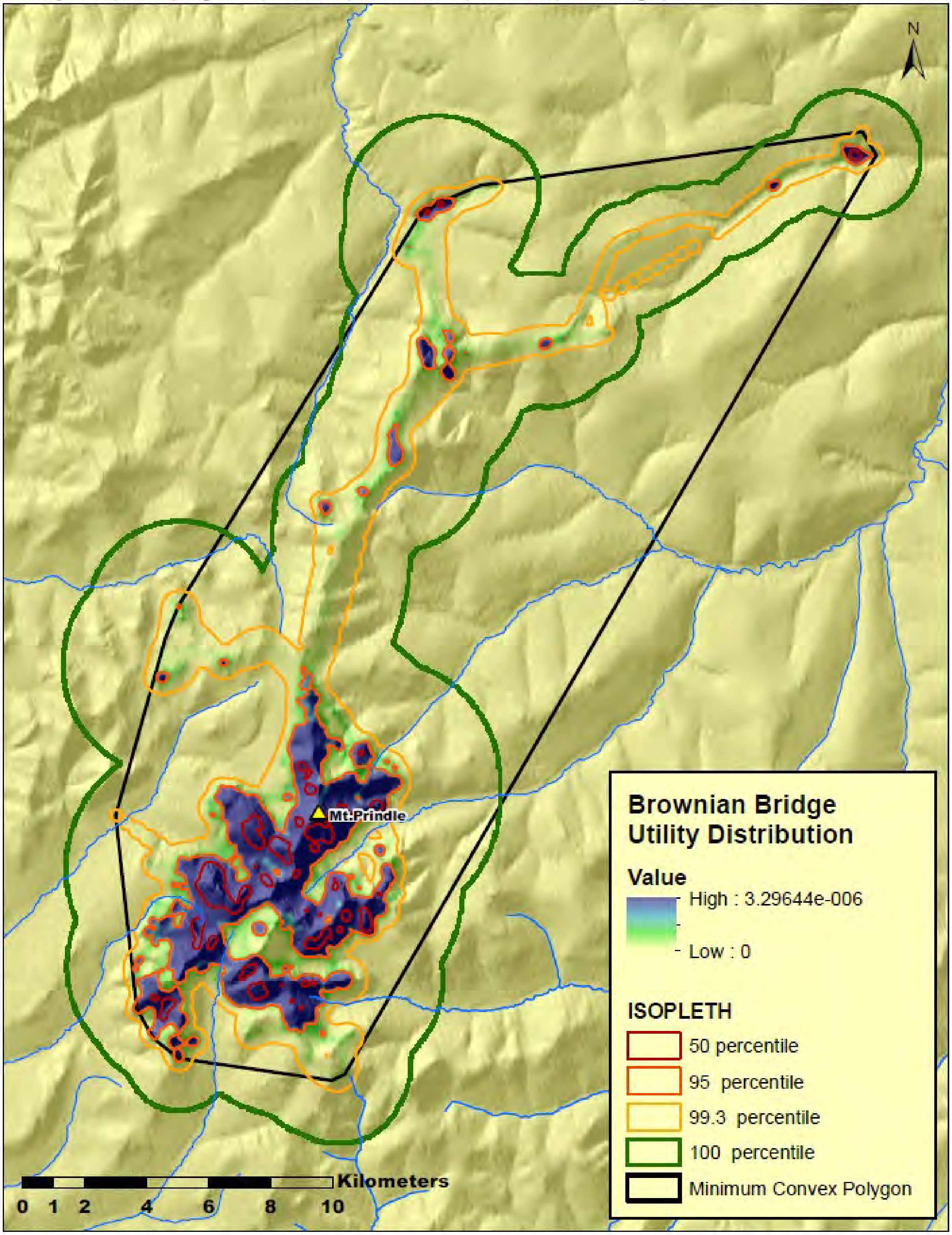
Sheep 73, Ewe, 5 years, Limestone R, Lotek 1-hr, n=13567, 600 days, 02/04/2007-9/26/2008



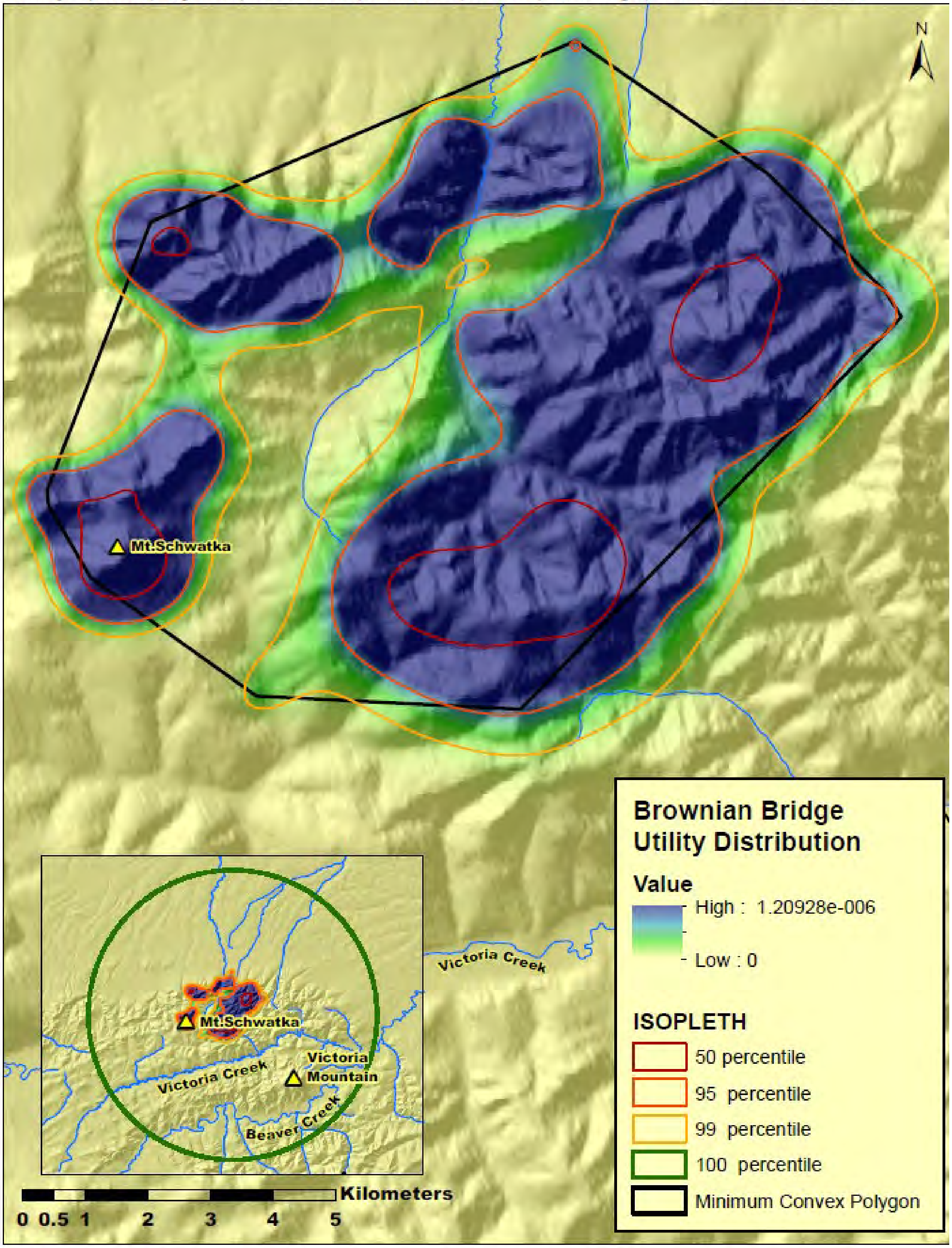
Sheep 75, Ewe, unk age, Victoria, Lotek 1-hr, n=8354, 364 days, 09/28/2007-9/26/2008



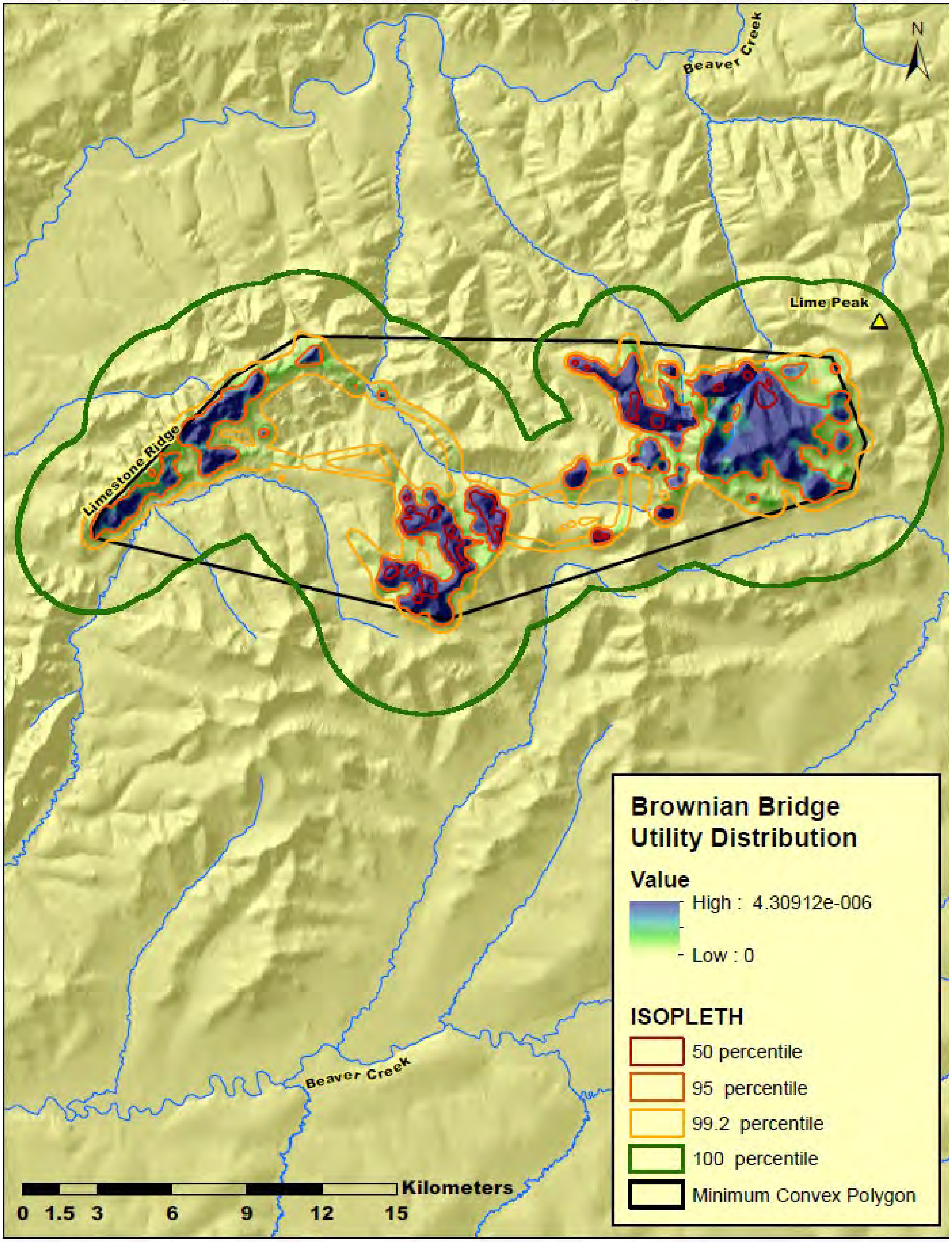
Sheep 167, Ewe, 5 years, Prindle, Lotek 1-hr, n=8132, 355 days, 10/09/2007-9/28/2008



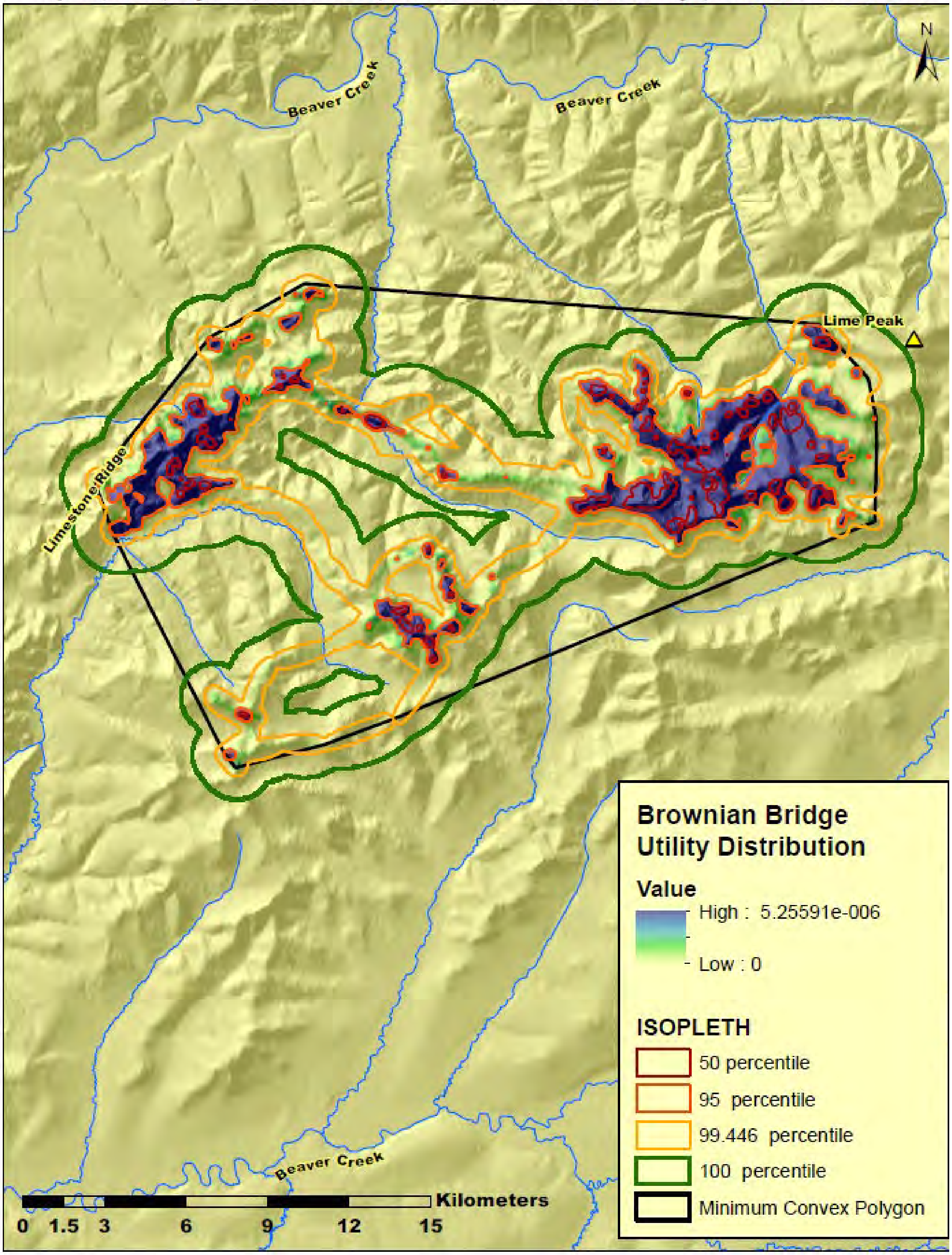
Sheep 4, Ram, 6 years, Schwatka, Telonics, n=510, 655 days, 10/18/2004-8/4/2006



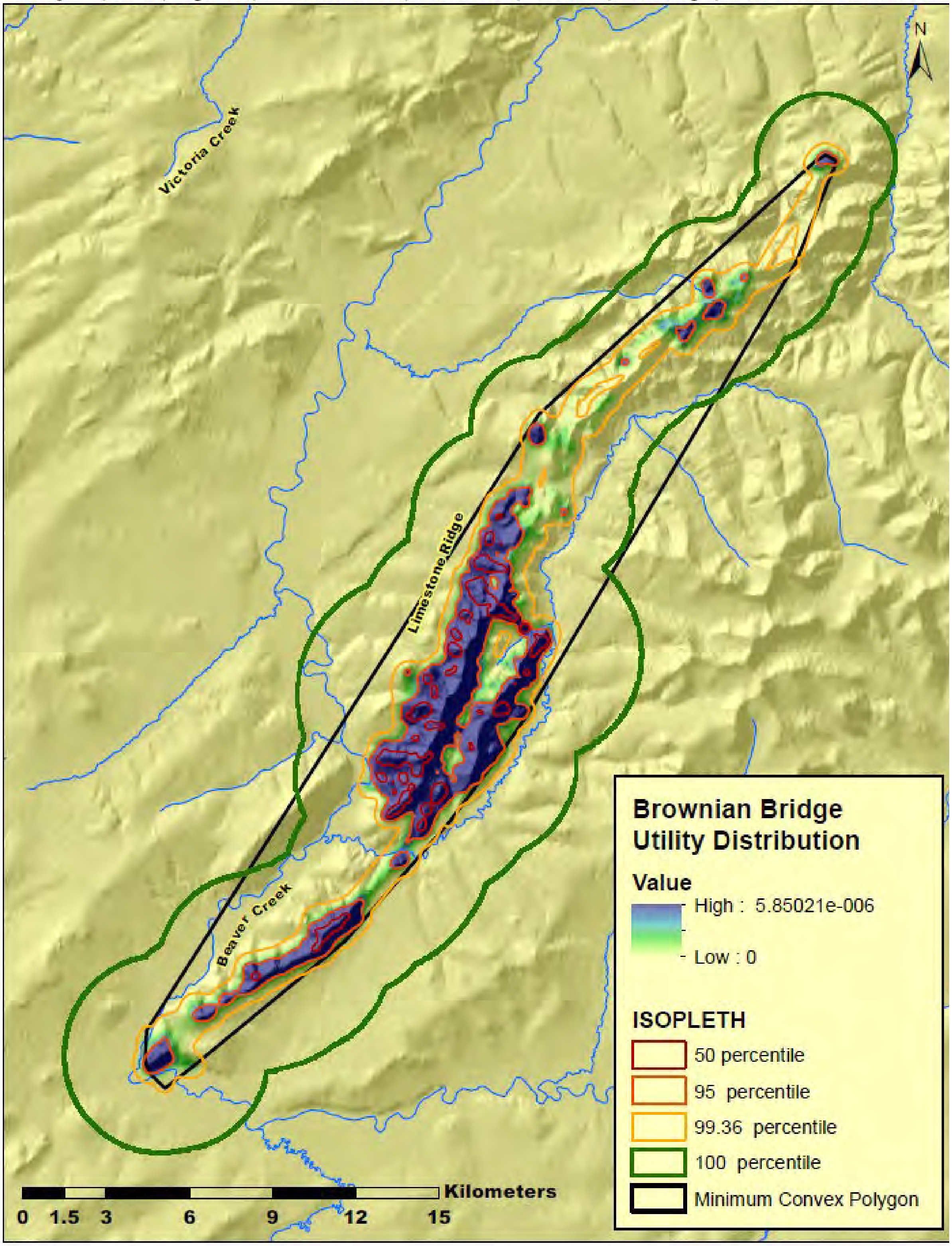
Sheep 8, Ram, 1 year, Lime Peak, Lotek-2hr, n=6173, 520 days, 9/22/2004-2/24/2006



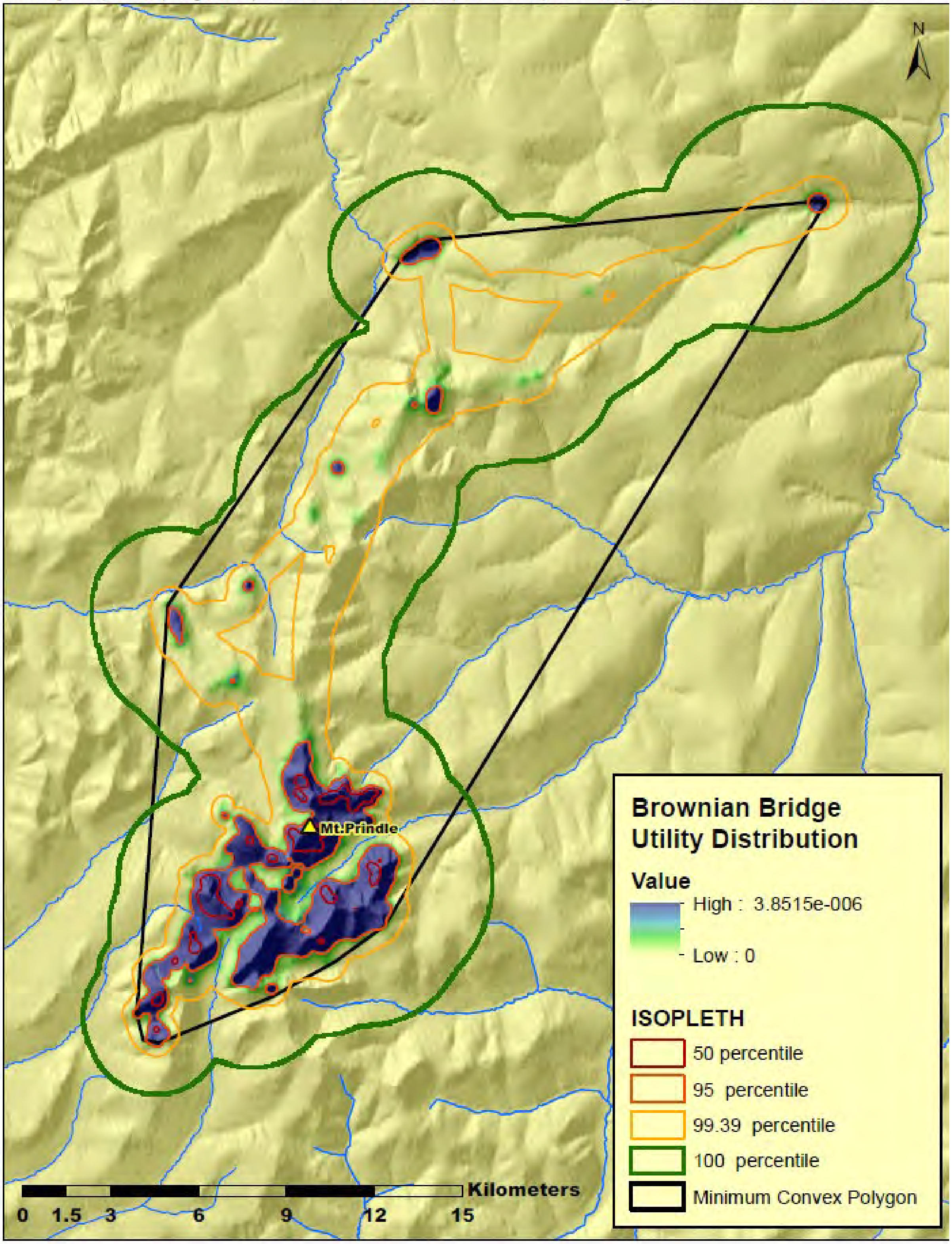
Sheep 11, Ram, 3 years, Lime Peak, Lotek-1hr, n=19027, 805 days, 9/22/2004-12/6/2006



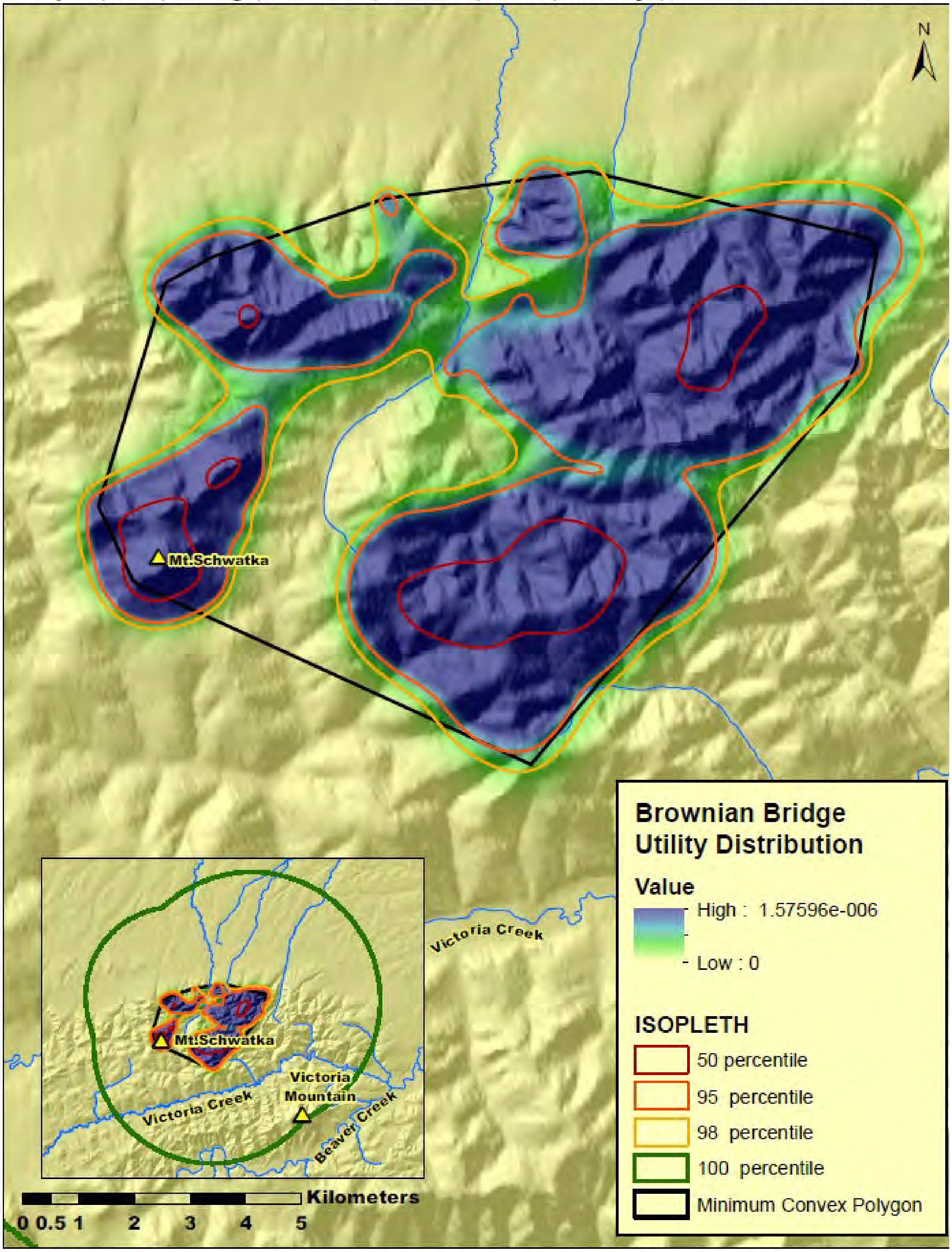
Sheep 16, Ram, 2 years, Limestone R, Lotek-2hr, n=9245, 799 days, 9/25/2004-12/3/2006



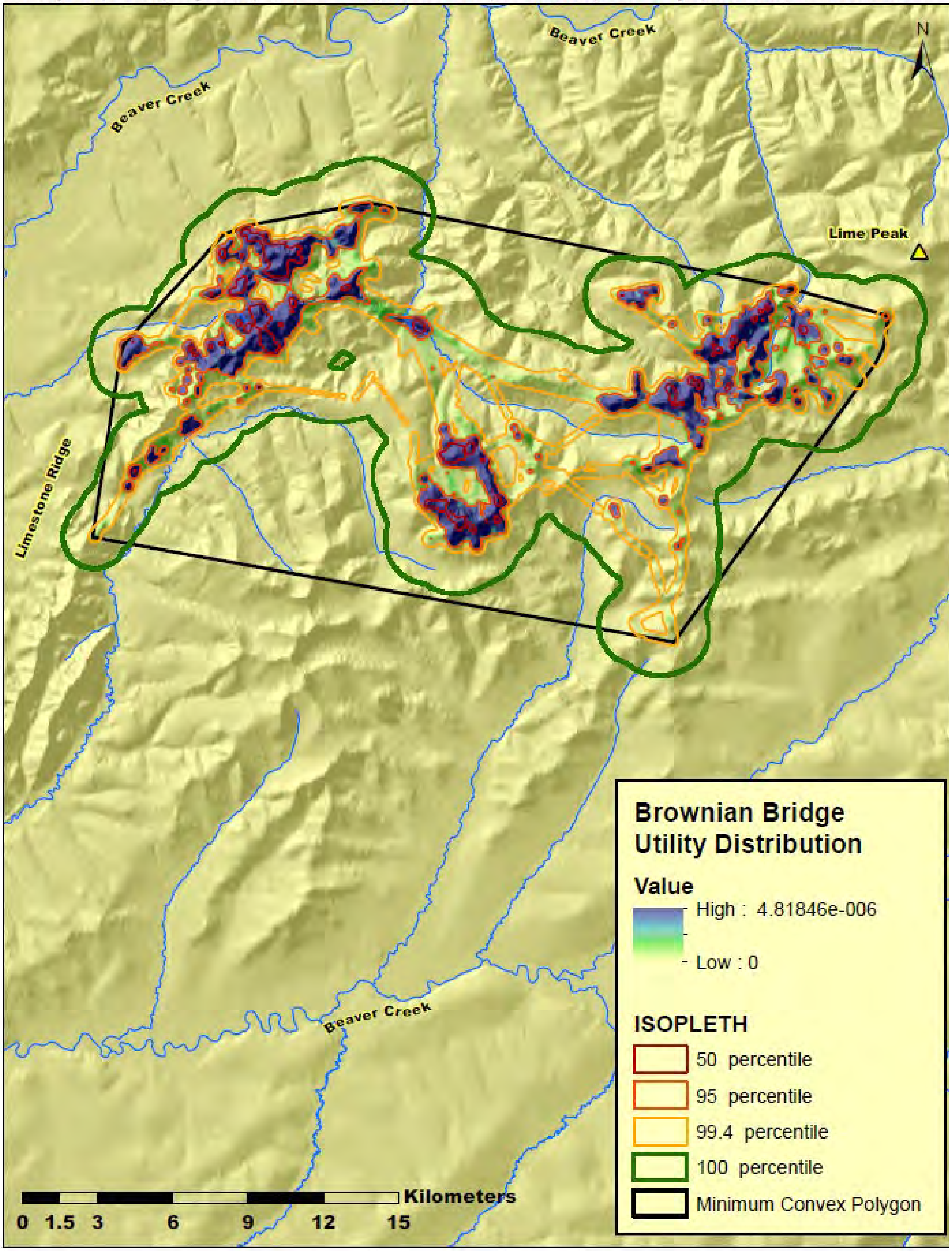
Sheep 30, Ram, 5 years, Prindle, Lotek-2hr, n=7267, 642 days, 11/08/2004-8/12/2006



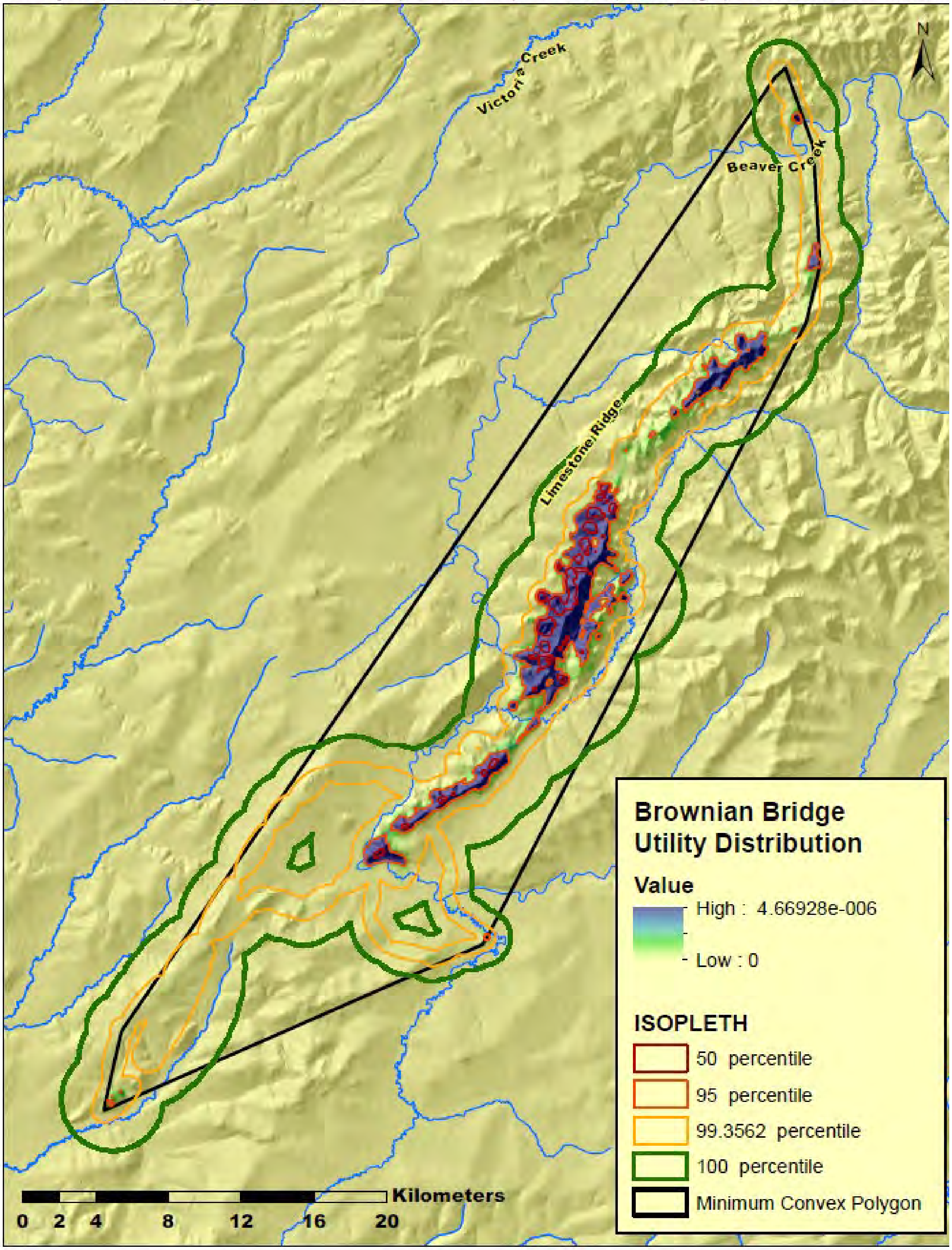
Sheep 31, Ram, unk age, Schwatka, Telonics, n=560, 660 days, 10/18/2004-8/9/2006



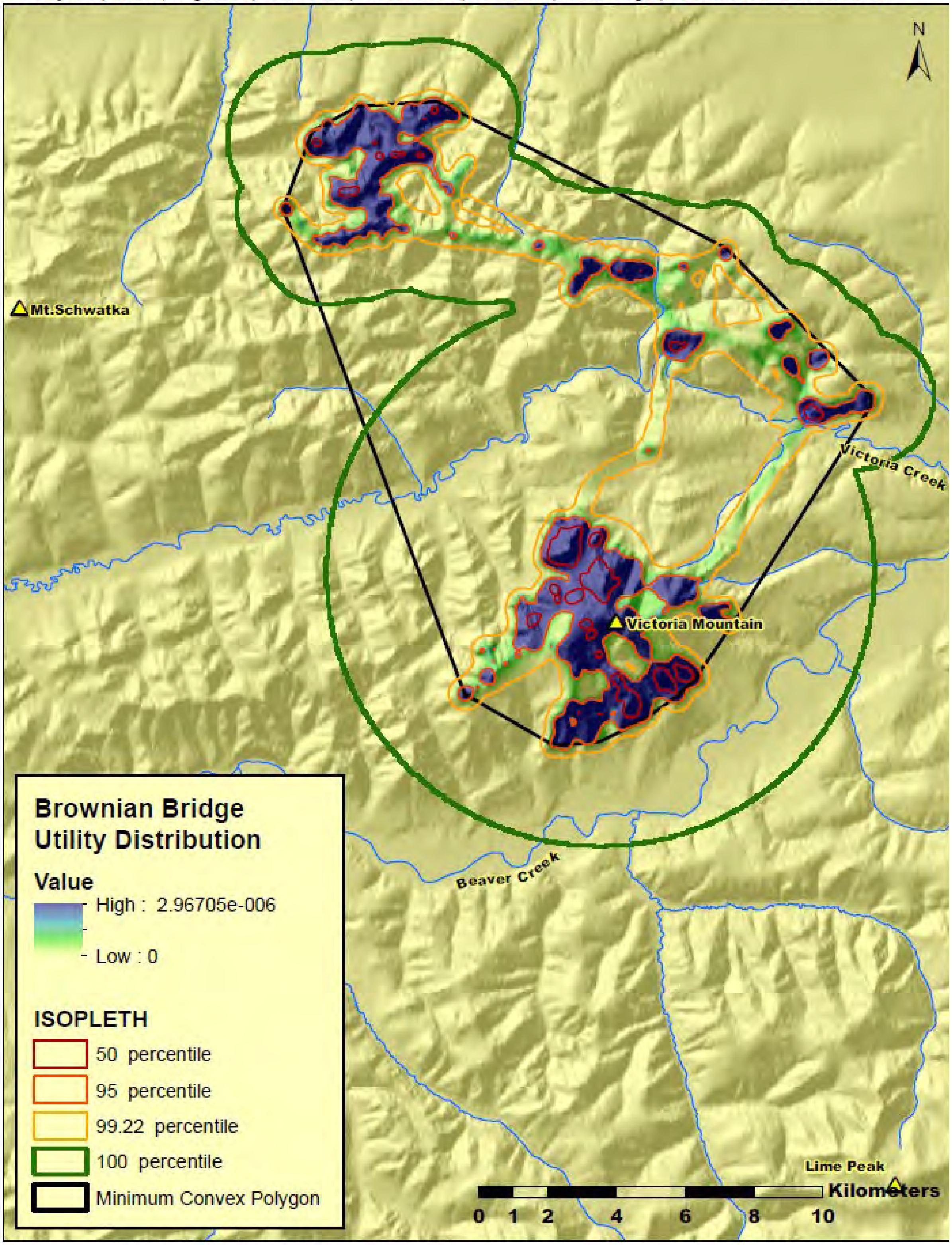
Sheep 45, Ram, 5 years, Lime Peak, Lotek-1hr, n=17228, 731 days, 9/28/2006-9/28/2008



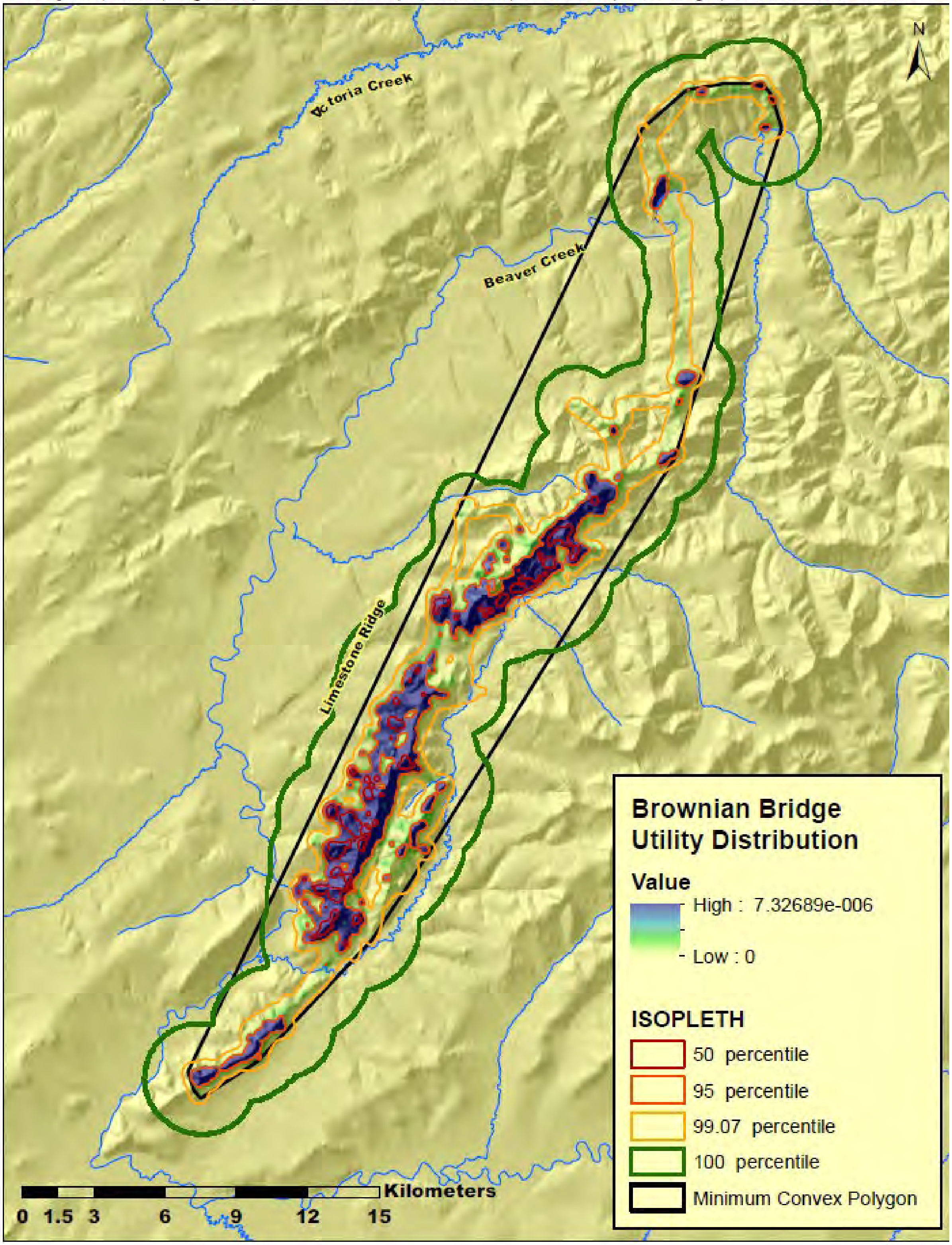
Sheep 50, Ram, 2 years, Limestone R, Lotek-1hr, n=15205, 660 days, 12/6/2006-9/26/2008



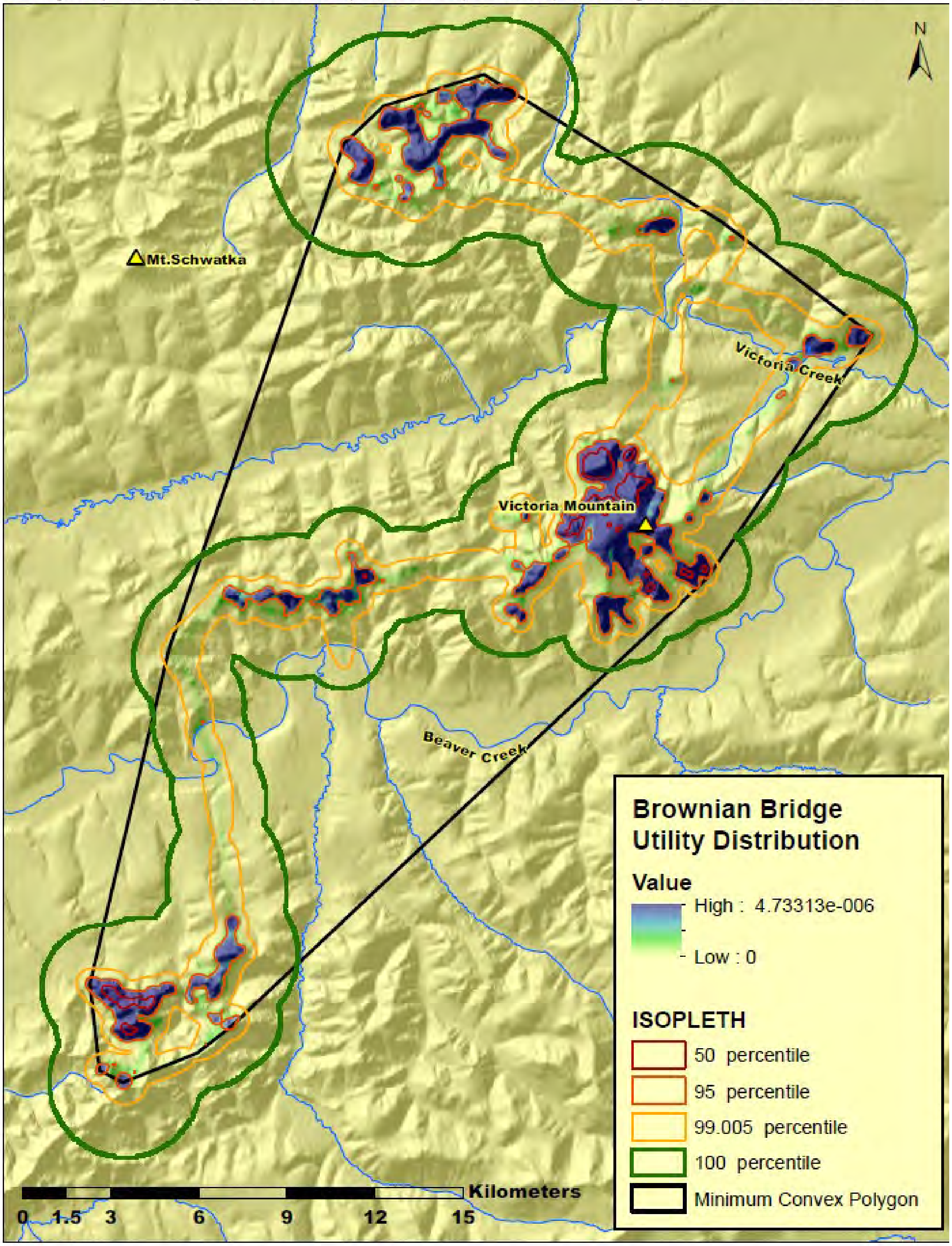
Sheep 56, Ram, 2 years, Victoria, Lotek-1hr, n=7012, 295 days, 2/03/2007-11/25/2007



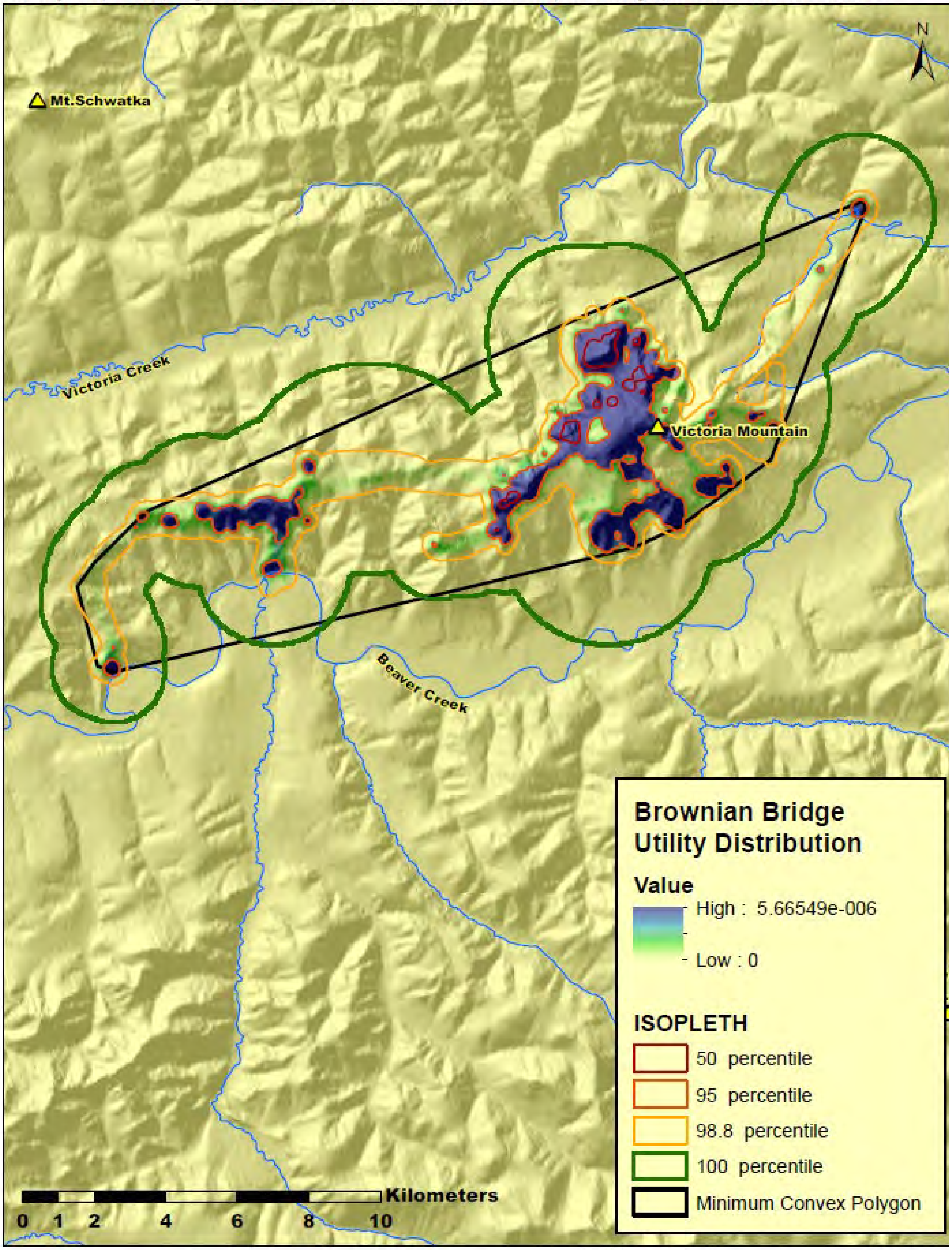
Sheep 62, Ram, 5 years, Limestone R, Lotek-1hr, n=15356, 660 days, 12/06/2006-9/26/2008



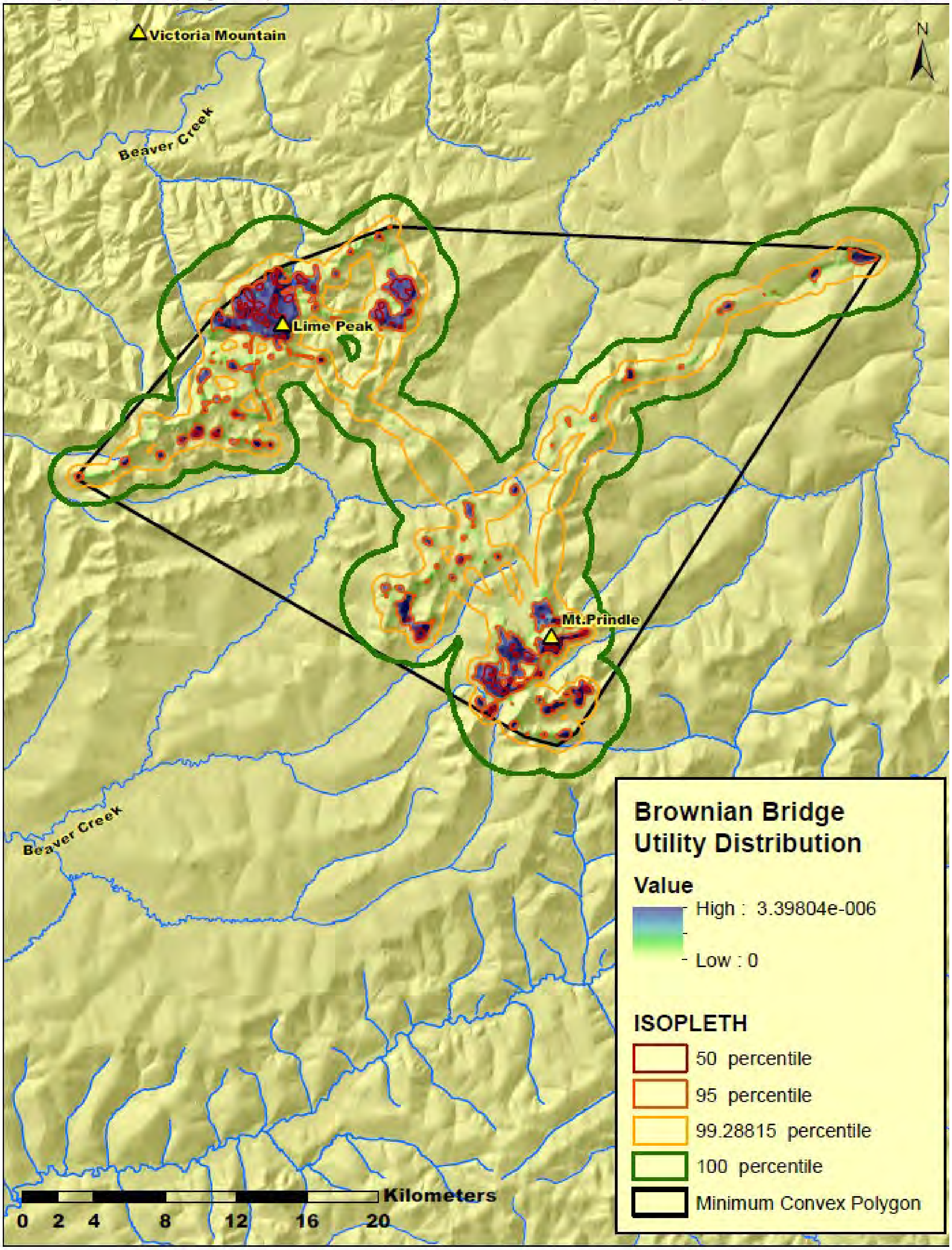
Sheep 74, Ram, 2 years, Victoria, Lotek-1hr, n=8503, 364 days, 9/28/2007-9/26/2008



Sheep 83, Ram, 4 years, Victoria, Lotek-1hr, n=8123, 364 days, 9/28/2007-9/26/2008



Sheep 172, Ram, 3 years, Lime Peak, Lotek-1hr, n=8033, 355 days, 10/09/2007-9/28/2008

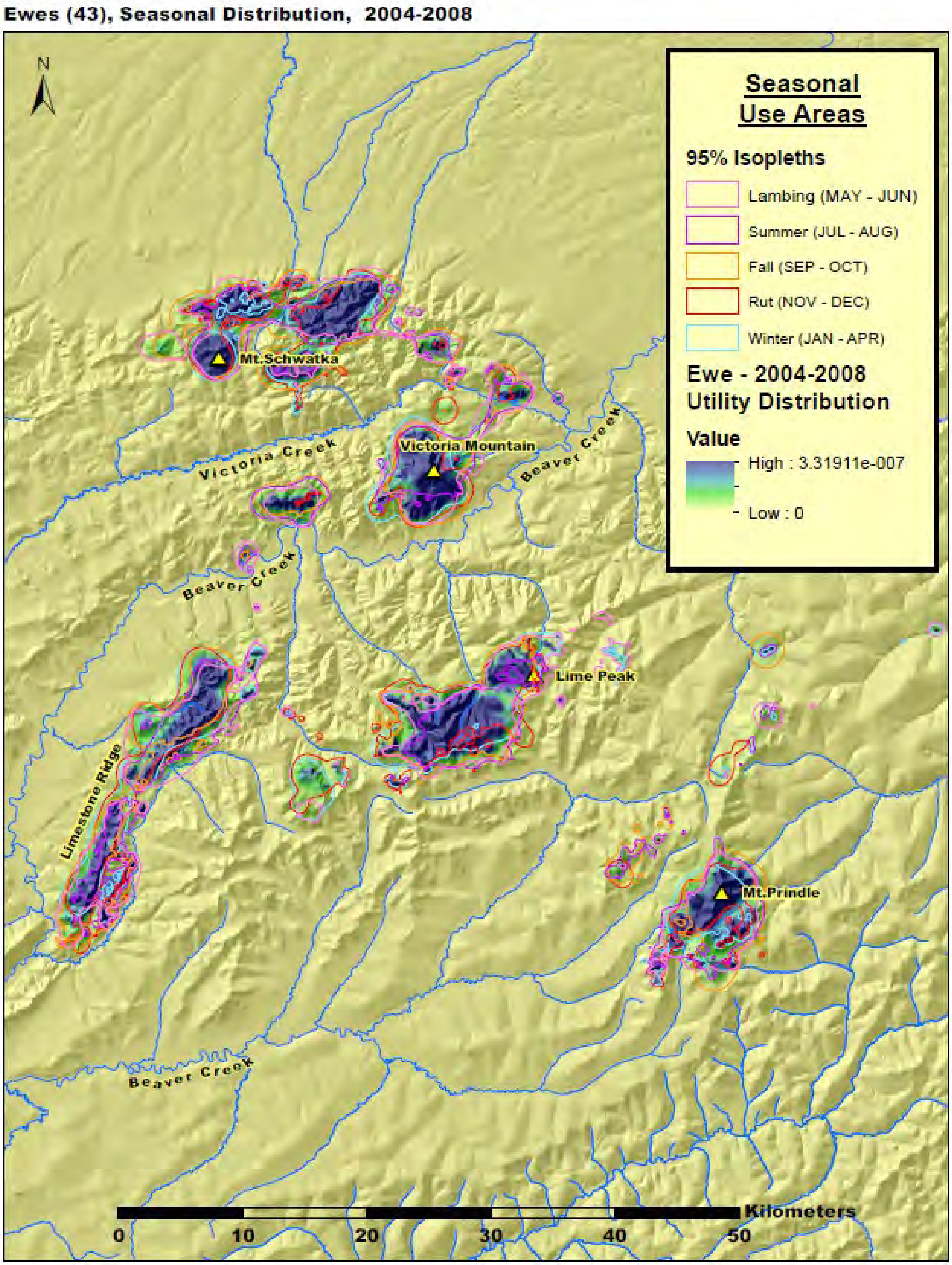


Appendix E1. Mean BBMM isopleth home range estimates at the 50 and 95 percentile and number of sheep seasons for seasonal movements of Dall's sheep by sex and radio collar type in the White Mountains, Alaska, USA 2004-2008.

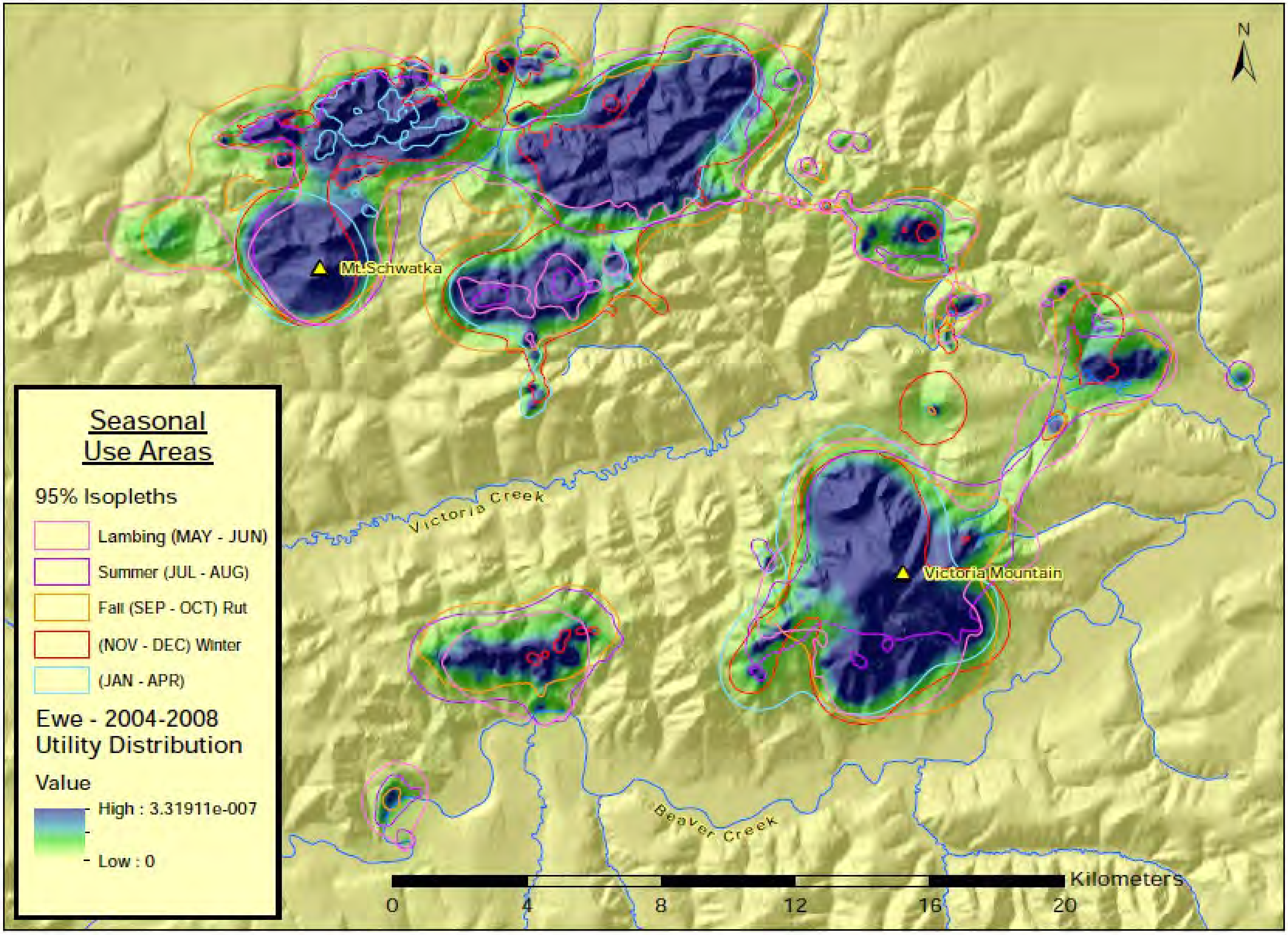
Sex-Season-Collar Type-Sample Size	Sheep Seasons	50 Percentile Area (km2)	95 Percentile Area (km2)
Ewes			
Lambing - All Collars (39)	84	38.927	395.004
Lambing - Lotek (20)	36	20.485	145.089
Lambing - Telonics (19)	48	44.976	487.409
Summer - All Collars (39)	84	38.181	304.433
Summer - Lotek (20)	36	25.129	178.433
Summer - Telonics (19)	48	38.828	322.000
Fall - All Collars (37)	57	57.676	402.612
Fall - Lotek (18)	24	23.462	146.087
Fall - Telonics (19)	33	81.476	458.867
Rut - All Collars (43)	86	29.542	312.740
Rut - Lotek (23)	41	11.610	84.910
Rut - Telonics (20)	45	41.439	369.926
Winter - All Collars (41)	79	30.979	309.272
Winter - Lotek (21)	32	10.209	74.445
Winter - Telonics (20)	47	41.808	348.400
Rams[1]			
Spring - All Collars (13)	21	25.785	207.907
Spring - Lotek (11)	17	22.074	167.558
Spring - Telonics (2)	4	5.868	54.464
Summer - All Collars (13)	18	25.979	158.589
Summer - Lotek (11)	16	21.896	133.972
Summer - Telonics (2)	2	4.469	29.311
Fall - All Collars (10)	12	20.710	127.900
Fall - Lotek (8)	10	15.134	99.432
Fall - Telonics (2)	2	8.814	34.943
Rut - All Collars (12)	19	14.631	104.064
Rut - Lotek (10)	15	8.920	63.210
Rut - Telonics (2)	4	9.516	42.272
Winter - All Collars (12)	20	10.274	85.069
Winter - Lotek (10)	16	6.543	54.767
Winter - Telonics (2)	4	4.454	33.274

[1] All telonics collars for rams deployed at Schwatka

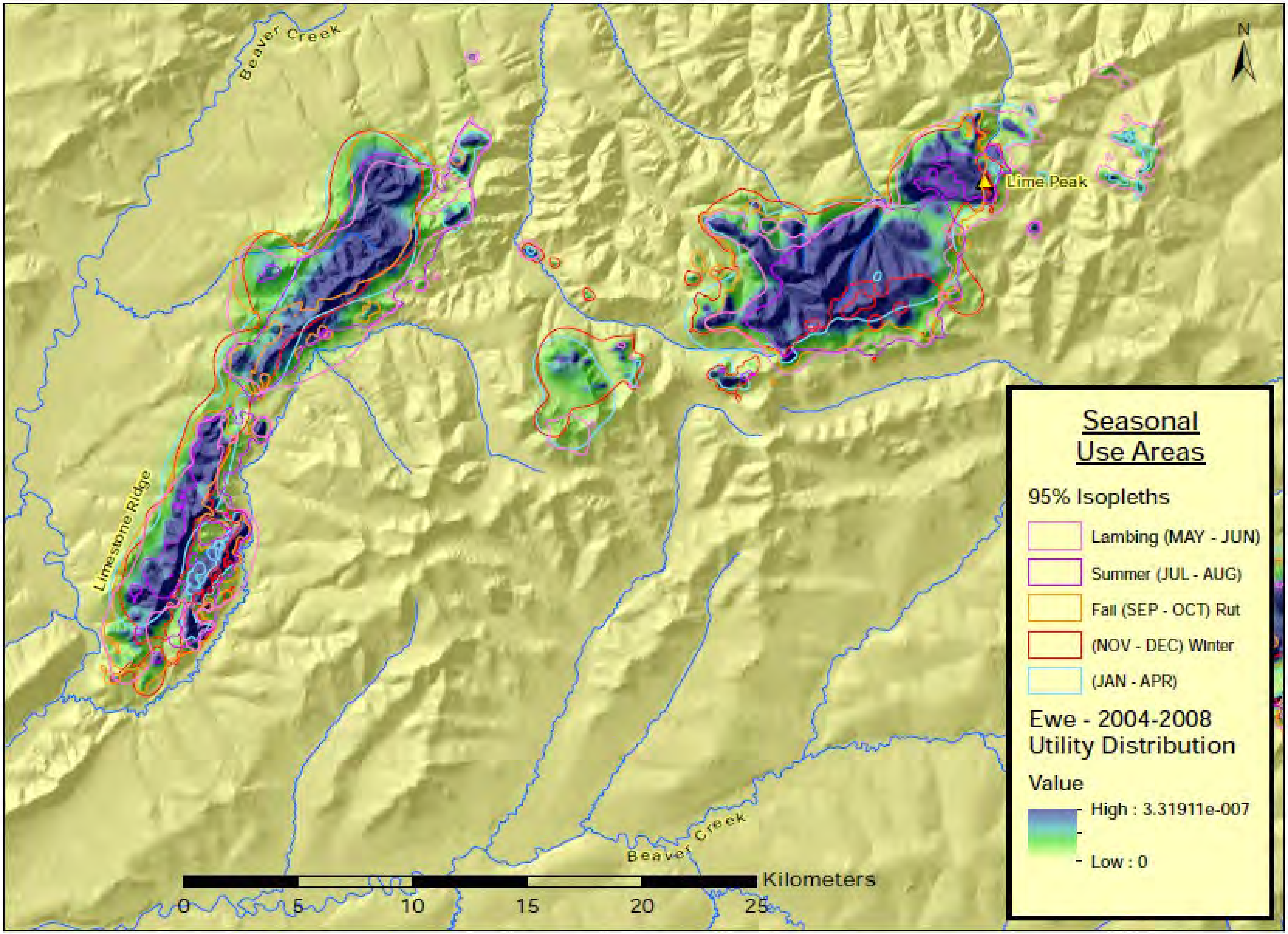
Appendix E2. (Maps) Mean BBMM isopleth home range estimates at the 50 and 95 percentile for seasonal use areas of Dall's sheep sex and radio collar type in the White Mountains, Alaska, USA 2004-2008.



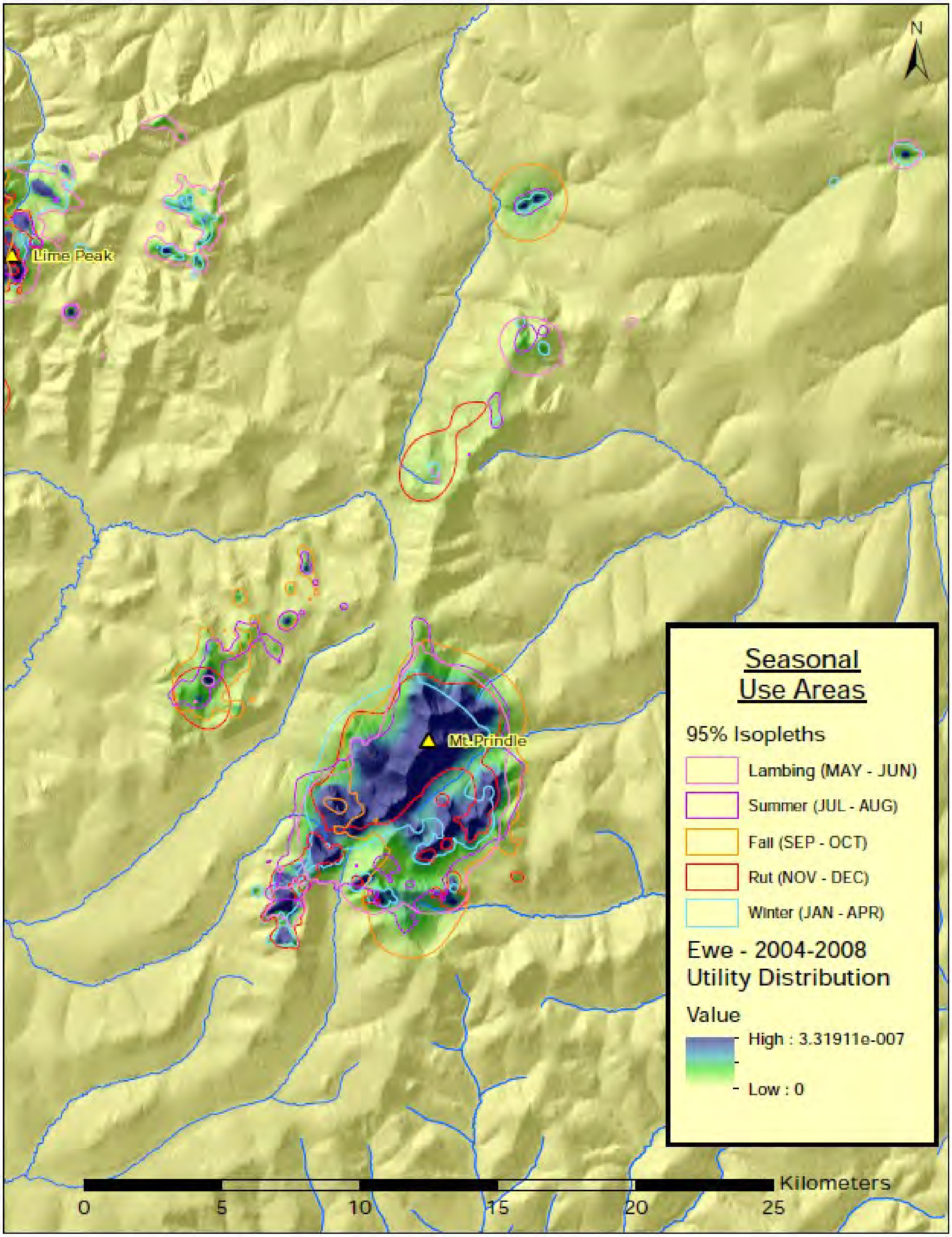
Ewes Seasonal Distribution, Mt. Schwatka & Victoria Mtn, 2004-2008



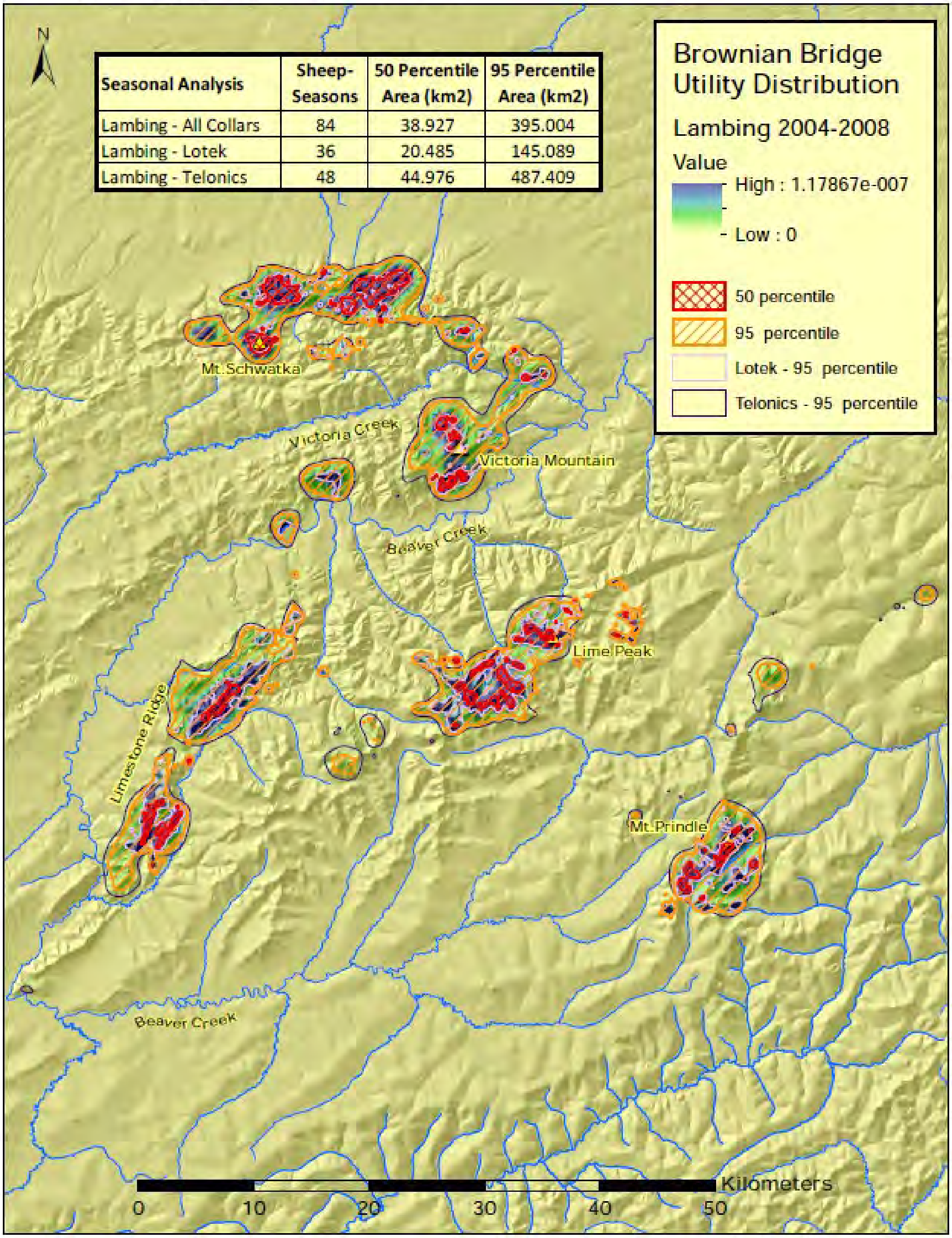
Ewes Seasonal Distribution, Lime Peak & Limestone Ridge, 2004-2008



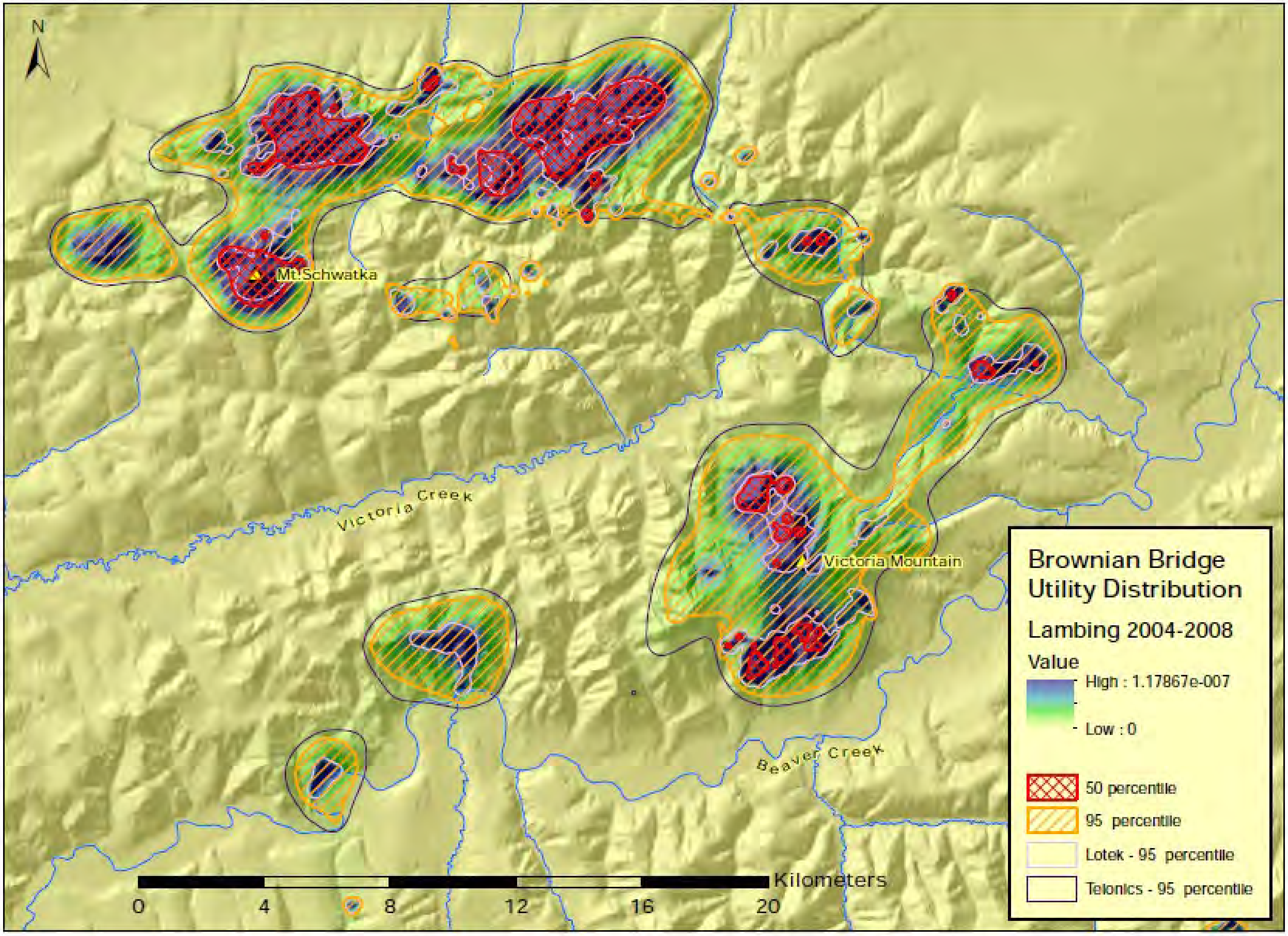
Ewes Seasonal Distribution, Mt Prindle, 2004-2008



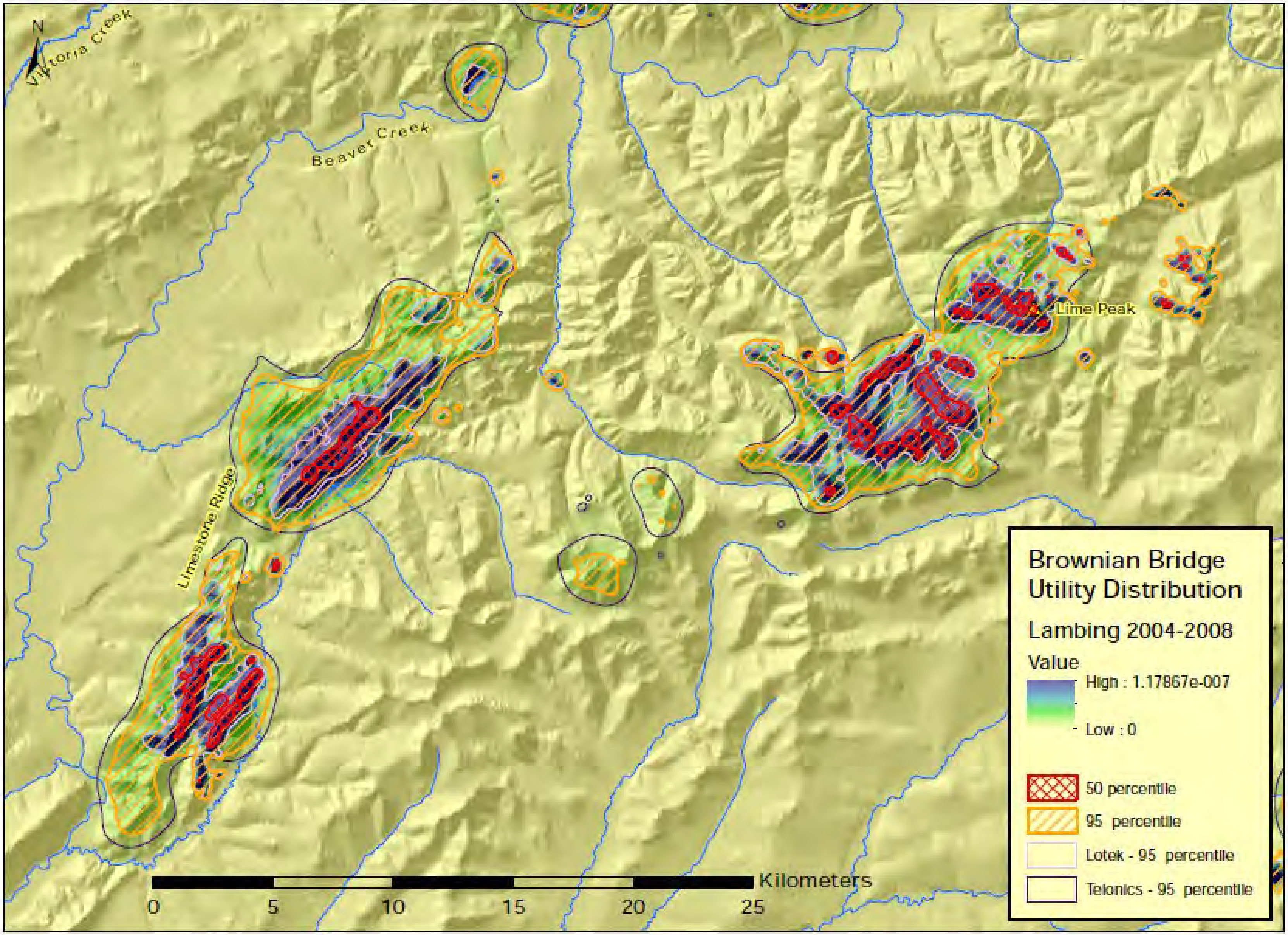
Lambing, Ewes **(39)**, May & June, 2004-2008



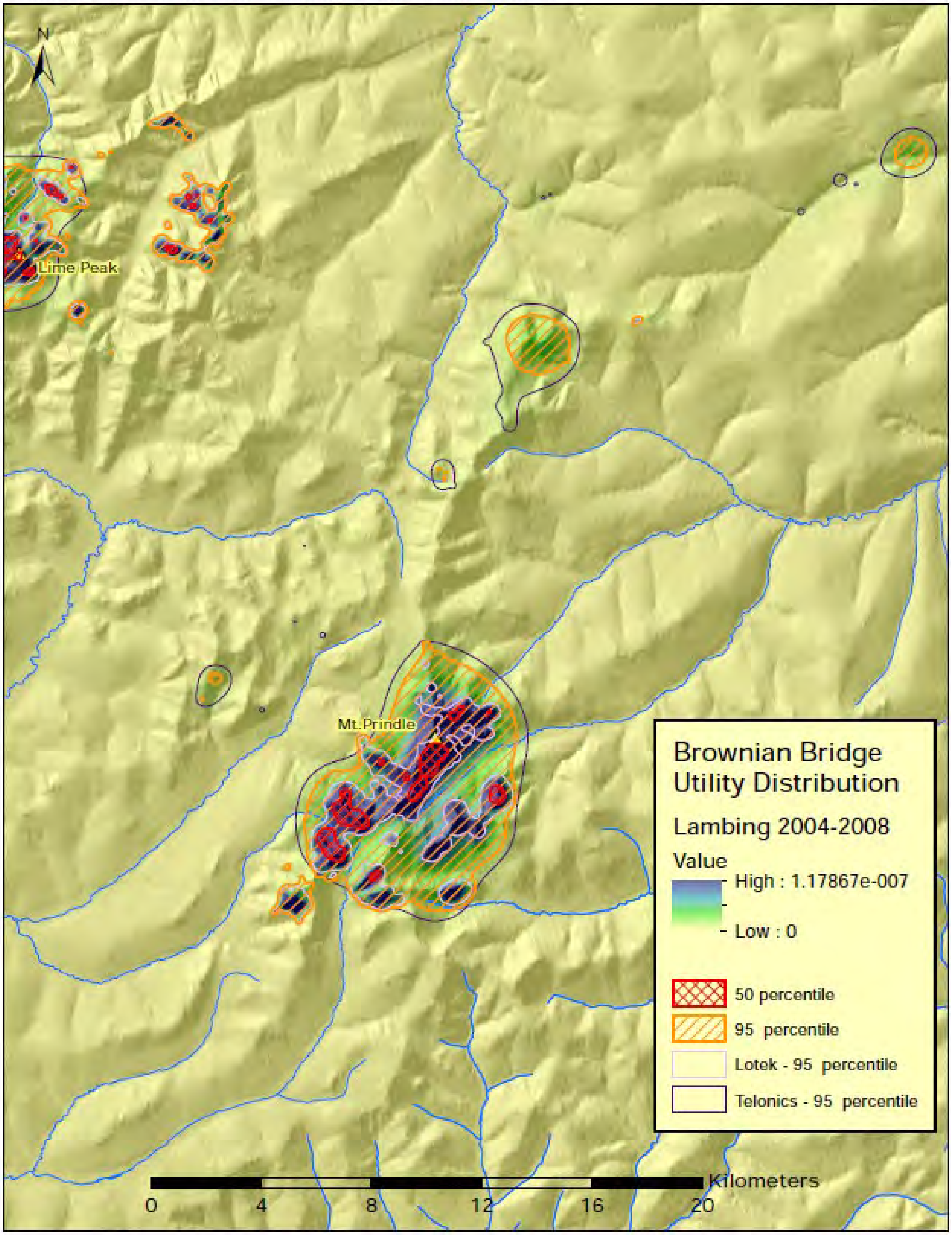
Lambing, Ewes, Mt. Schwatka & Victoria Mtn, May & June, 2004-2008



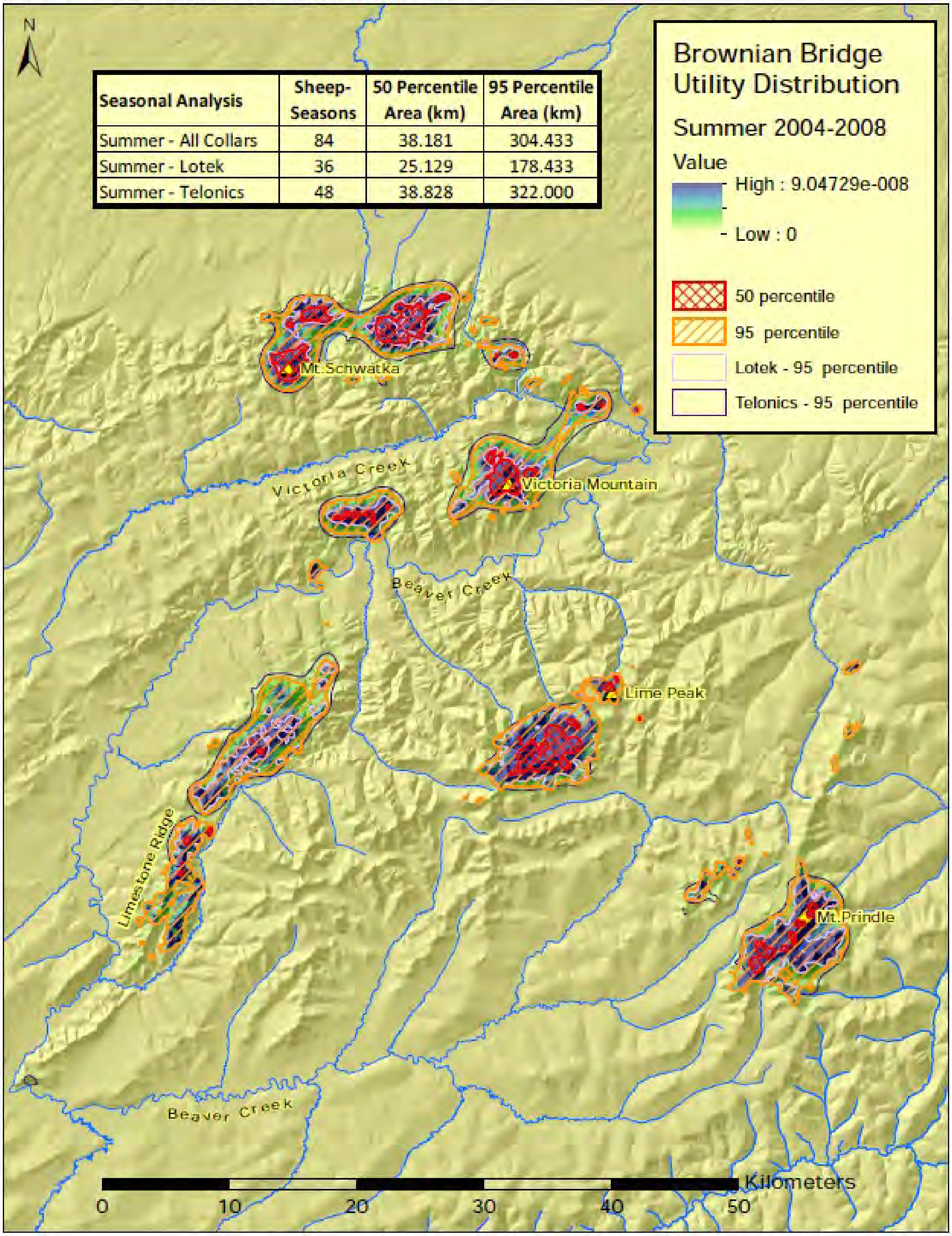
Lambing, Ewes, Lime Peak & Limestone Ridge, May & June, 2004-2008



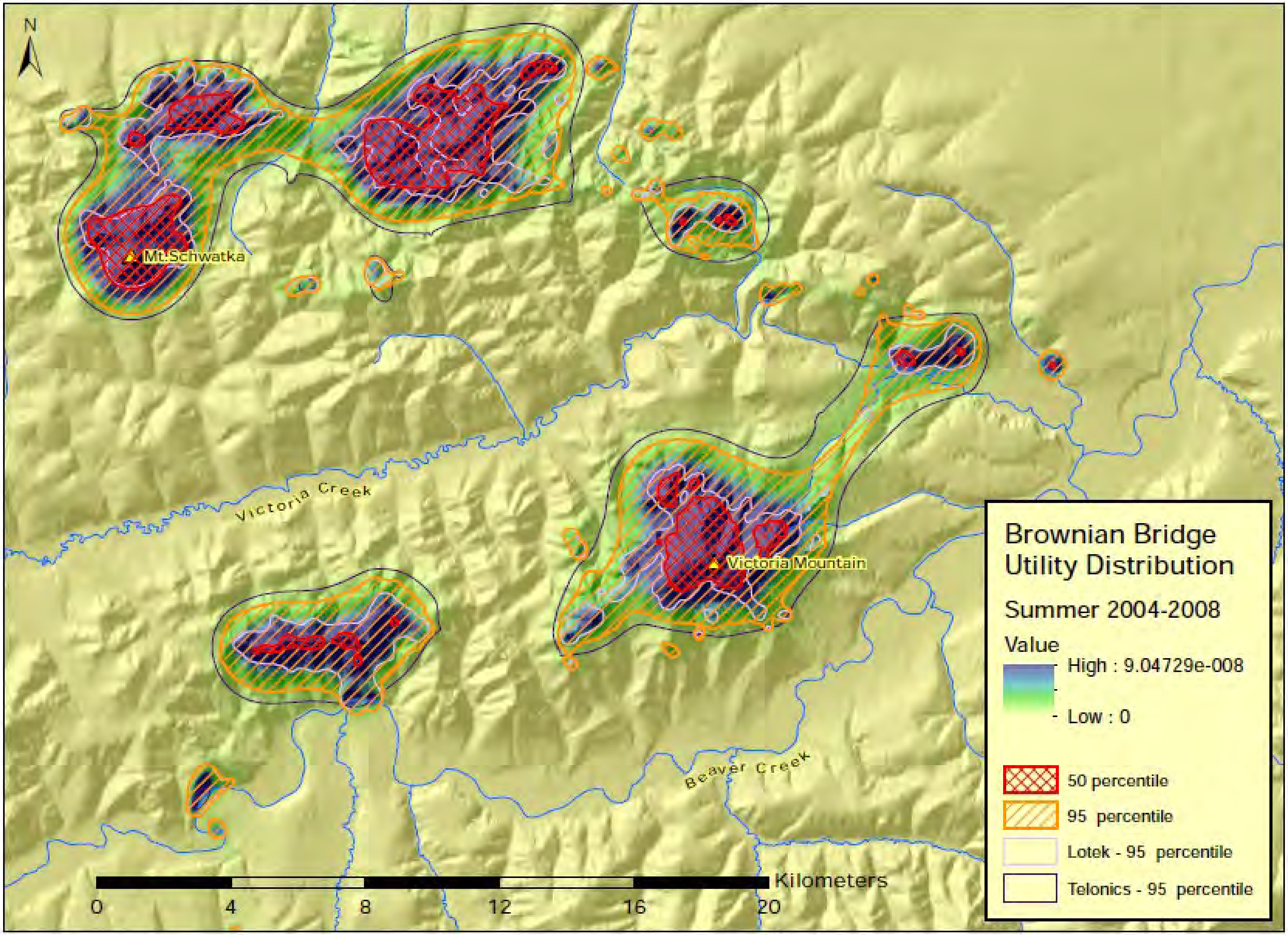
Lambing, Ewes, Mt. Prindle, May & June, 2004-2008,



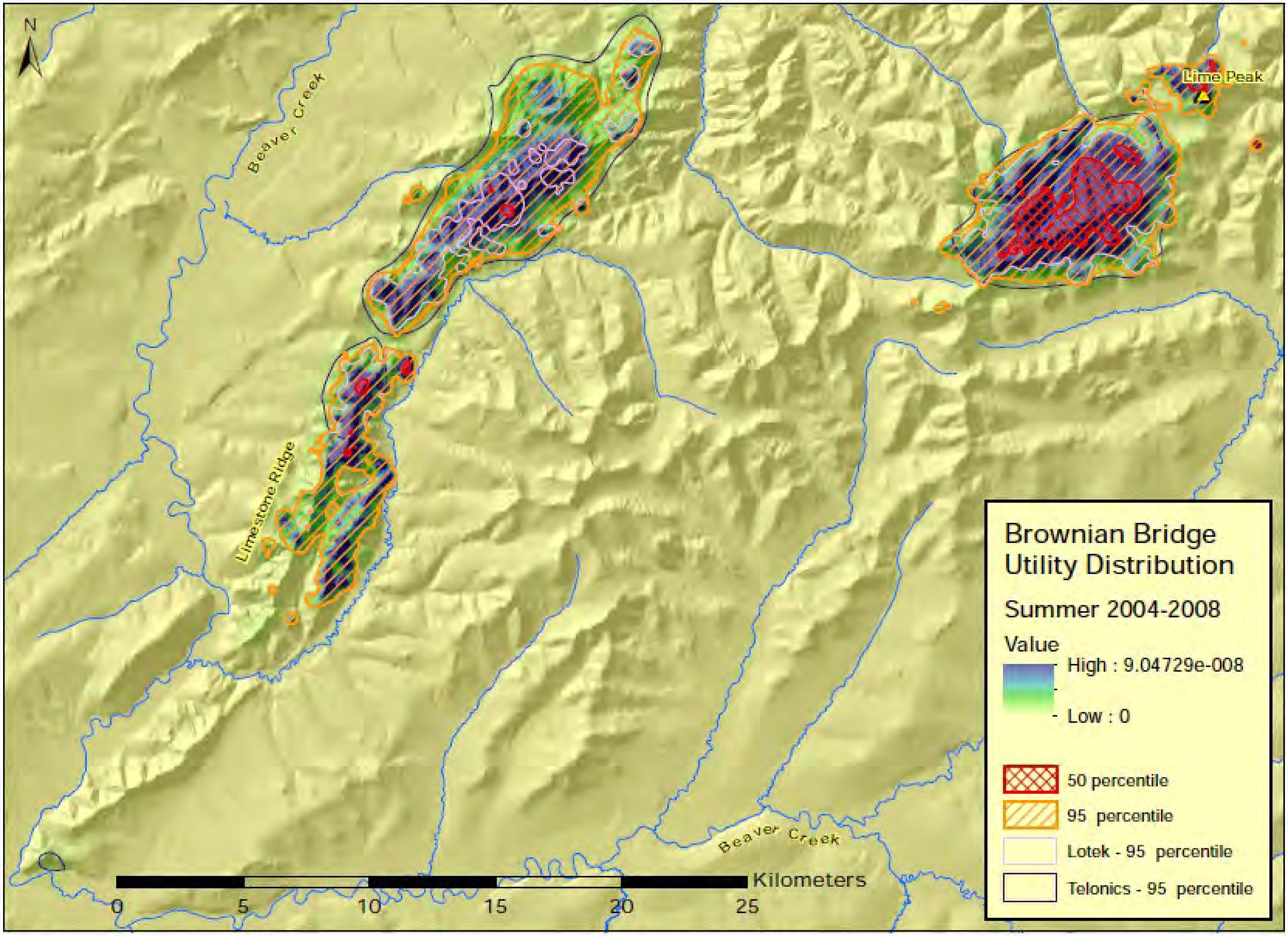
Summer, Ewes **(39)**, July & August, 2004-2008



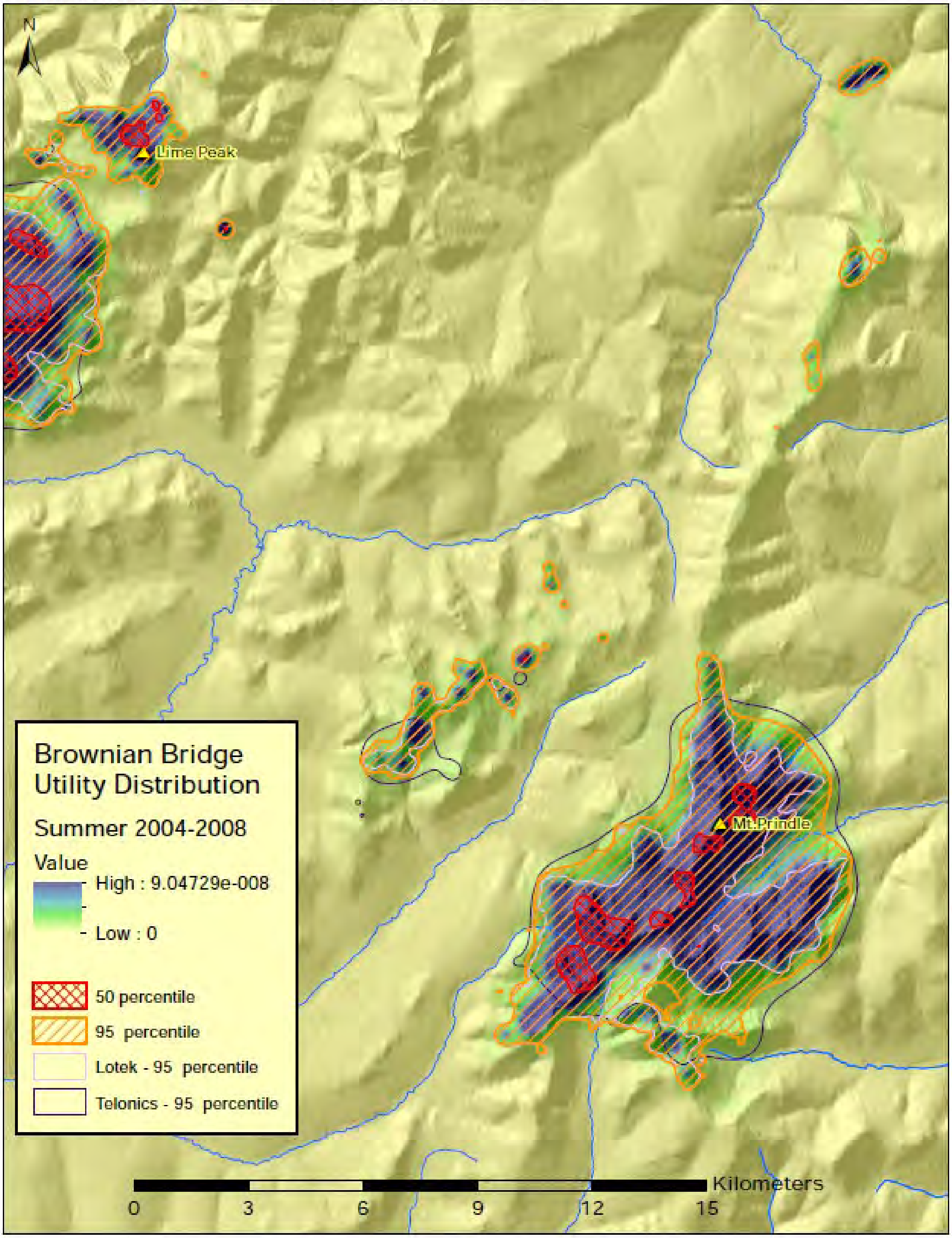
Summer, Ewes, Mt. Schatka & Victoria Mtn, July & August, 2004-2008



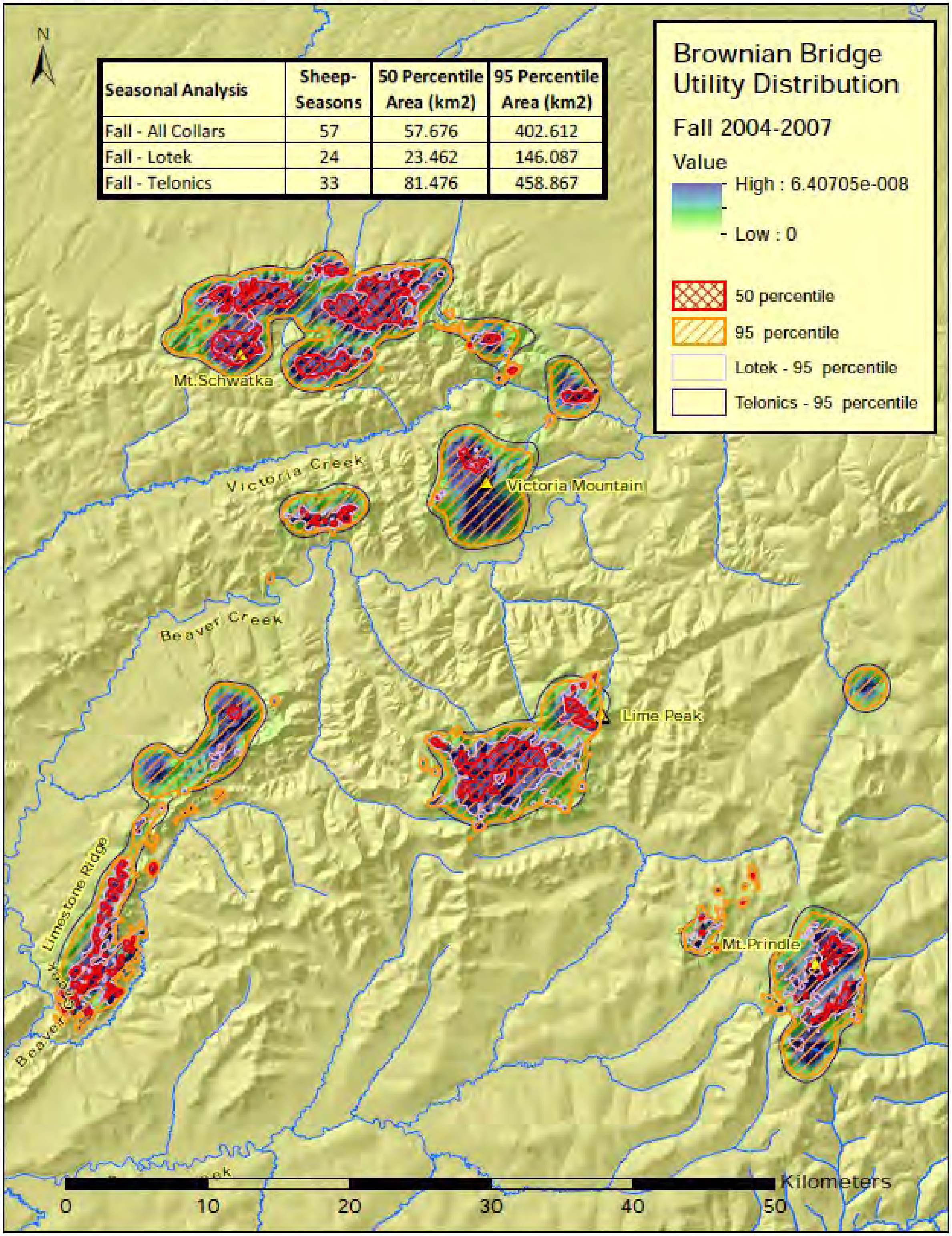
Summer, Ewes, Lime Peak & Limestone Ridge, July & August, 2004-2008



Summer, Ewes, Mt. Prindle, July & August, 2004-2008

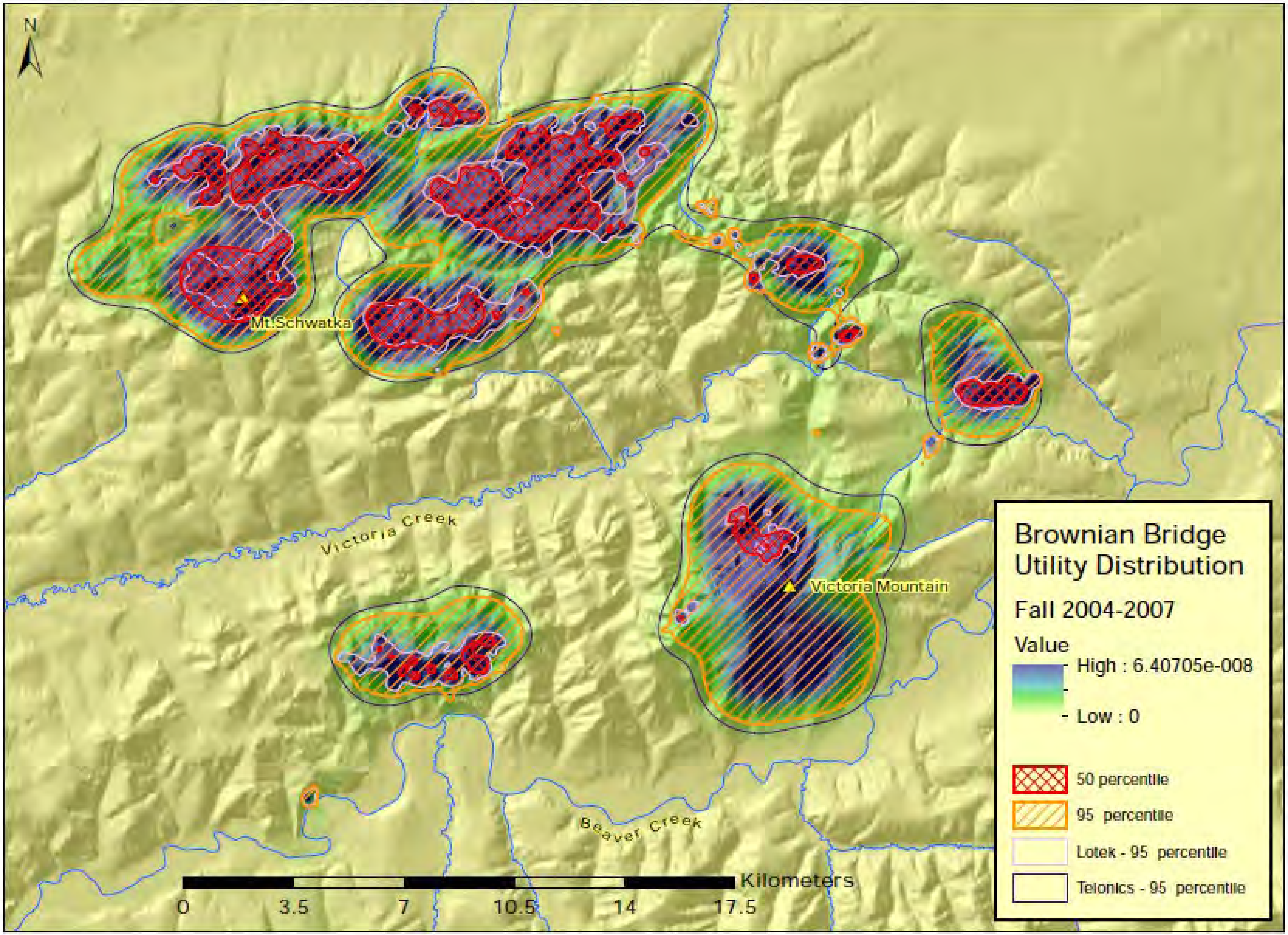


Fall, Ewes **(37)**, September & October, 2004-2007

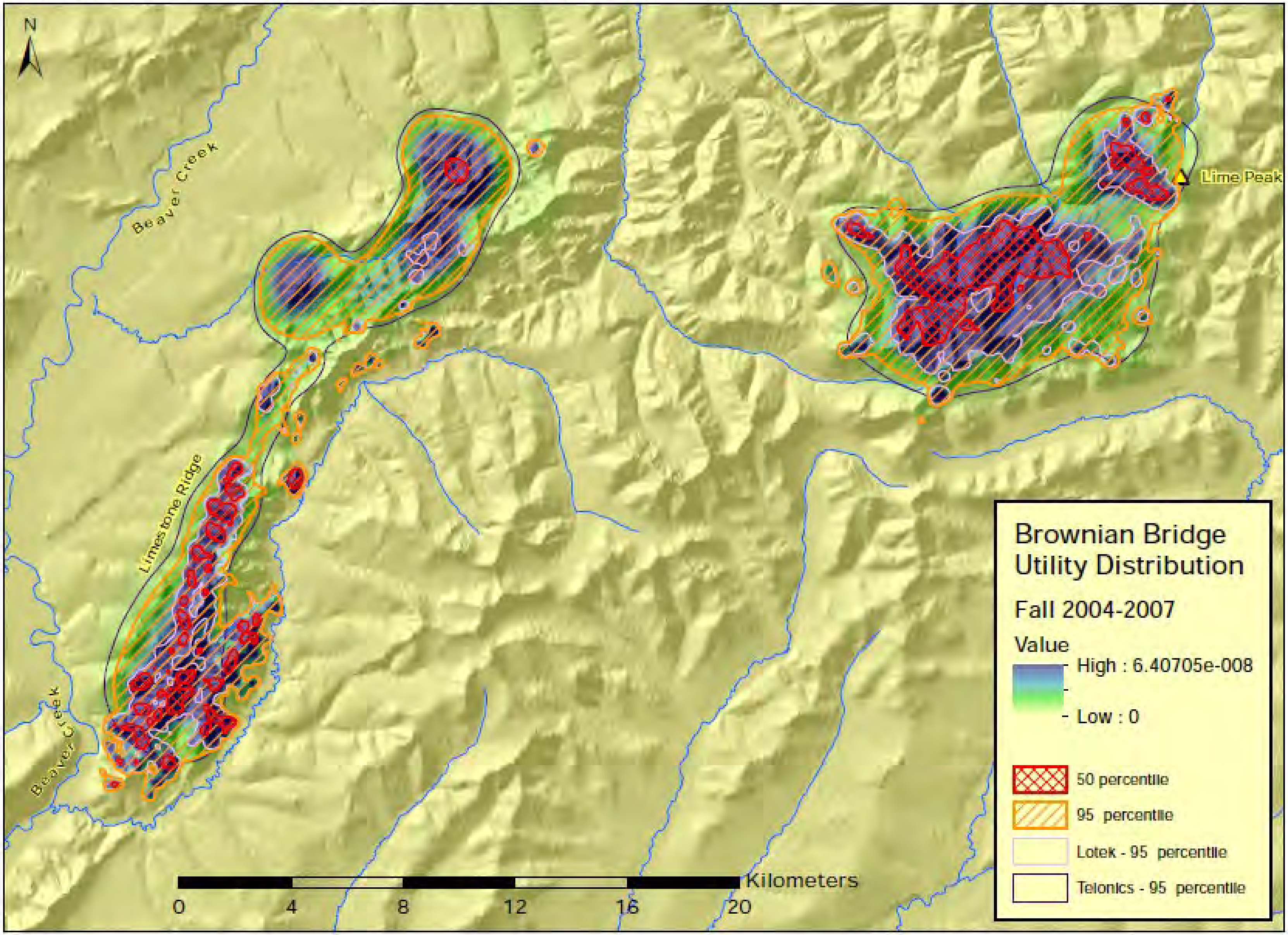


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km2)	95 Percentile Area (km2)
Fall - All Collars	57	57.676	402.612
Fall - Lotek	24	23.462	146.087
Fall - Telonics	33	81.476	458.867

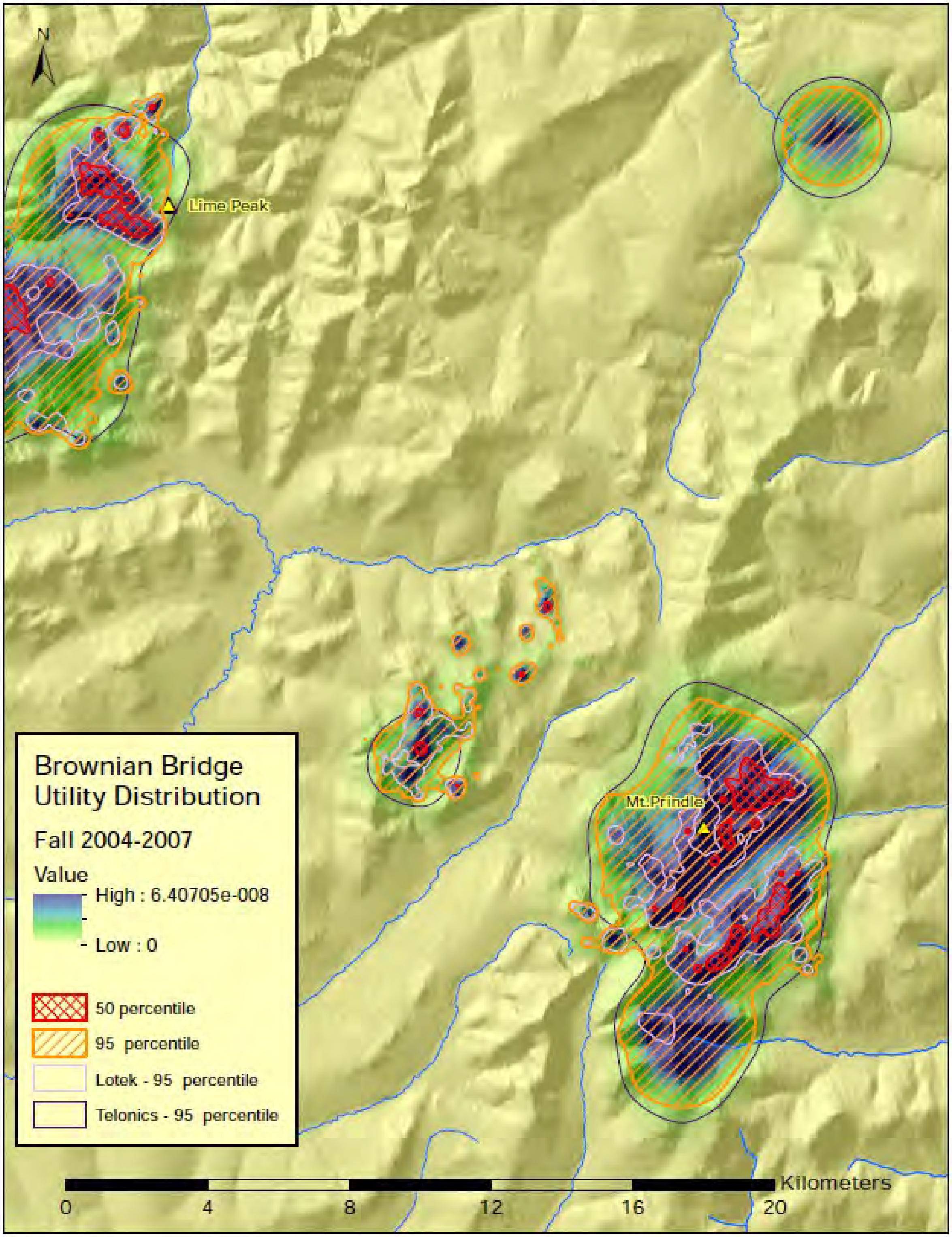
Fall, Ewes, Mt. Schwatka & Victoria Mtn, September & October, 2004-2007



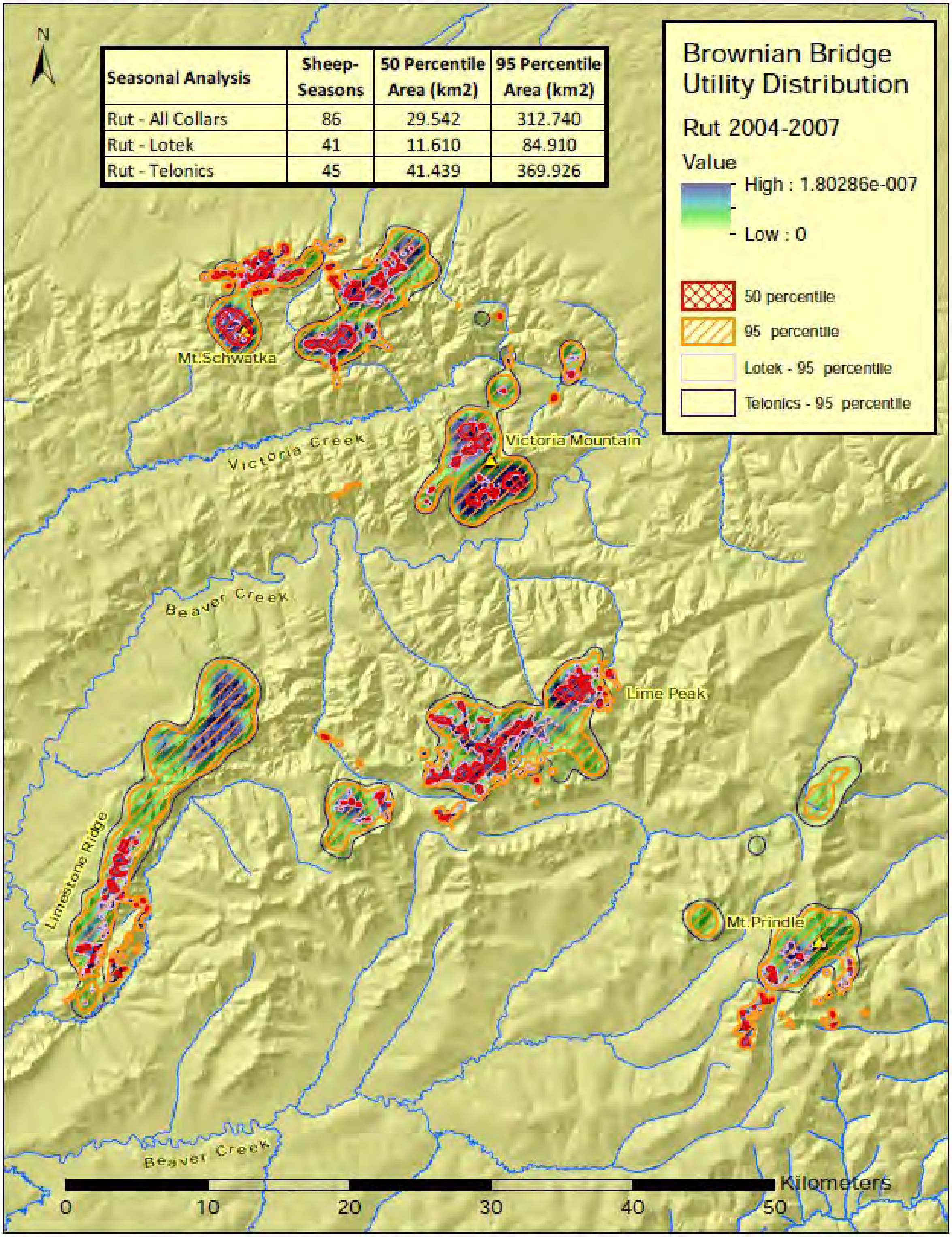
Fall, Ewes, Lime Peak & Limestone Ridge, September & October, 2004-2007



Fall, Ewes, Mt. Prindle, September & October, 2004-2007

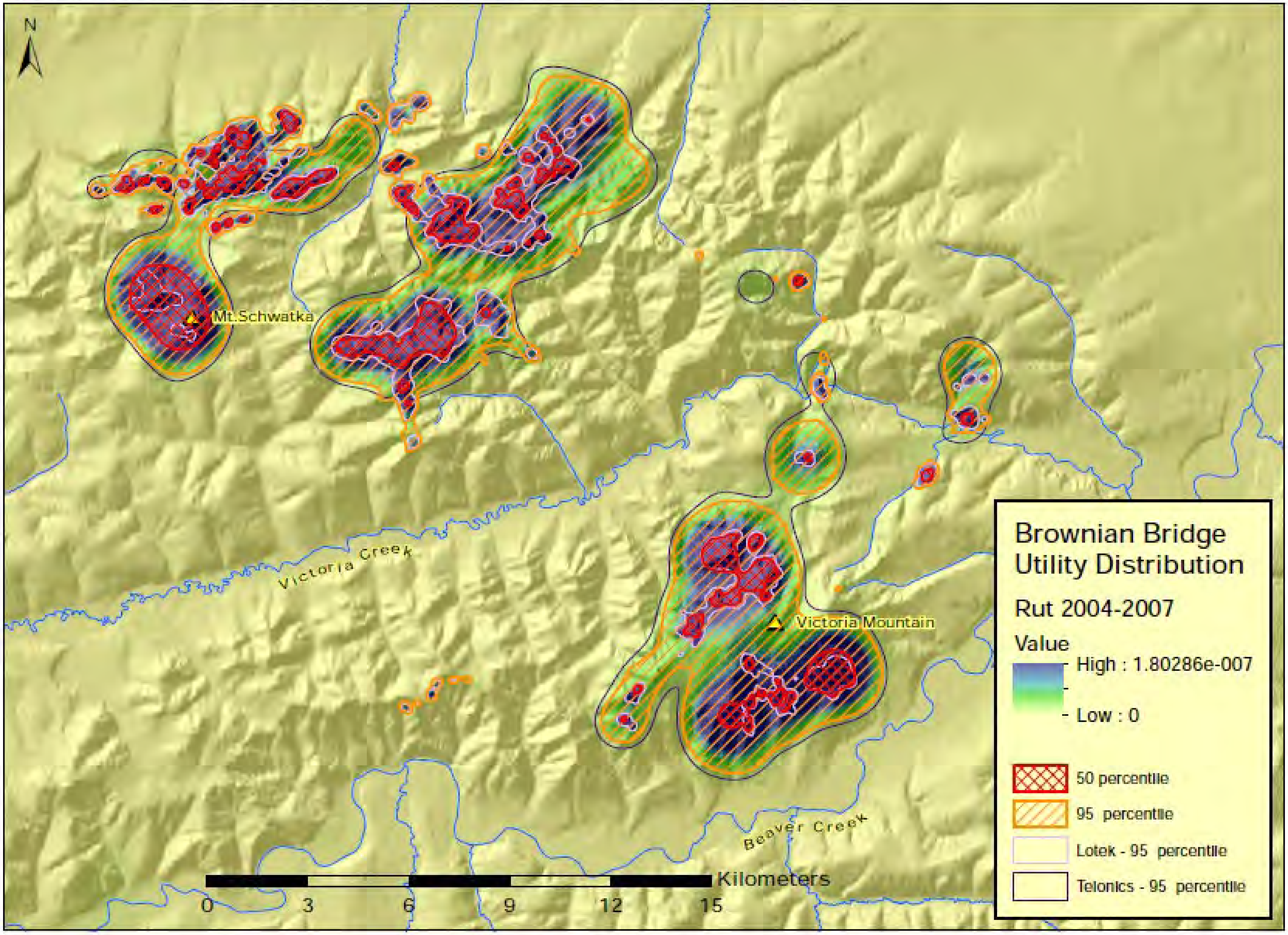


Rut, Ewes **(43)**, November & December, 2004-2007

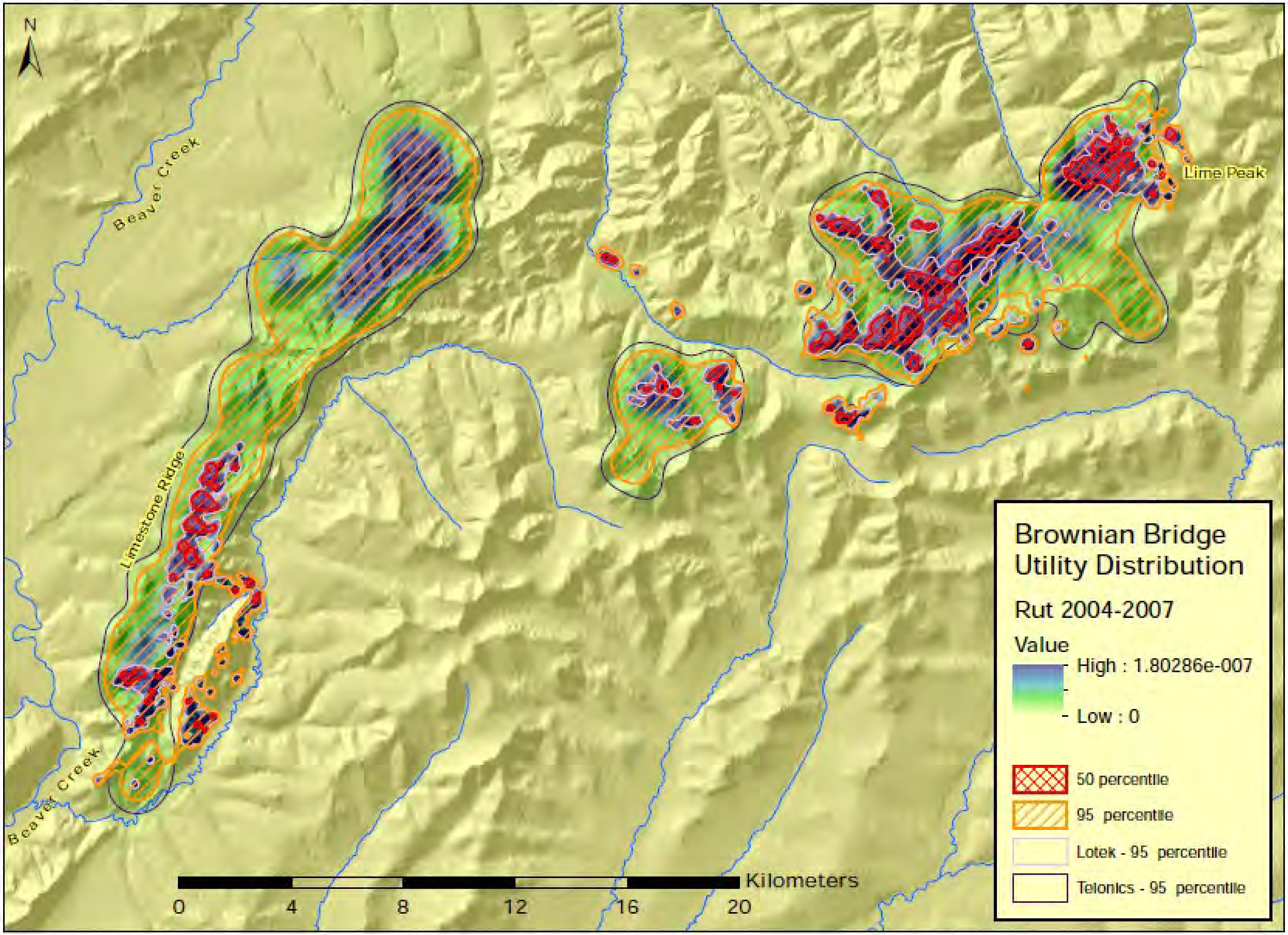


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km2)	95 Percentile Area (km2)
Rut - All Collars	86	29.542	312.740
Rut - Lotek	41	11.610	84.910
Rut - Telonics	45	41.439	369.926

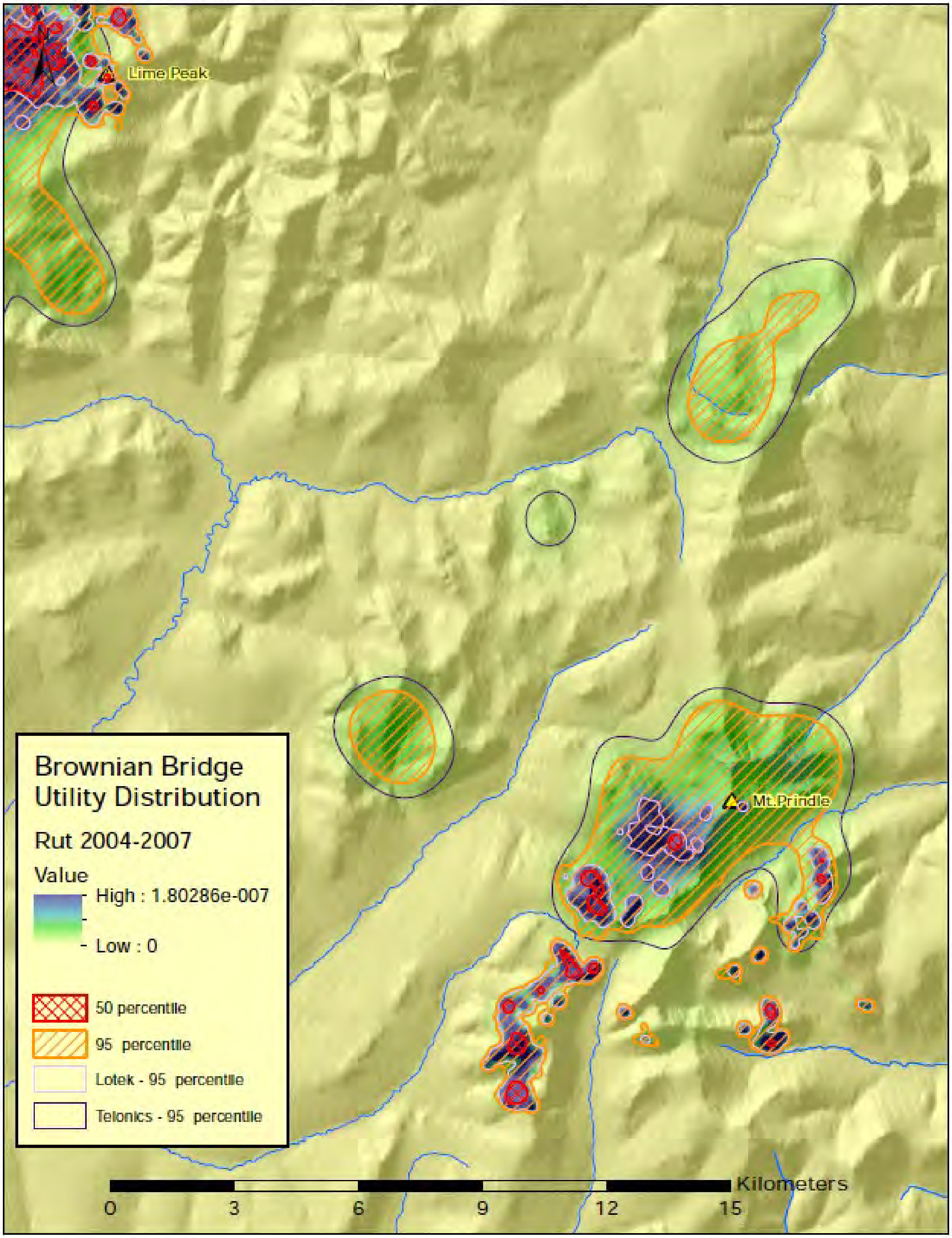
Rut, Ewes, Mt. Schwatka & Victoria Mtn, November & December, 2004-2007



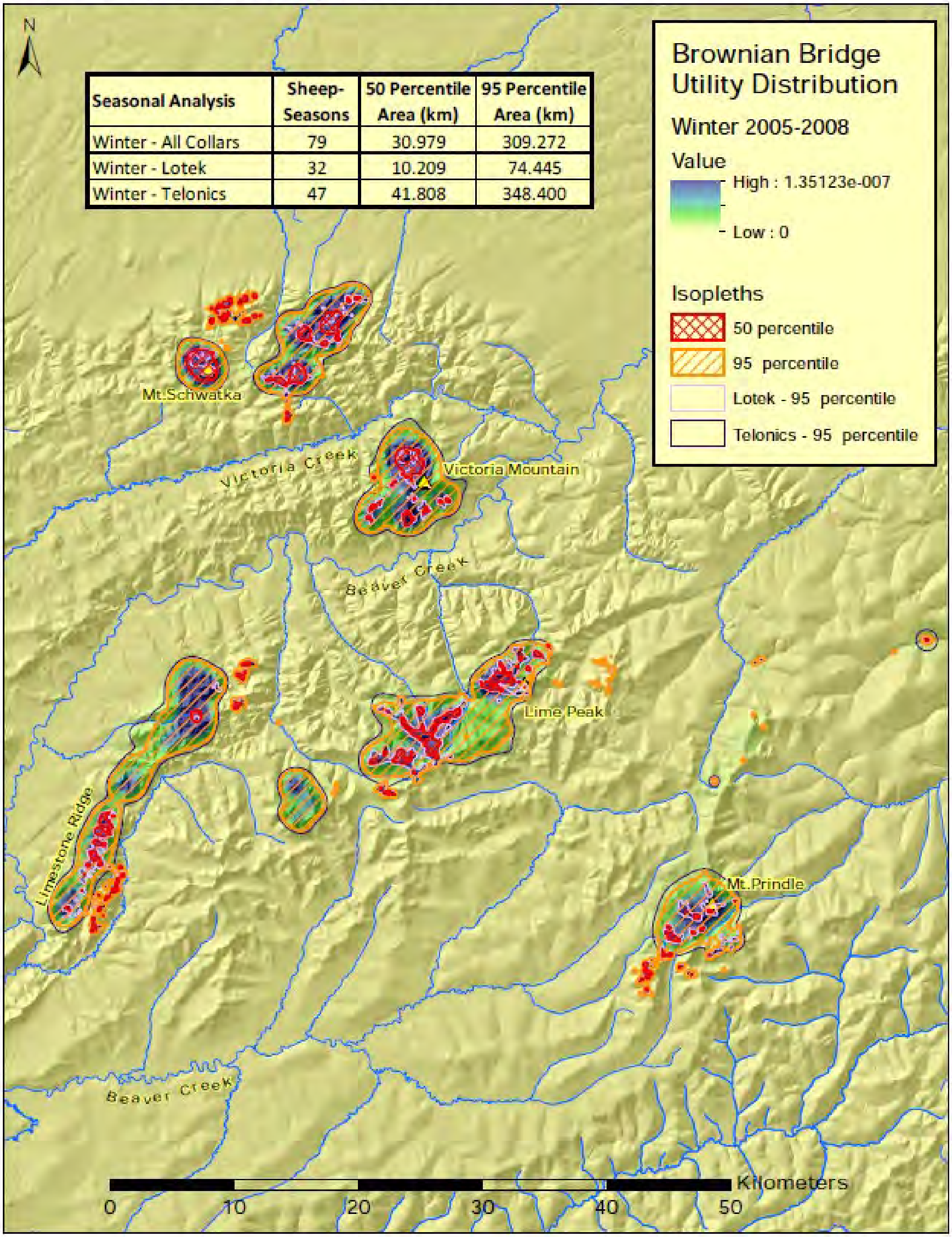
Rut, Ewes, Lime Peak & Limestone Ridge, November & December, 2004-2007



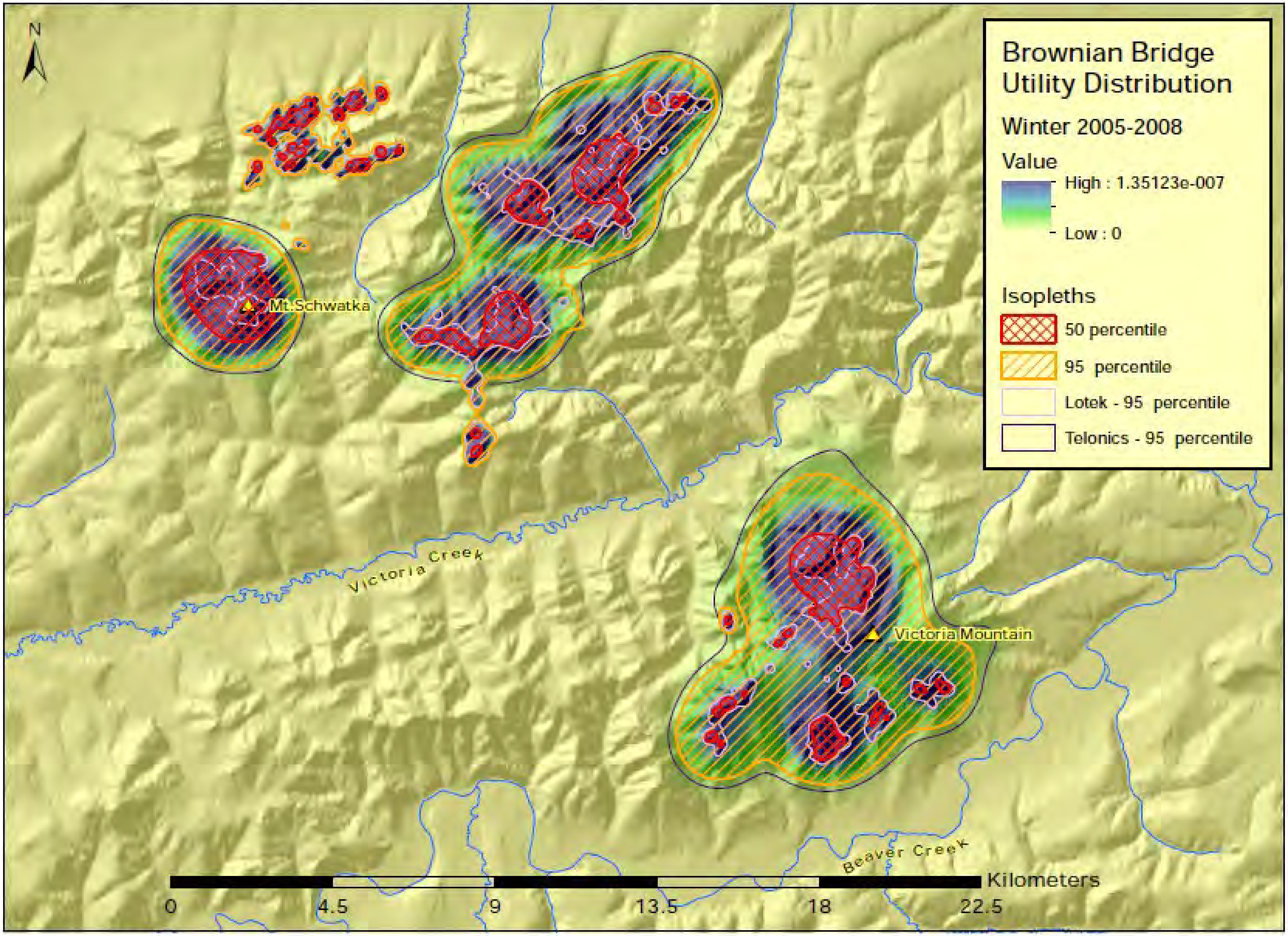
Rut, Ewes, Mt. Prindle, November & December, 2004-2007



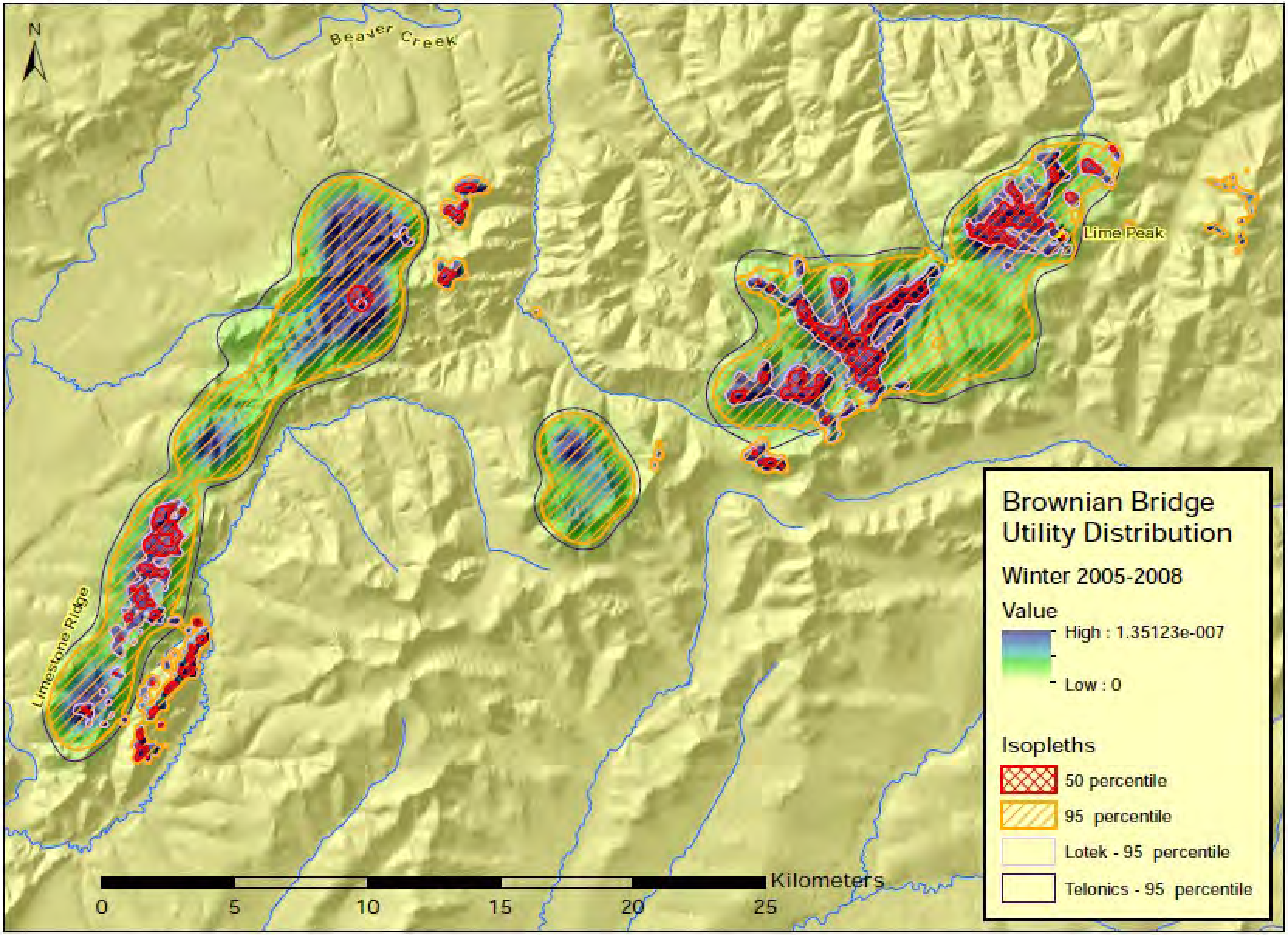
Winter, Ewes **(41)**, January - April, 2005-2008



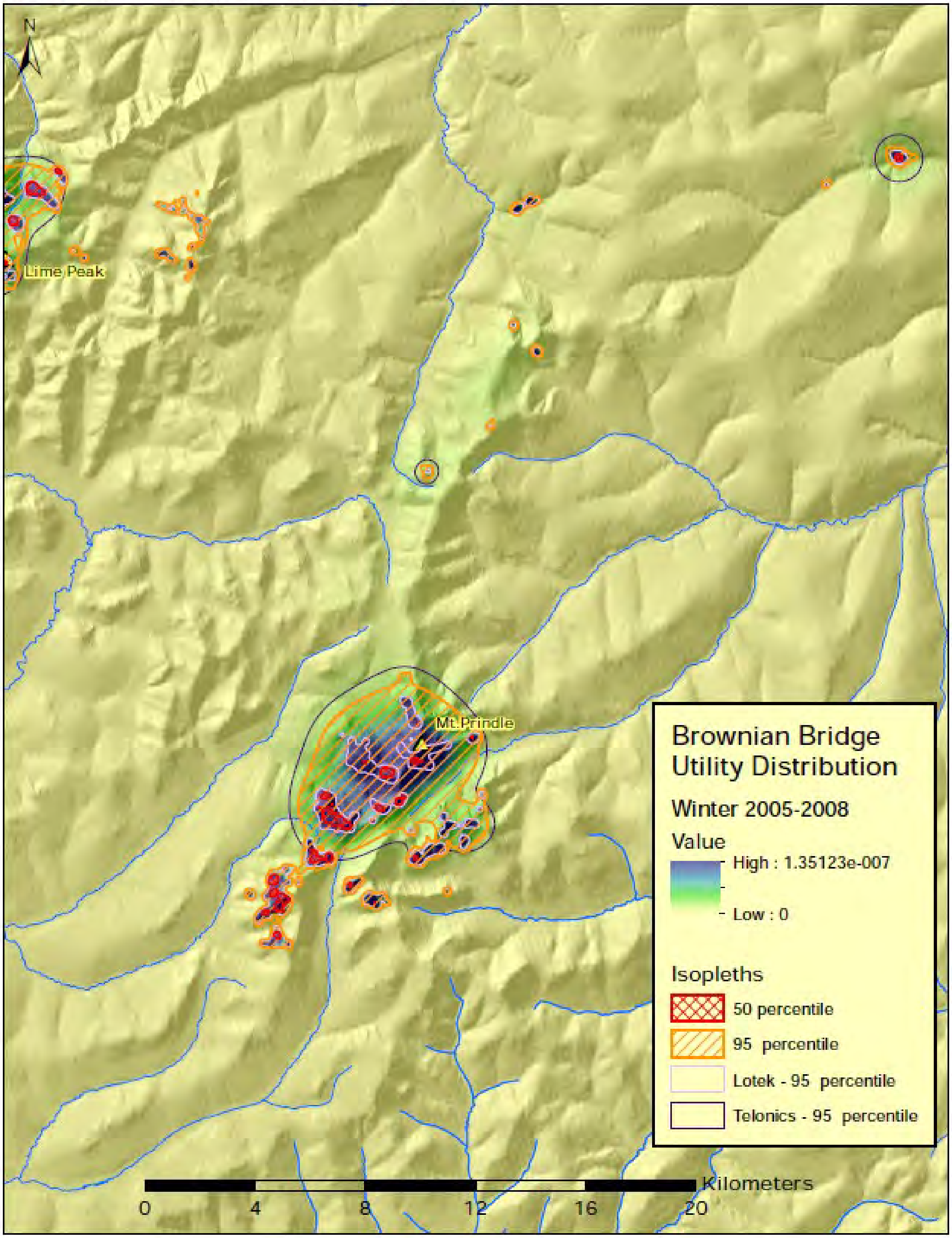
Winter, Ewes, Mt. Schwatka & Victoria Mtn, January - April, 2005-2008



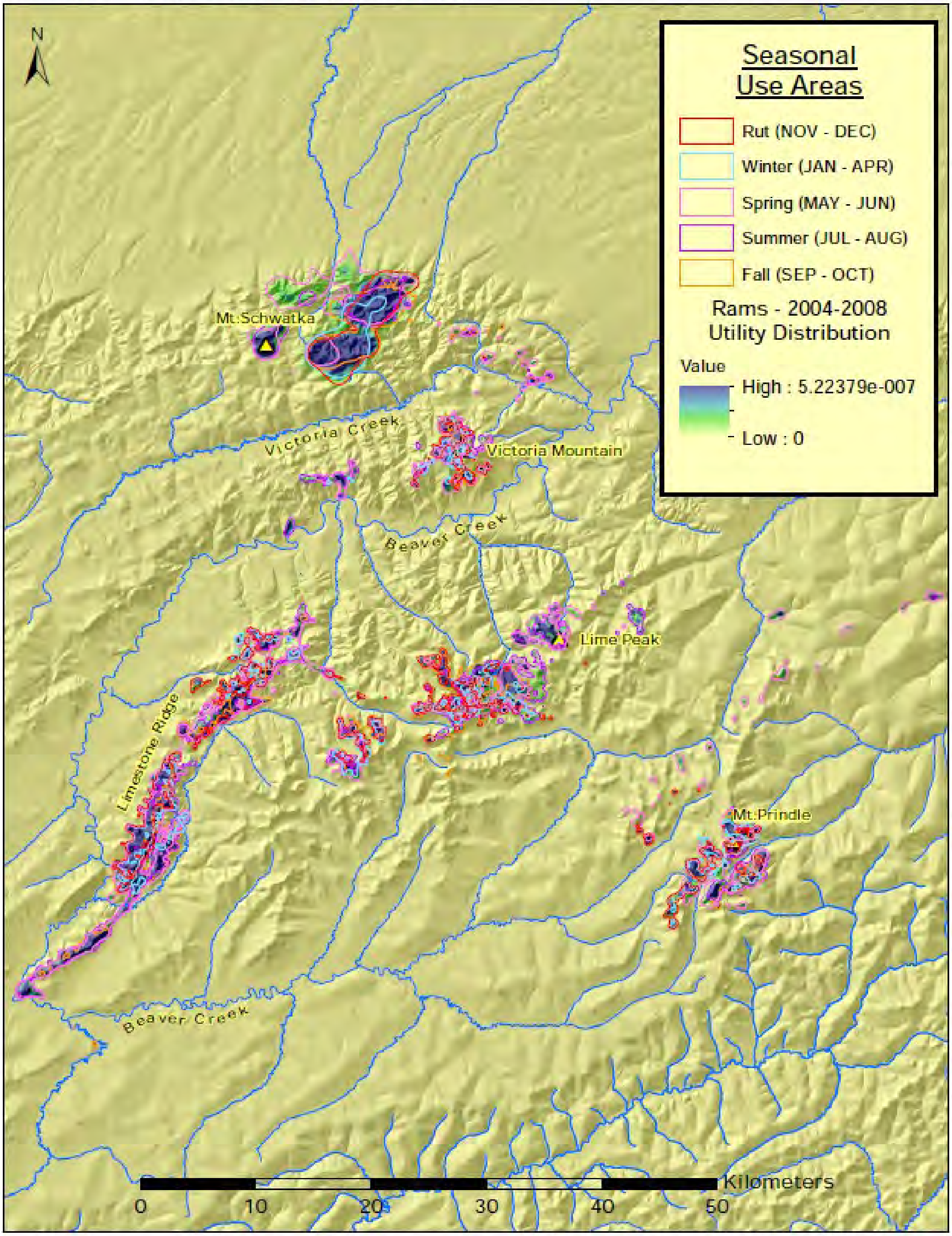
Winter, Ewes, Lime Peak & Limestone Ridge, January - April, 2005-2008



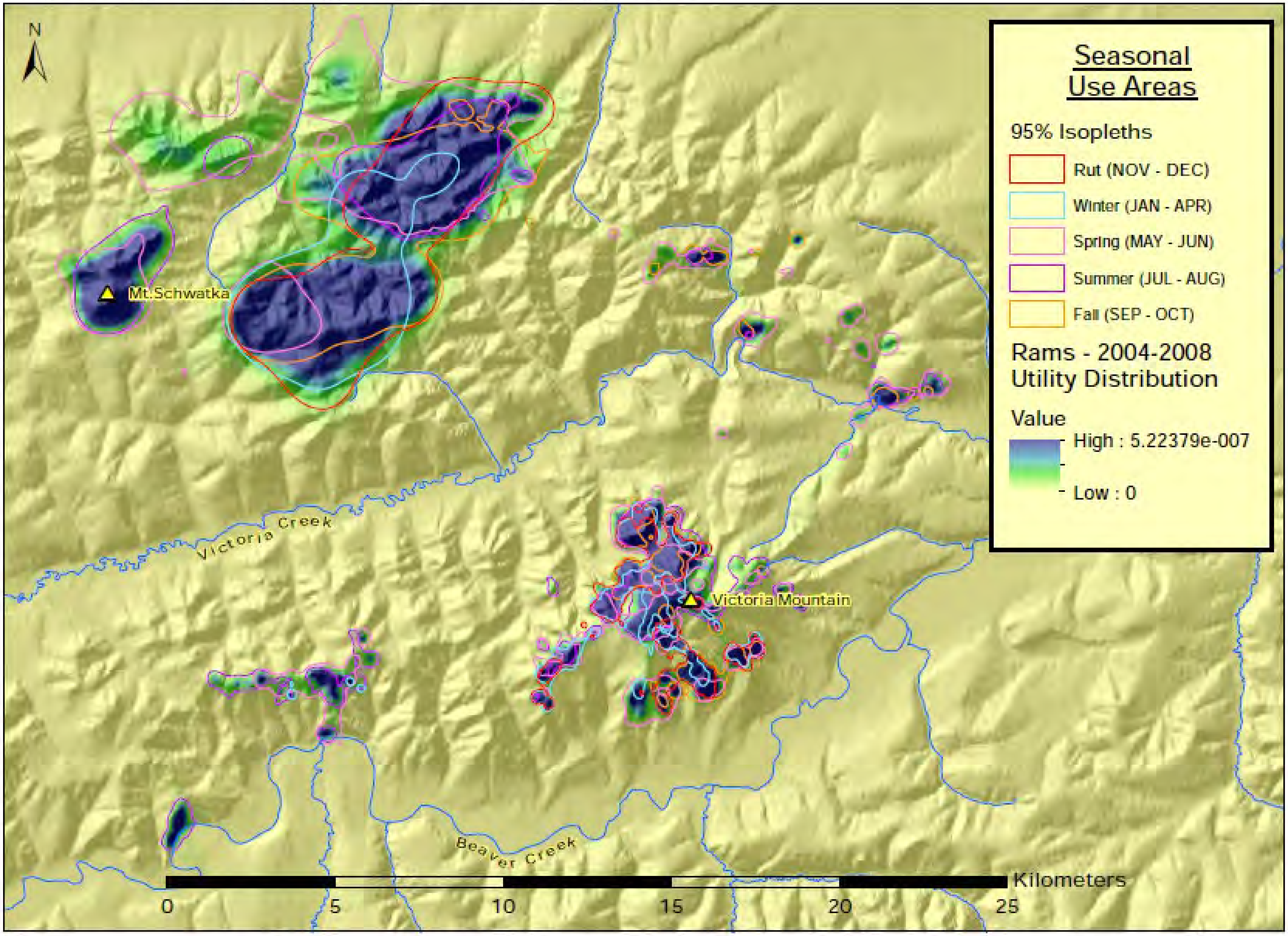
Winter, Ewes, Mt. Prindle January - April, 2005-2008



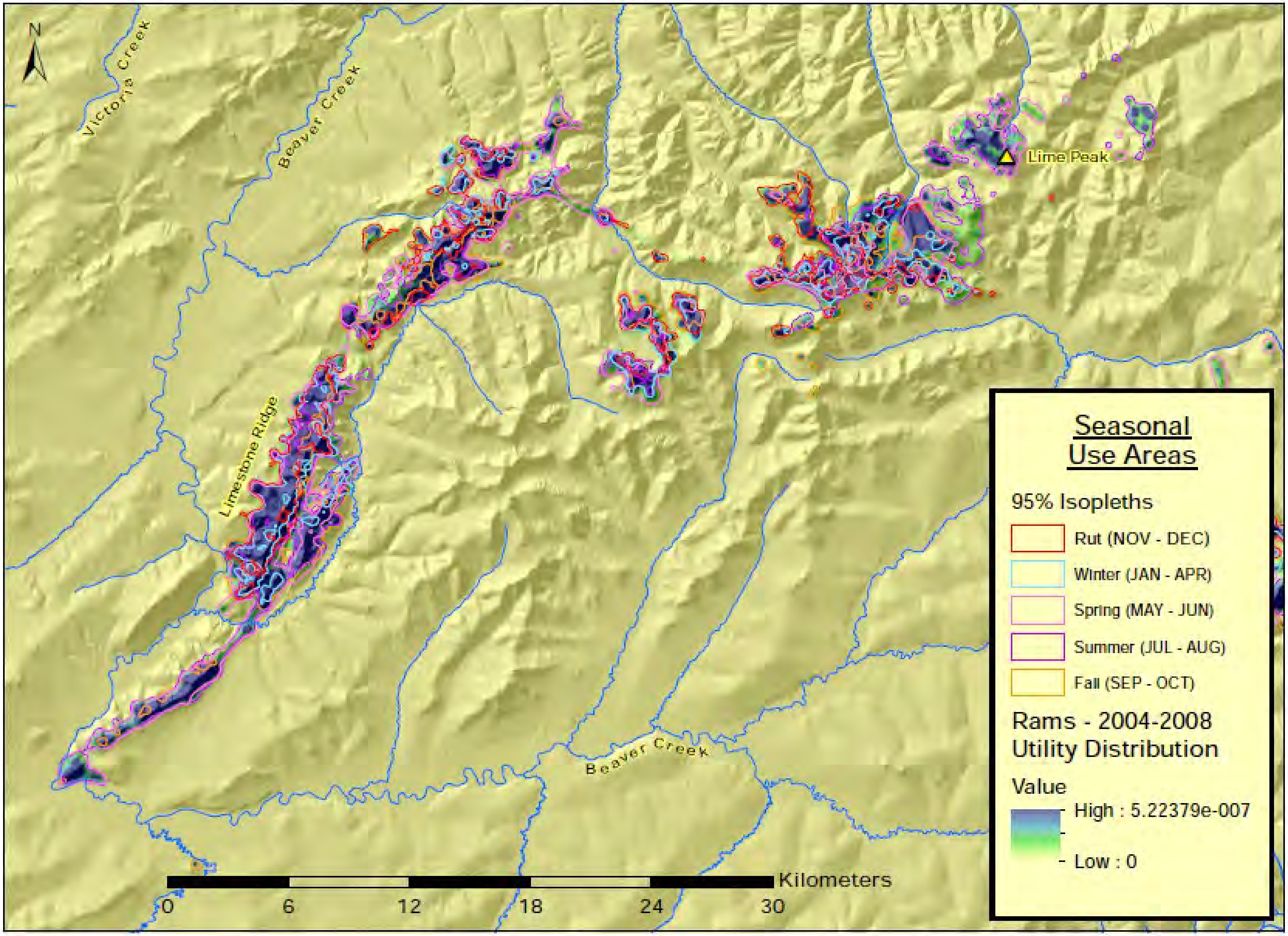
Rams (13), Seasonal Distribution, 2004-2008



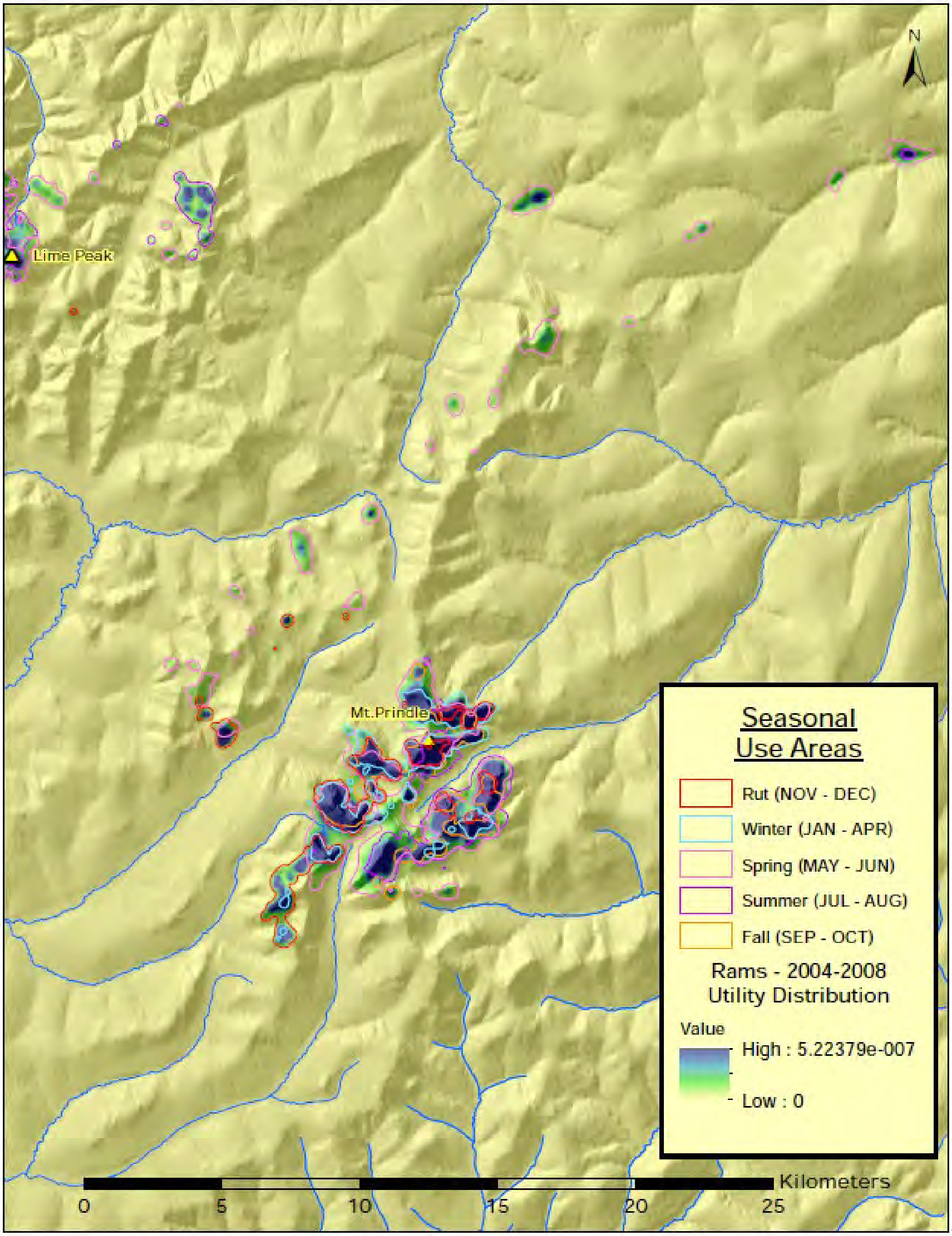
Rams Seasonal Distribution, Mt. Schwatka & Victoria Mtn, 2004-2008



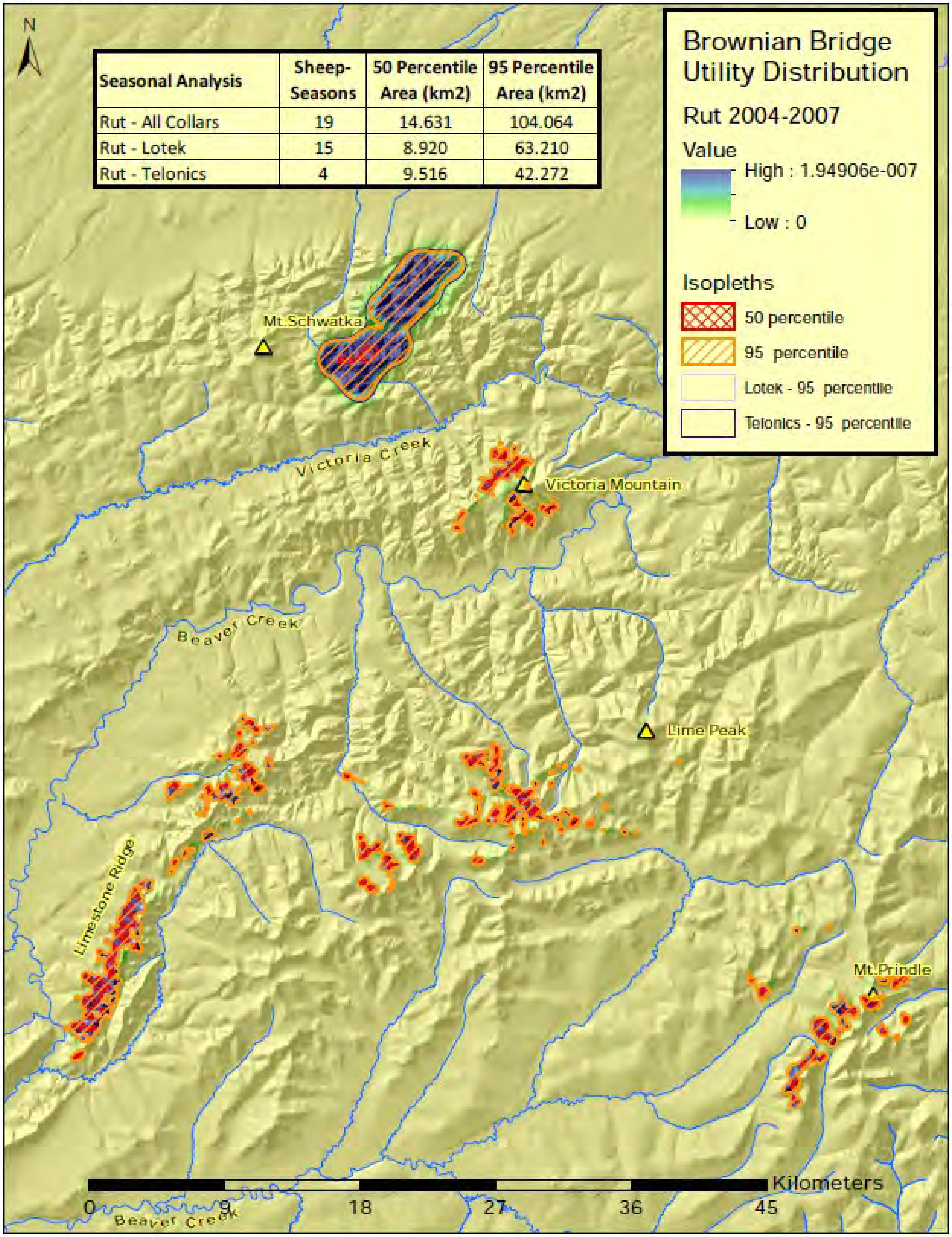
Rams Seasonal Distribution, Lime Peak & Limestone Ridge, 2004-2008



Rams Seasonal Distribution, Mt Prindle, 2004-2008

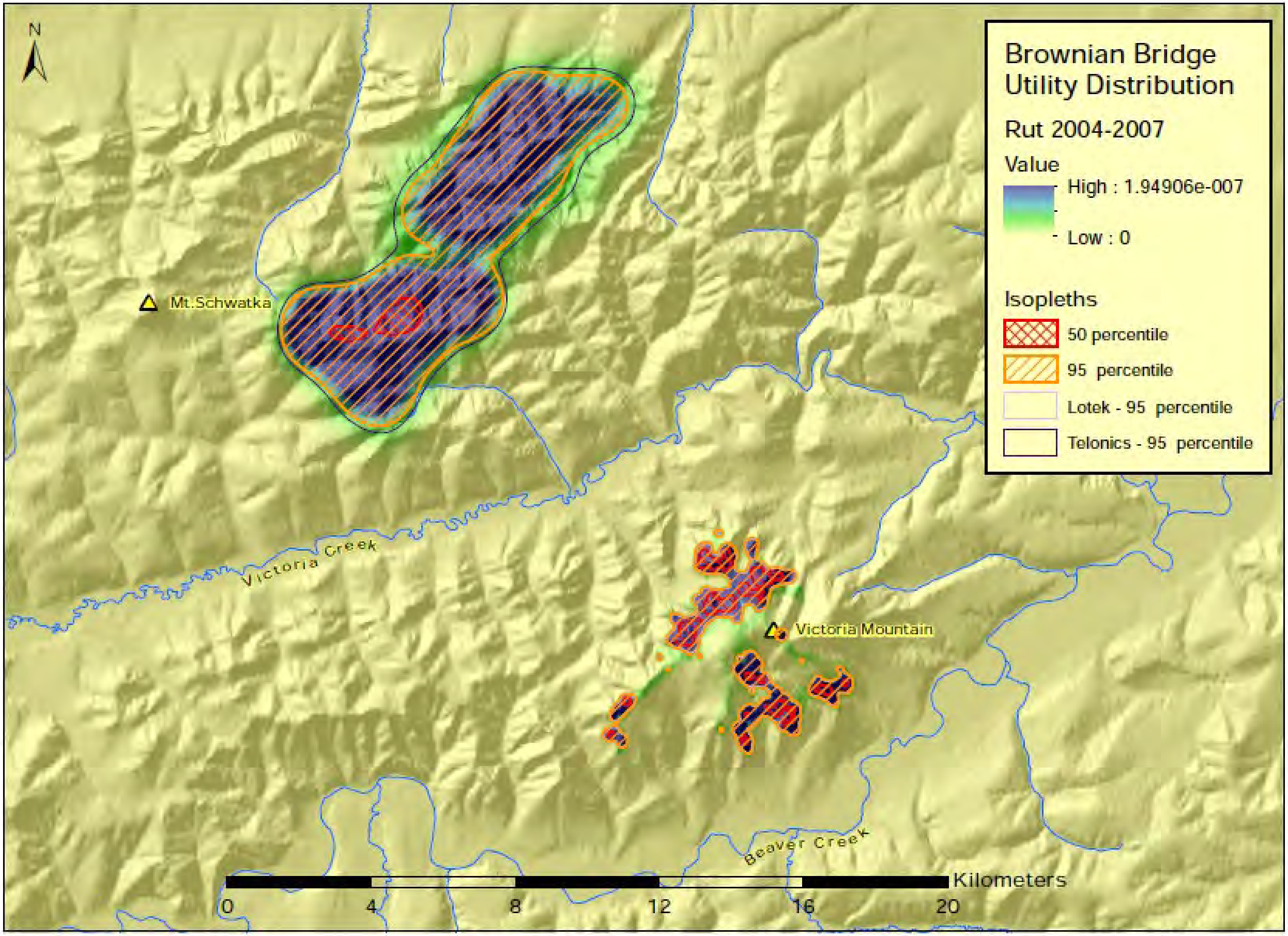


Rut, Rams (12), November - December, 2004-2007

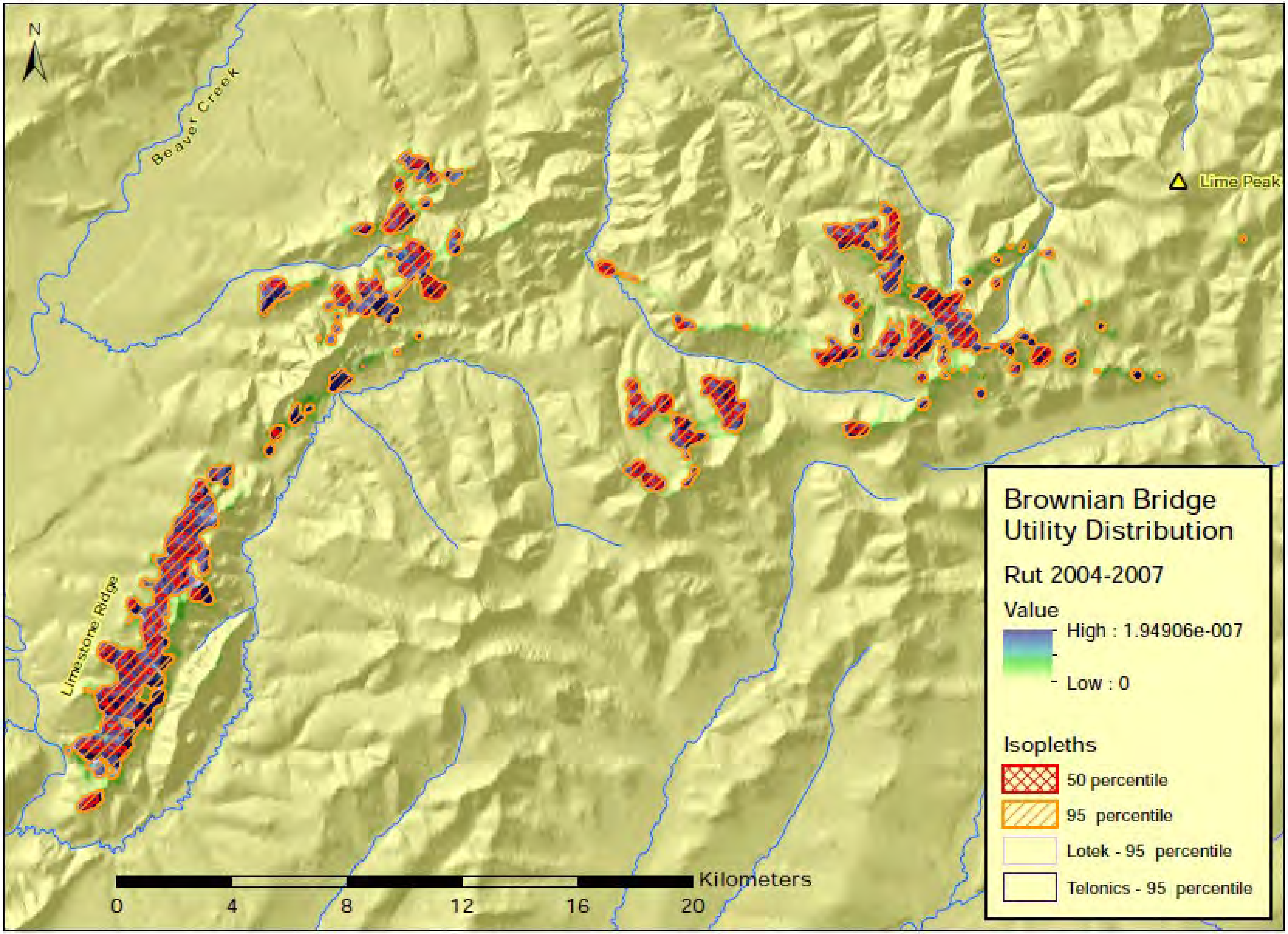


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km2)	95 Percentile Area (km2)
Rut - All Collars	19	14.631	104.064
Rut - Lotek	15	8.920	63.210
Rut - Telonics	4	9.516	42.272

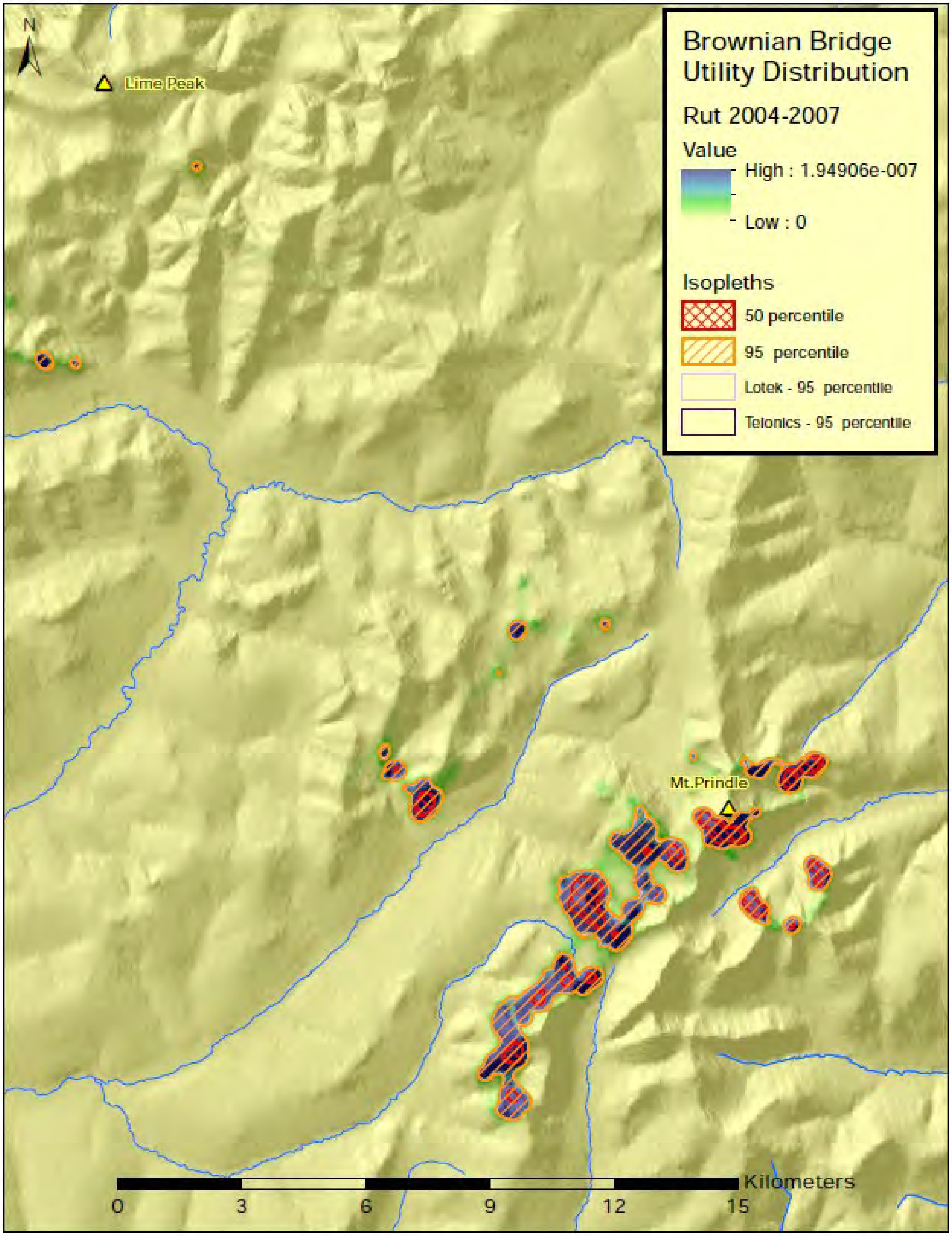
Rut, Rams, Mt. Schwatka & Victoria Mtn, November - December, 2004-2007



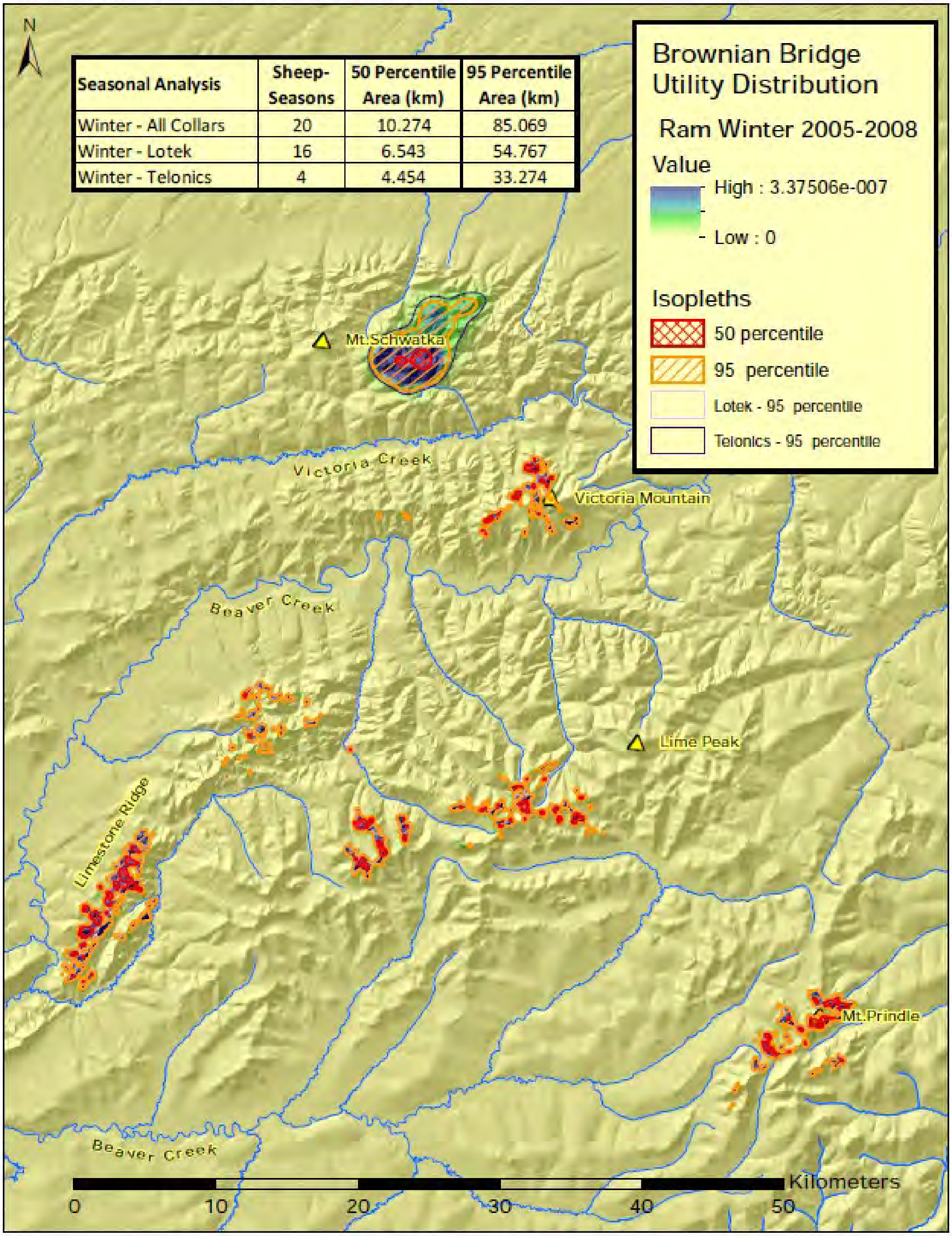
Rut, Rams, Lime Peak & Limestone Ridge, November - December, 2004-2007



Rut, Rams, Mt. Prindle, November - December, 2004-2007

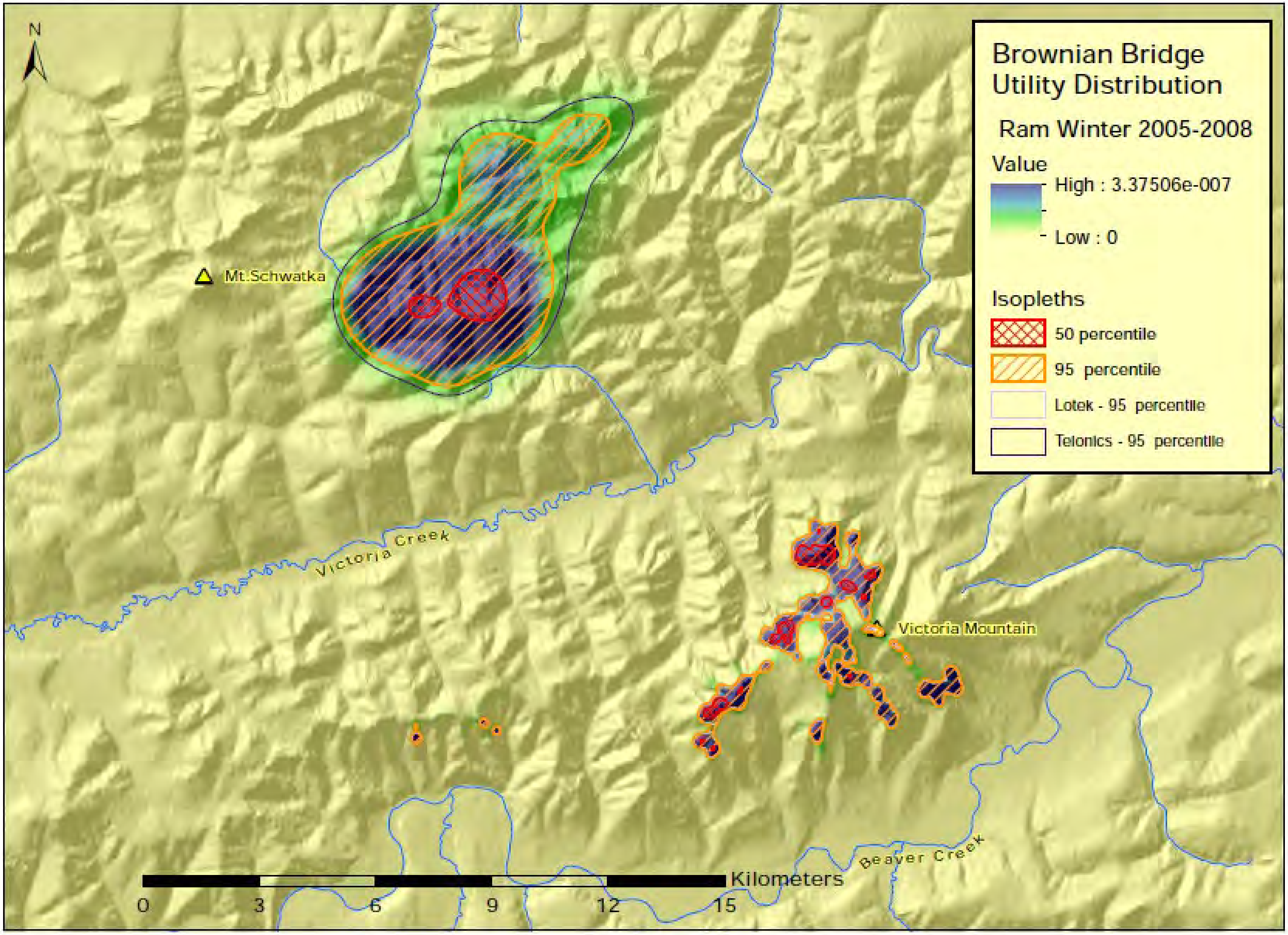


Winter, Rams (12), January - April, 2005-2008

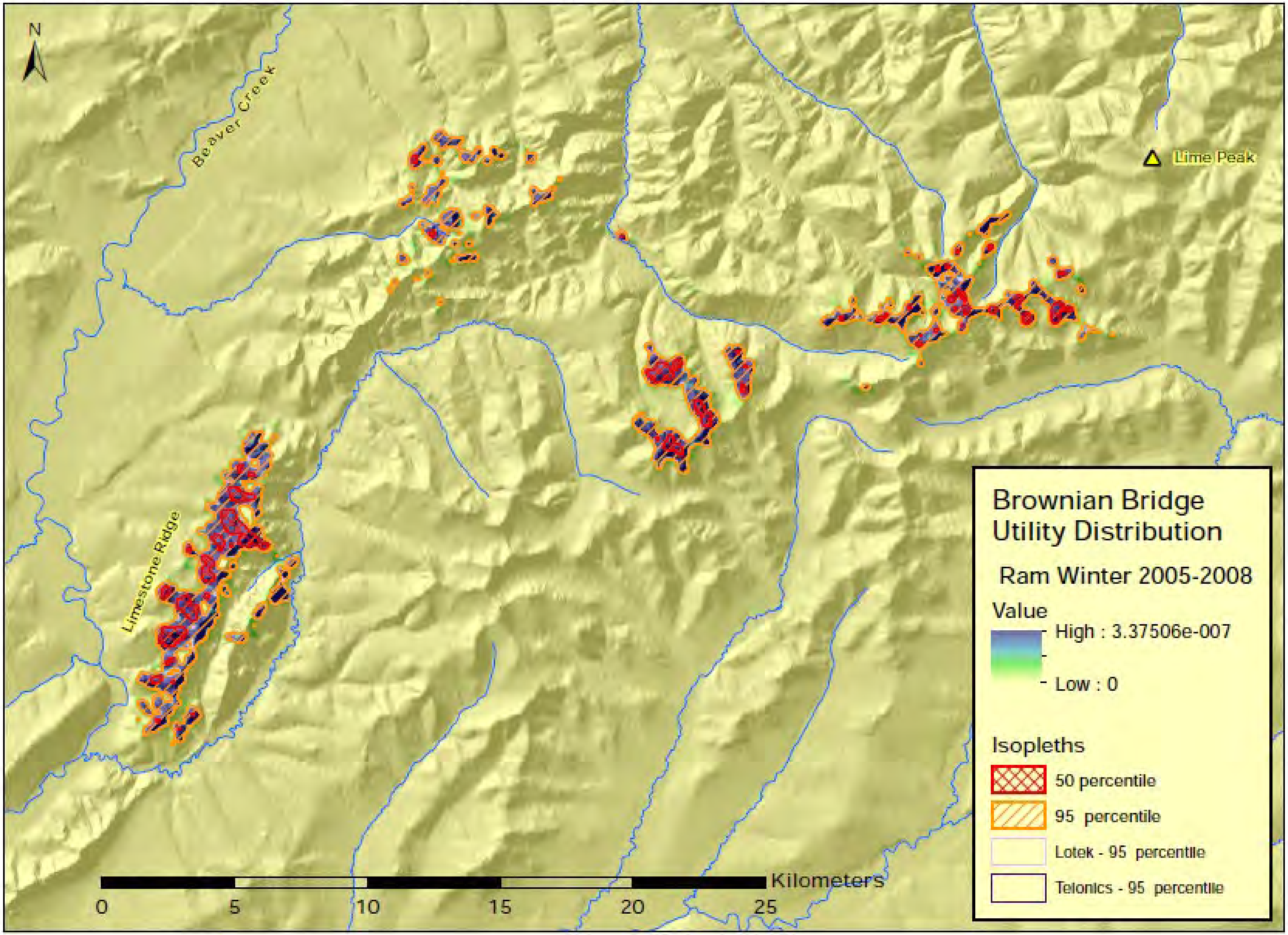


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km)	95 Percentile Area (km)
Winter - All Collars	20	10.274	85.069
Winter - Lotek	16	6.543	54.767
Winter - Telonics	4	4.454	33.274

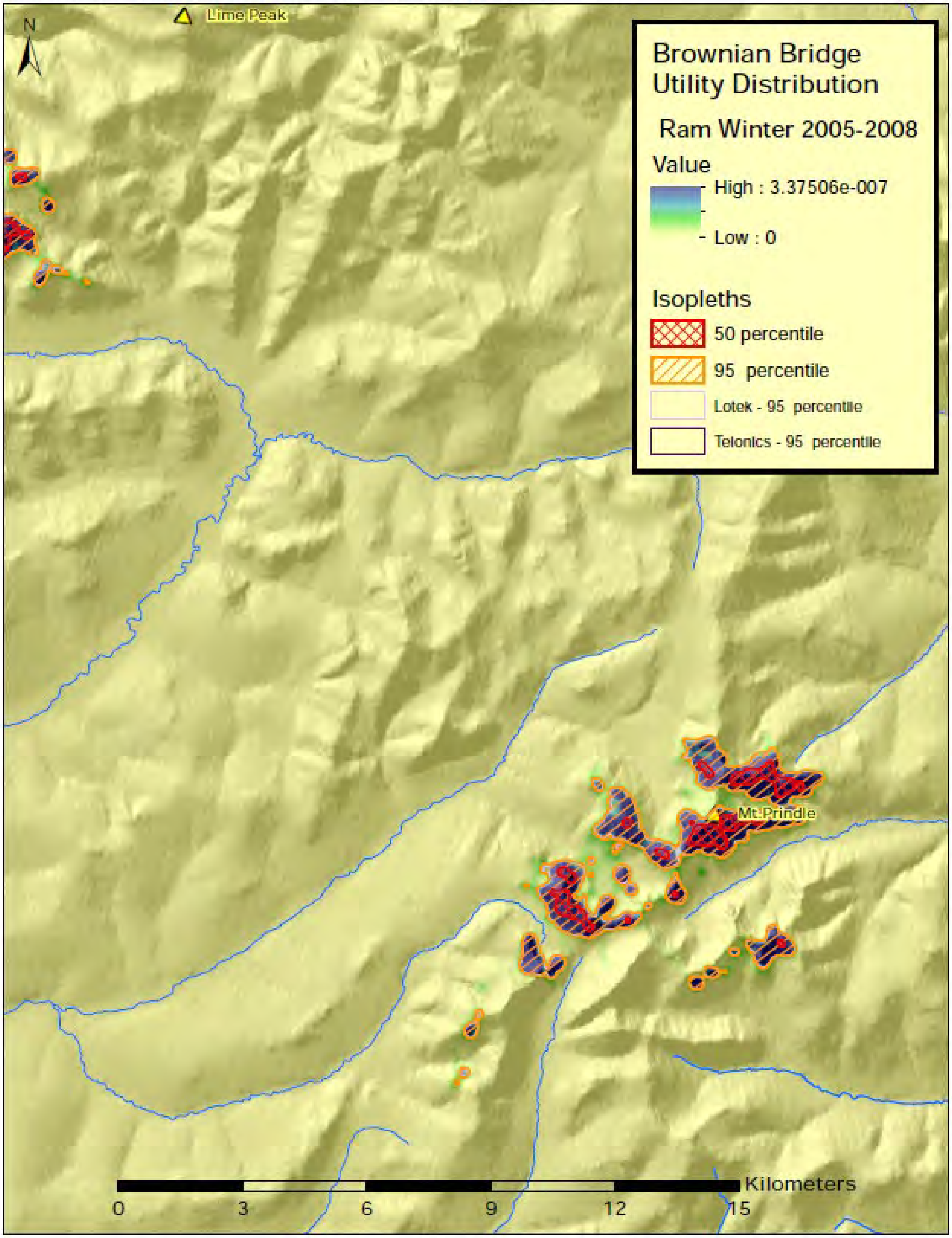
Winter, Rams, Mt. Schwatka & Victoria Mtn, January - April, 2005-2008



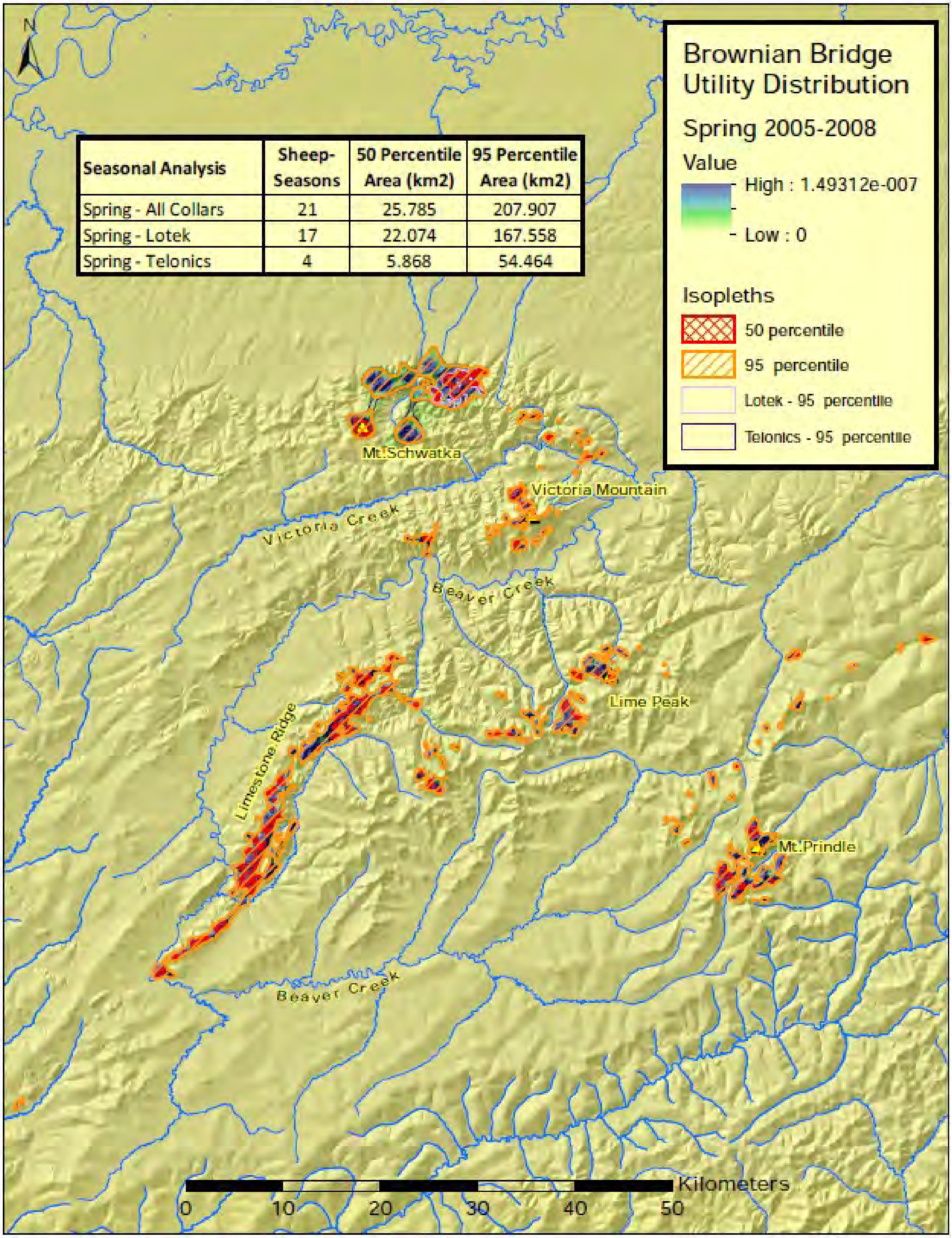
Winter, Rams, Lime Peak & Limestone Ridge, January - April, 2005-2008



Winter, Rams, Mt Prindle, January - April, 2005-2008

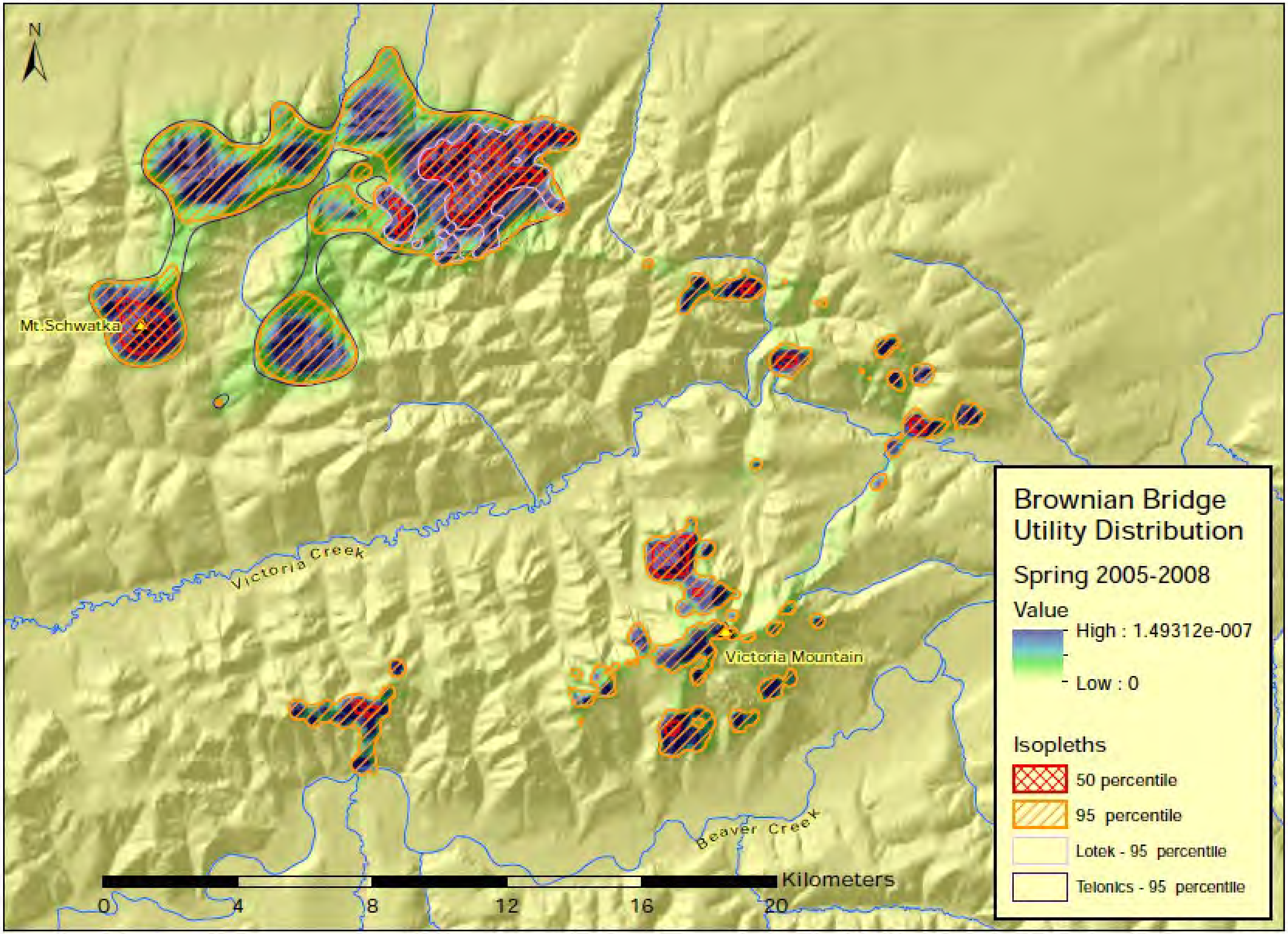


Spring, Rams (13), May - June, 2005-2008

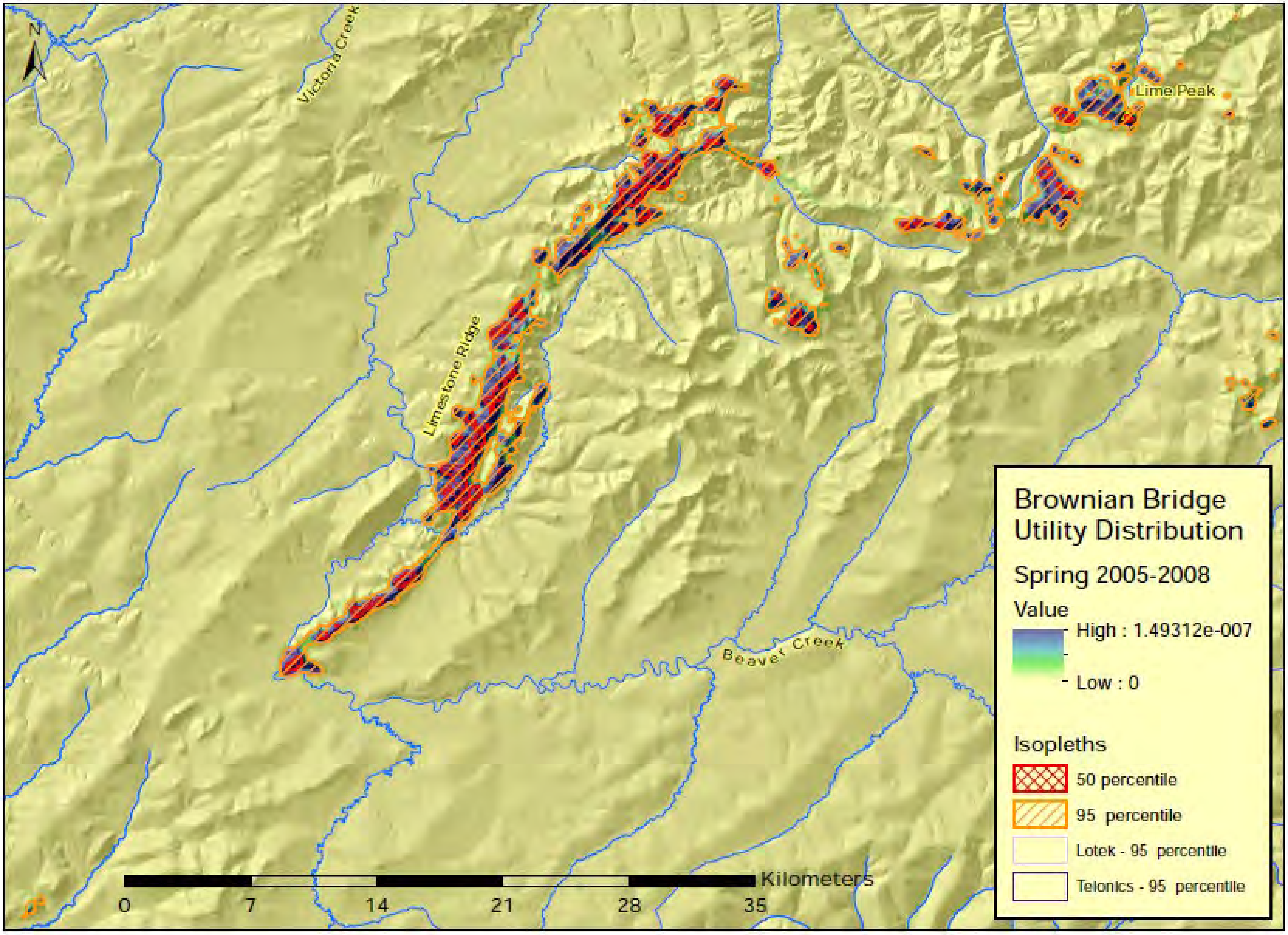


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km2)	95 Percentile Area (km2)
Spring - All Collars	21	25.785	207.907
Spring - Lotek	17	22.074	167.558
Spring - Telonics	4	5.868	54.464

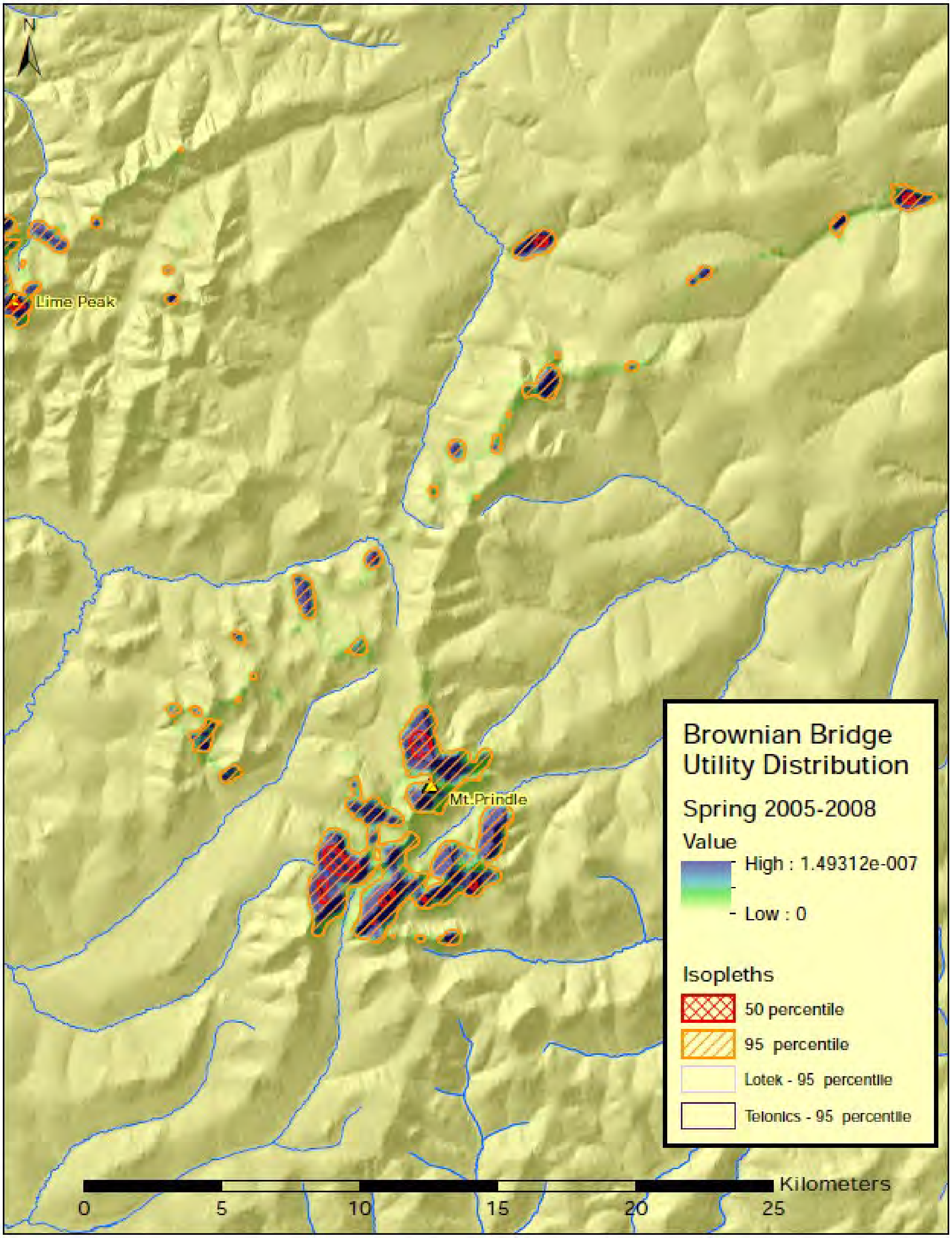
Spring, Rams, Mt. Schwatka & Victoria Mtn, May - June, 2005-2008



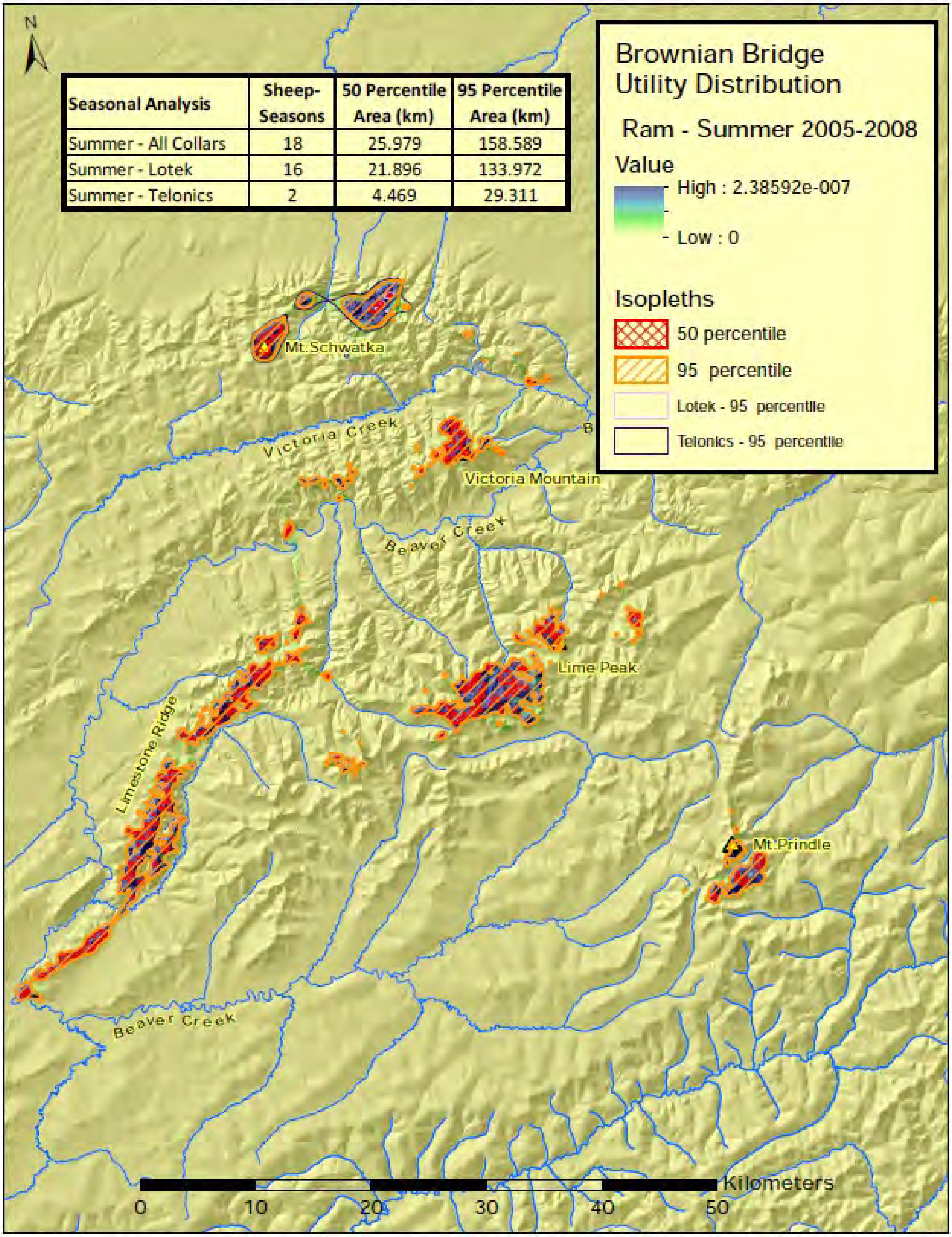
Spring, Rams, Lime Peak & Limestone Ridge, May - June, 2005-2008



Spring, Rams, Mt. Prindle, May - June, 2005-2008

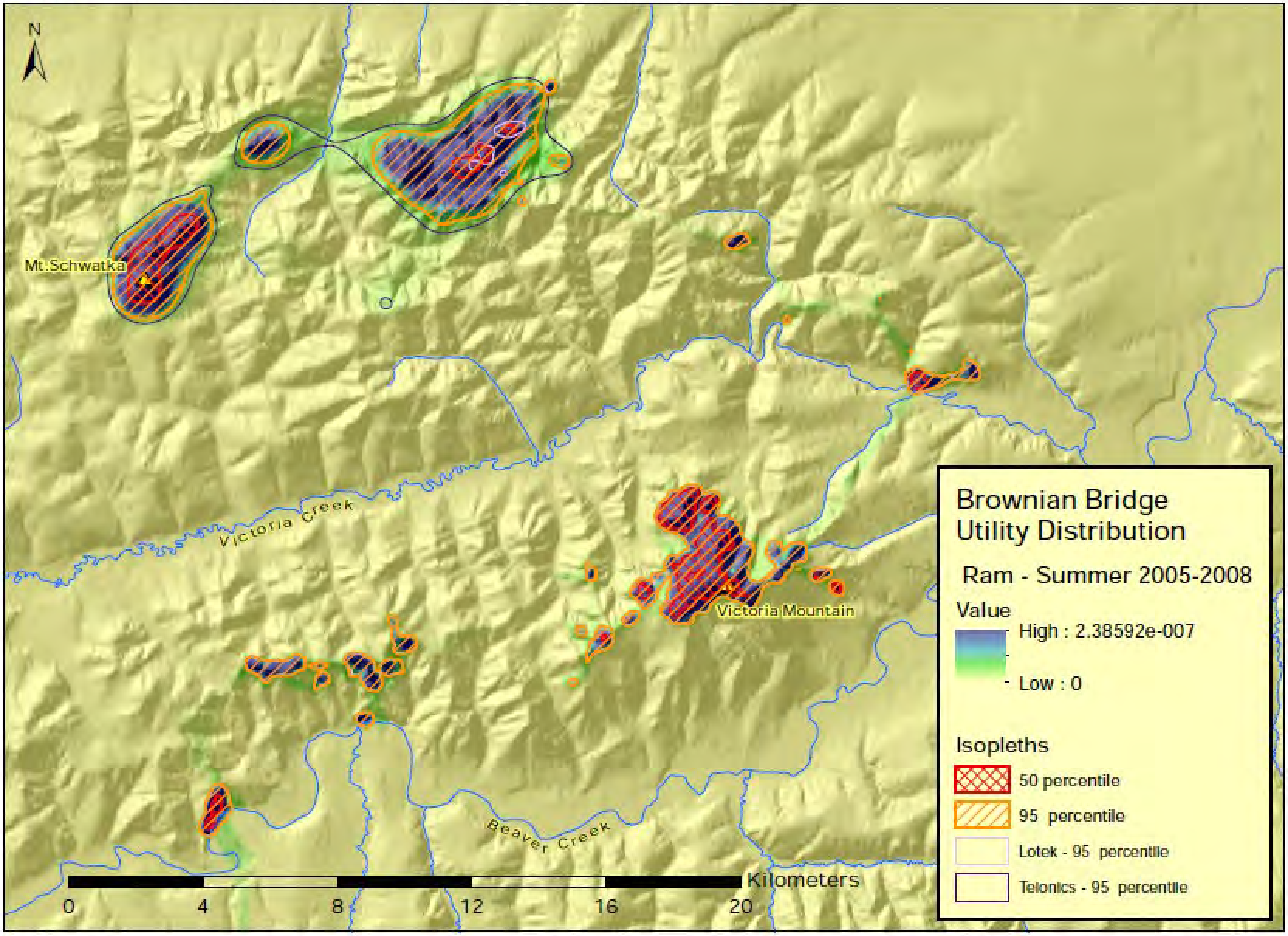


Summer, Rams (13), July - August, 2005-2008

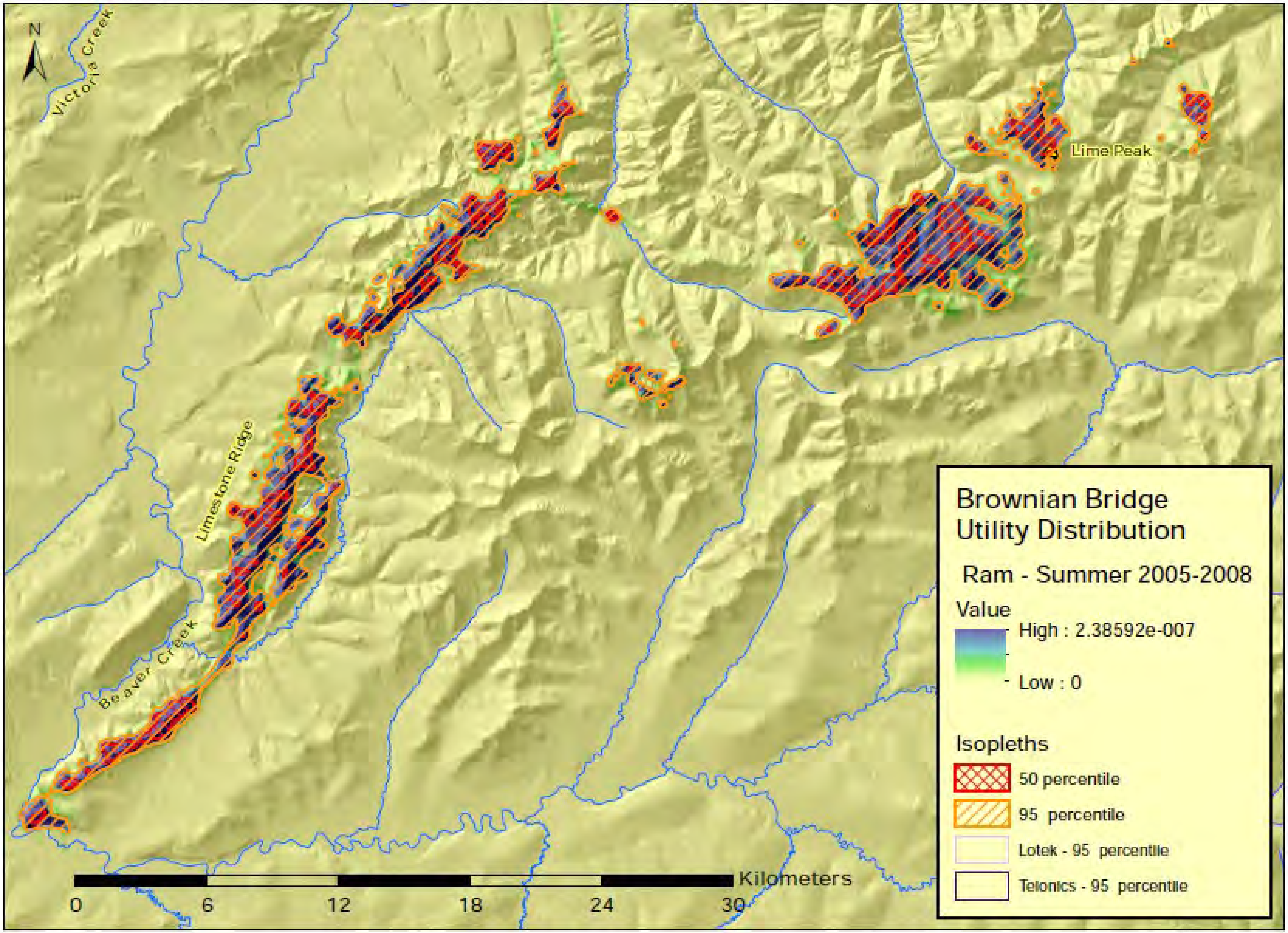


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km)	95 Percentile Area (km)
Summer - All Collars	18	25.979	158.589
Summer - Lotek	16	21.896	133.972
Summer - Telonics	2	4.469	29.311

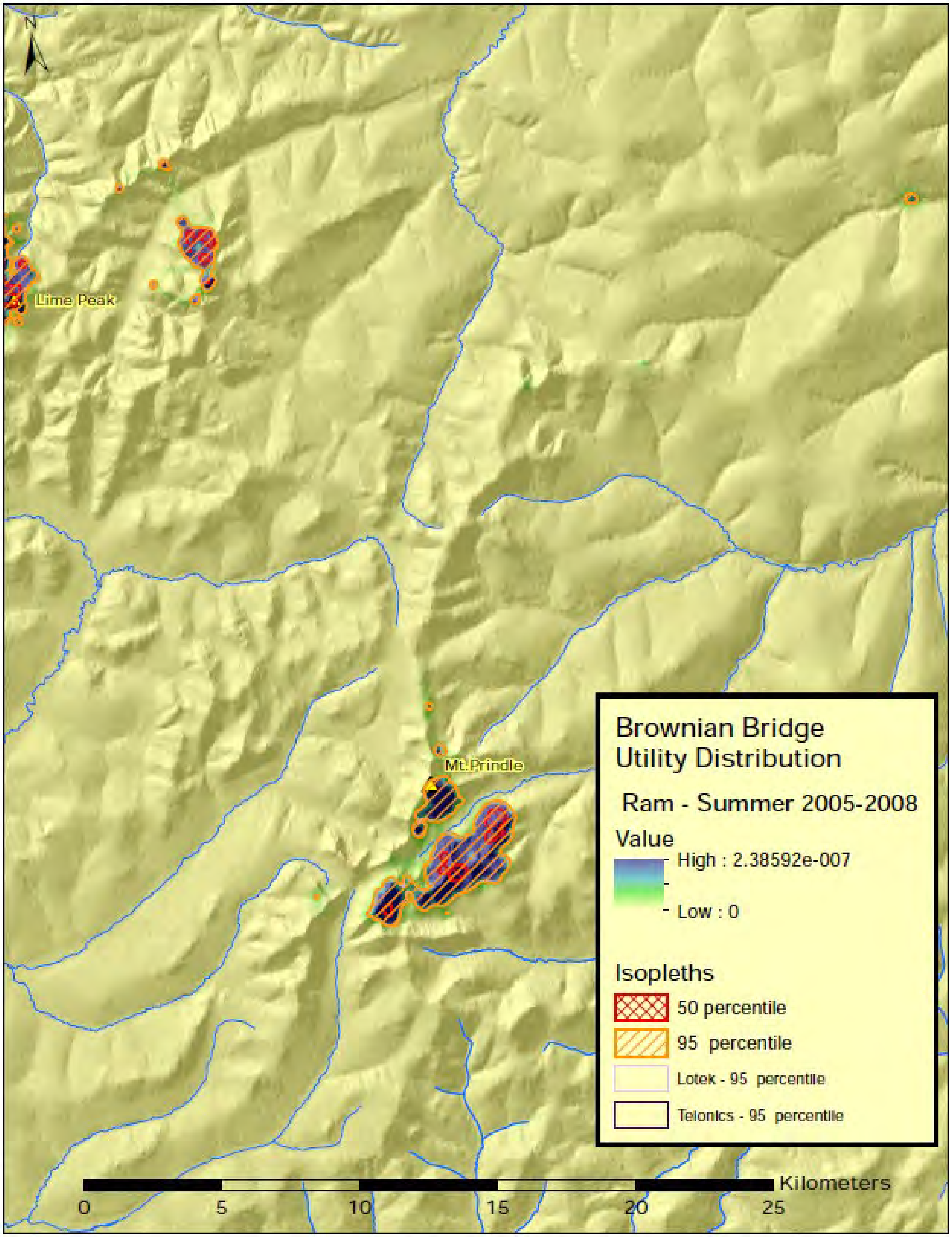
Summer, Rams, Mt. Schwatka & Victoria Mtn, July - August, 2005-2008



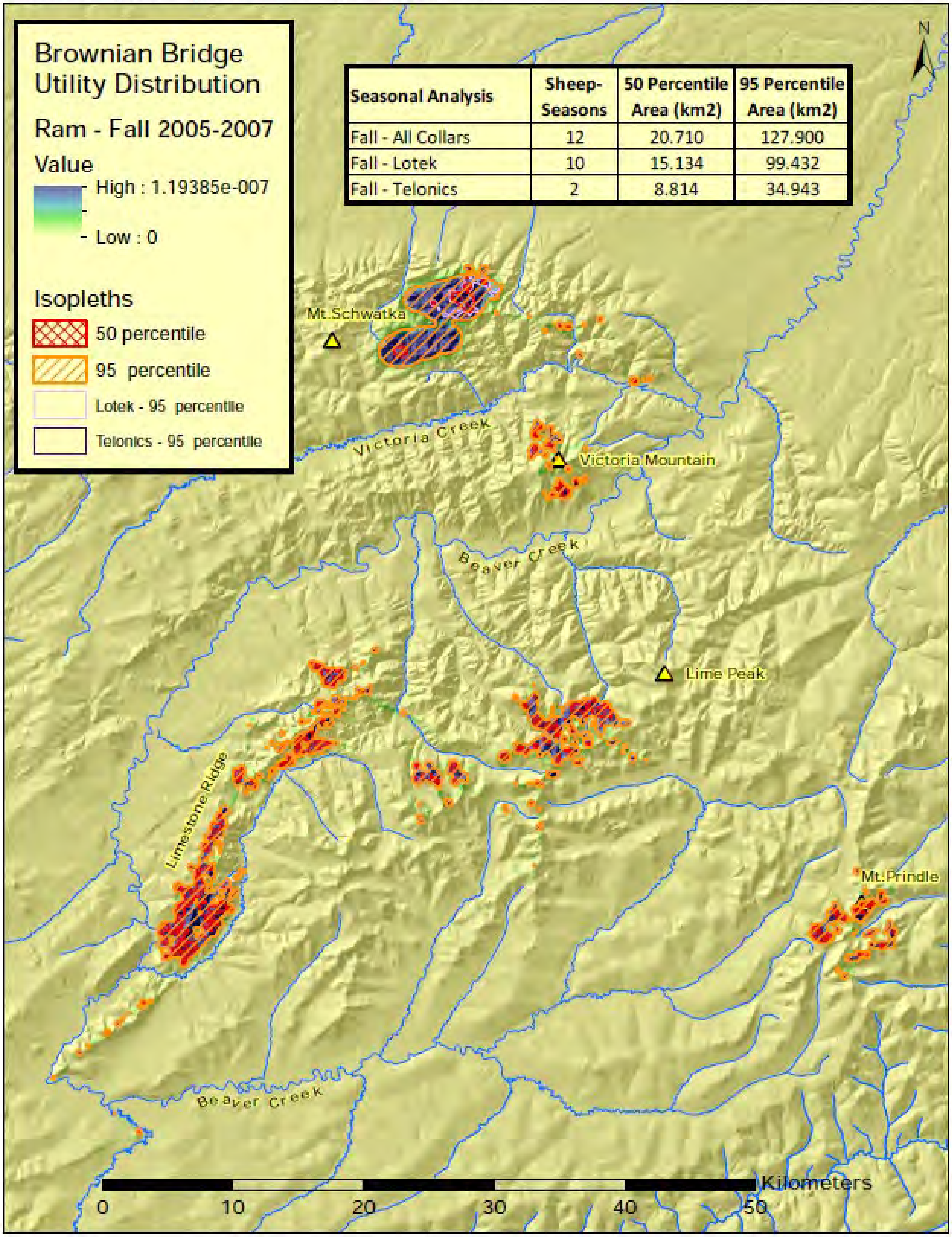
Summer, Rams, Lime Peak & Limestone Ridge, July - August, 2005-2008



Summer, Rams, Mt. Prindle, July - August, 2005-2008

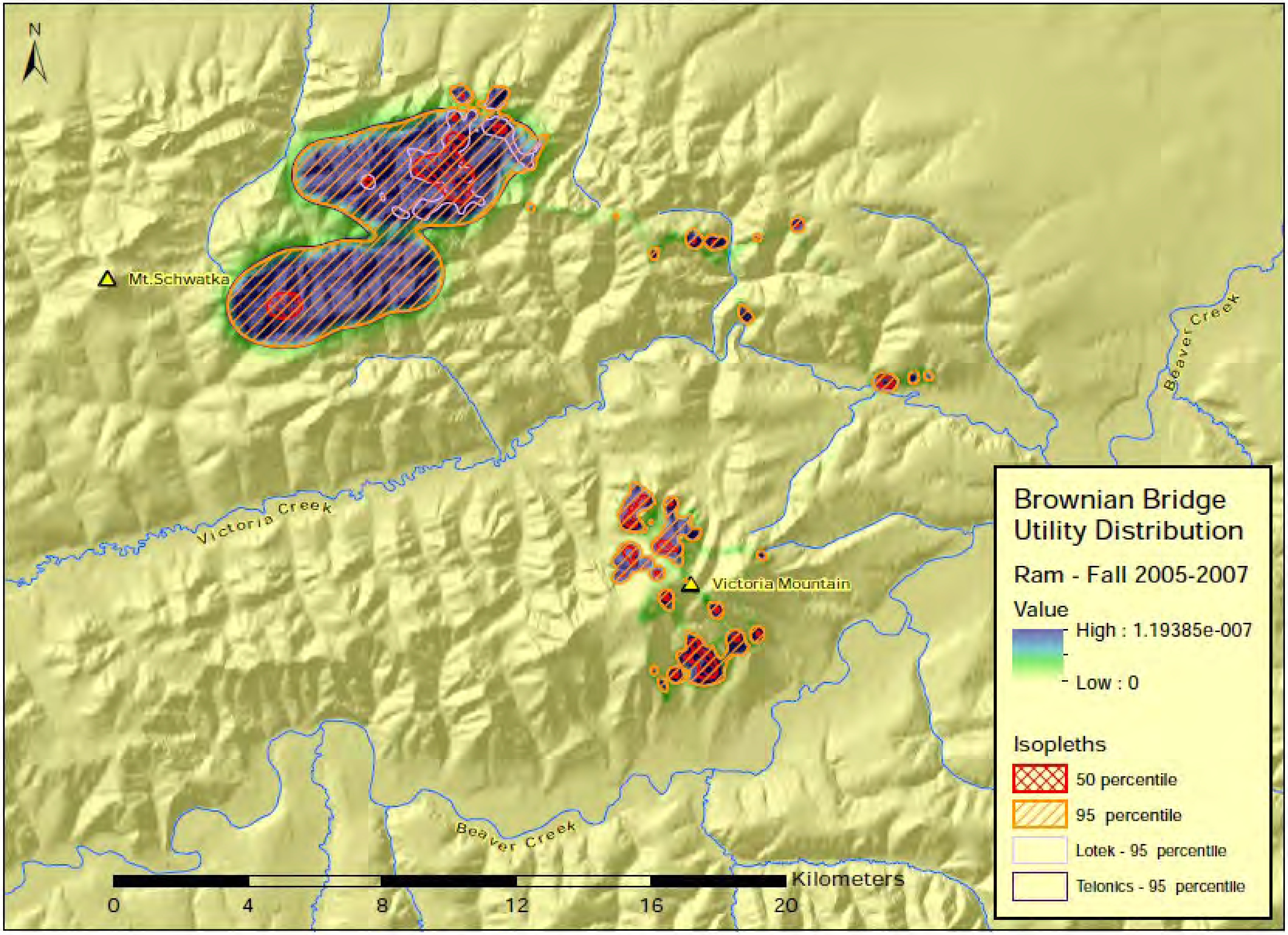


Fall,Rams (10), September - October 2005-2007

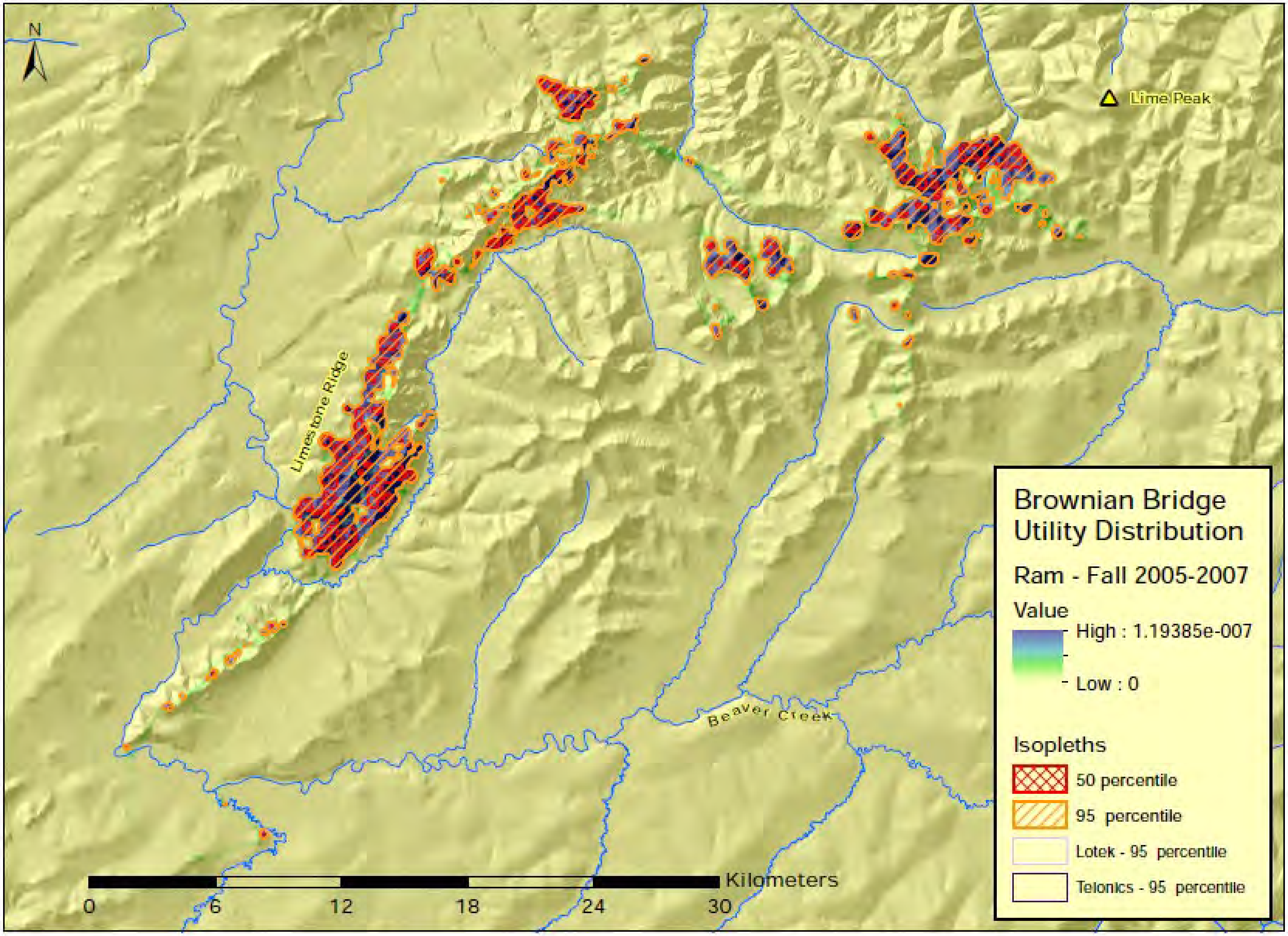


Seasonal Analysis	Sheep-Seasons	50 Percentile Area (km2)	95 Percentile Area (km2)
Fall - All Collars	12	20.710	127.900
Fall - Lotek	10	15.134	99.432
Fall - Telonics	2	8.814	34.943

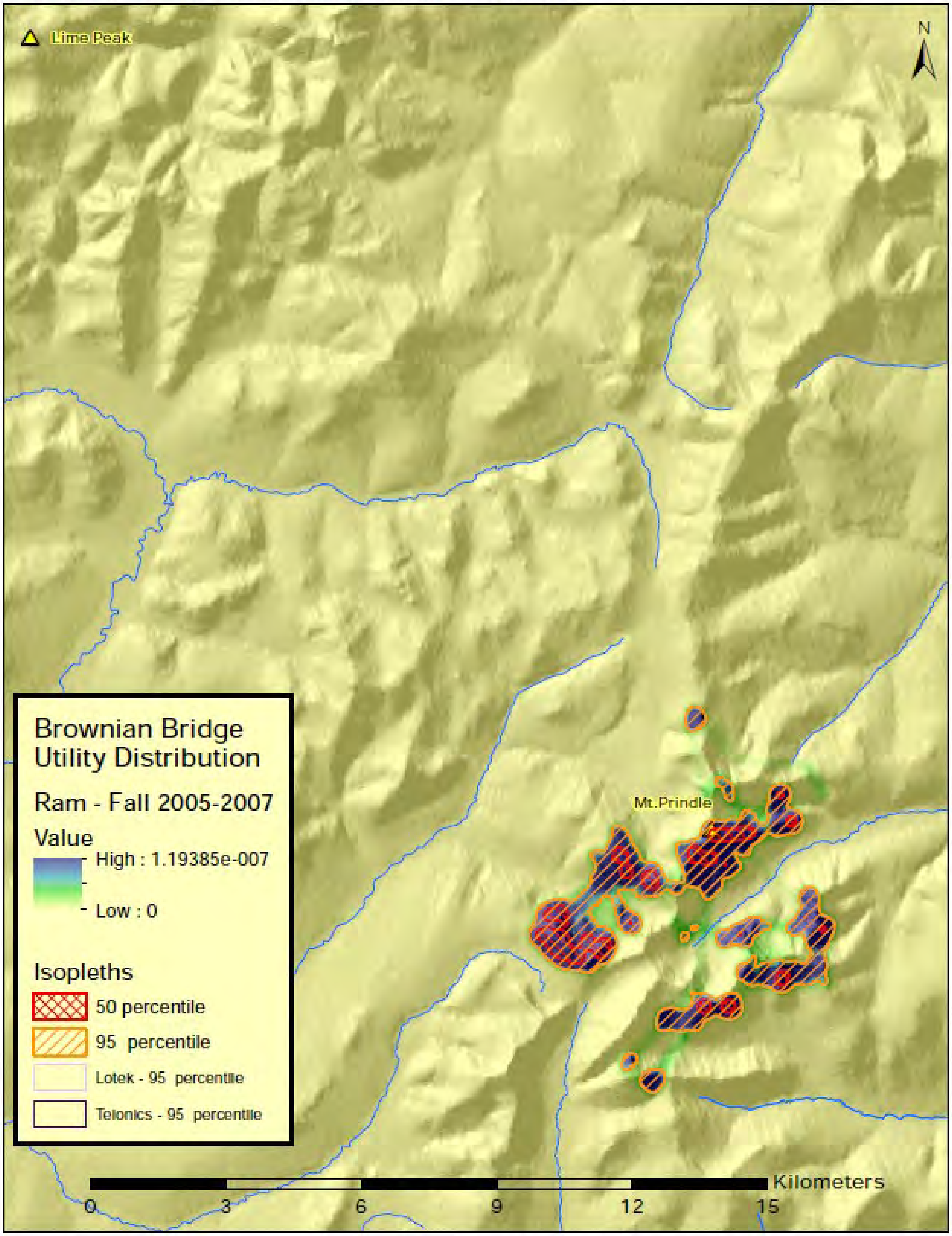
Fall, Rams, Mt. Schwatka & Victoria Mtn, September - October, 2005-2007



Fall, Rams, Lime Peak & Limestone Ridge, September - October, 2005-2007



Fall, Rams, Mt. Prindle, September - October 2005-2007

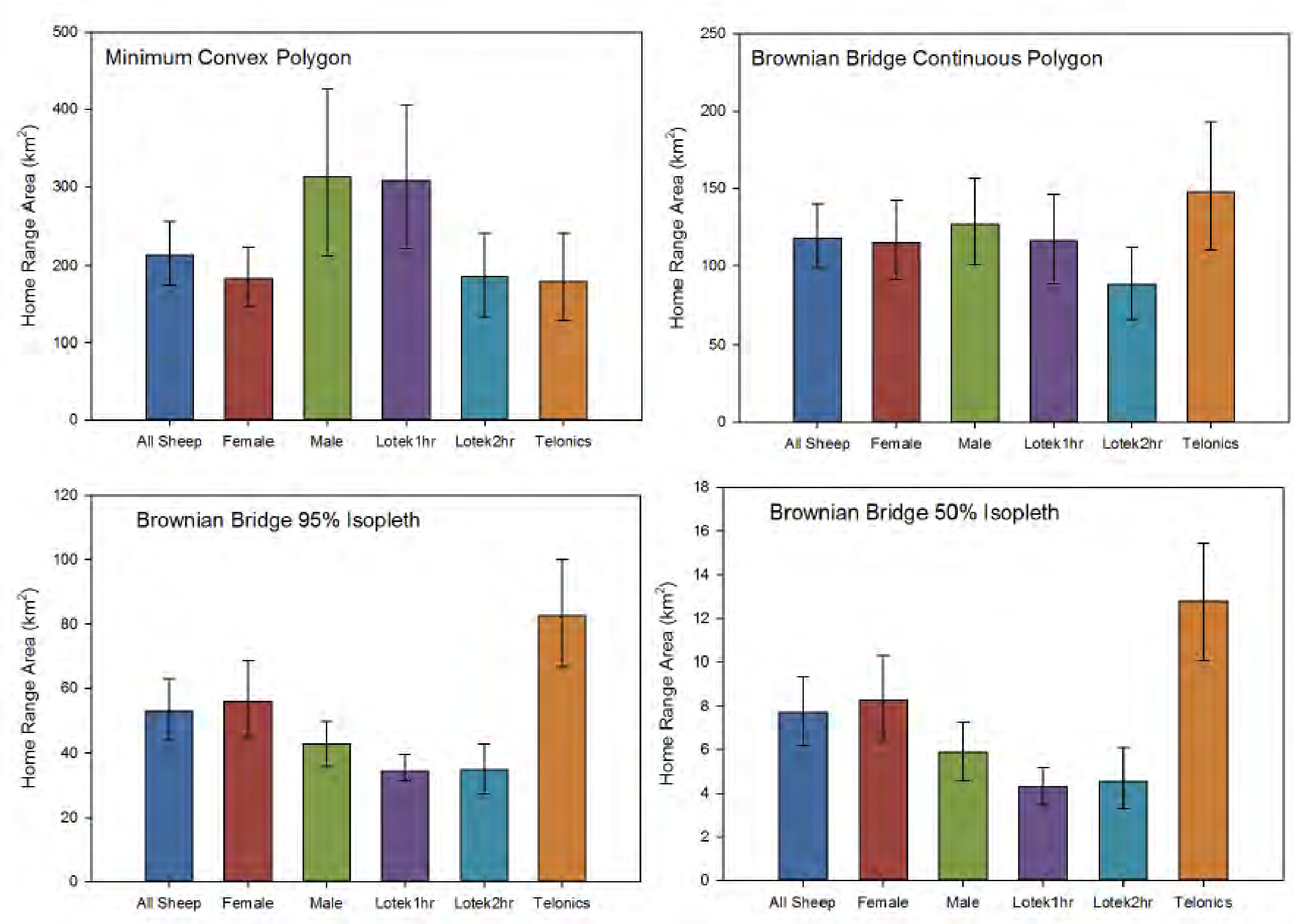


Appendix F1. Mean minimum convex polygon and BBMM isopleth home range estimates with confidence intervals for all Dall's sheep by sex and radio collar type in the White Mountains, Alaska, USA 2004-2008.

	MCP Mean Area (km2)	Minimum Convex Polygon Confidence Intervals[1]	BB Isopleth Continuous Polygon Mean Area (km^2)	BBMM Isopleth Continuous Polygon Confidence Intervals[1]	BB Isopleth 95 percentile Mean Area (km^2)	BBMM Isopleth 95 Percentile Confidence Intervals[1]	BB Isopleth 50 Percentile Mean Area (km^2)	BBMM Isopleth 50 Percentile Confidence Intervals[1]
All Sheep	213.729	Lower CI 2.5%= 174.4433 Upper CI 97.5%= 257.0128 SD= 21.07397	117.671	Lower CI 2.5%= 98.26478 Upper CI 97.5%= 140.0697 SD= 10.65719	53.071	Lower CI 2.5%= 44.04195 Upper CI 97.5%= 63.02113 SD= 4.844967	7.707	Lower CI 2.5%= 6.190892 Upper CI 97.5%= 9.343323 SD= 0.8086065
Female	183.598	Lower CI 2.5%= 146.942 Upper CI 97.5%= 224.3039 SD= 19.74881	114.927	Lower CI 2.5%-91.27691 Upper CI 97.5%-142.7184 SD-13.1799	56.183	Lower CI 2.5%= 44.76796 Upper CI 97.5%= 68.76354 SD= 6.136135	8.267	Lower CI 2.5%= 6.360669 Upper CI 97.5%= 10.31548 SD= 1.015971
Male	313.094	Lower CI 2.5%= 212.843 Upper CI 97.5%= 426.8123 SD= 54.80199	126.685	Lower CI 2.5%-100.6141 Upper CI 97.5%-156.4904 SD-14.28938	42.827	Lower CI 2.5%= 35.77469 Upper CI 97.5%= 49.83159 SD= 3.590998	5.859	Lower CI 2.5% = 4.556462 Upper CI 97.5%= 7.236467 SD= 0.6866436
Lotek 1-hour	308.602	Lower CI 2.5%= 222.1436 Upper CI 97.5%= 405.3854 SD= 46.908	116.383	Lower CI 2.5%= 88.77338 Upper CI 97.5%= 145.9397 SD= 14.59673	34.310	Lower CI 2.5%= 31.31544 Upper CI 97.5%= 39.65975 SD= 2.815754	4.305	Lower CI 2.5%= 3.452937 Upper CI 97.5%= 5.17875 SD= 0.4423423
Lotek 2-hour	185.695	Lower CI 2.5%= 133.8056 Upper CI 97.5%= 241.7372 SD= 27.50269	88.384	Lower CI 2.5%= 66.02767 Upper CI 97.5%= 111.879 SD= 11.6803	34.892	Lower CI 2.5%= 27.24771 Upper CI 97.5%= 42.87136 SD= 3.977491	4.536	Lower CI 2.5%= 3.290058 Upper CI 97.5%= 6.069562 SD= 0.7129871
Telonics	179.461	Lower CI 2.5%= 129.088 Upper CI 97.5%= 241.5099 SD= 28.83017	147.469	Lower CI 2.5%= 110.1046 Upper CI 97.5%= 193.3402 SD= 21.32809	82.689	Lower CI 2.5%= 66.67789 Upper CI 97.5%= 100.0765 SD= 8.553973	12.771	Lower CI 2.5%= 10.07091 Upper CI 97.5%= 15.45932 SD= 1.37727

1 Calculated using R-code Bootstrap method

Appendix F2. cont. Mean minimum convex polygon and BBMM isopleth home range estimates with confidence intervals for Dall's sheep by sex and radio collar type in the White Mountains, Alaska, USA, 2004-2008.



Appendix G1. Annual survival rate[1], all marked Dall's sheep, White Mountains, March 2004-March 2005.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2004-4/22/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2004-5/23/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2004-6/23/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
120	6/24/2004-7/24/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2004-8/25/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
180	8/26/2004-9/26/2004	1	0	1.0000	0	11	0.0000	1.0000	1.0000
210	9/27/2004-10/27/2004	12	0	1.0000	0	21	0.0000	1.0000	1.0000
240	10/28/2004-11/28/2004	33	2	0.9394	0	2	0.0016	0.8605	1.0183
270	11/29/2004-12/29/2005	33	0	0.9394	0	0	0.0016	0.8605	1.0183
300	12/30/2004-1/29/2005	33	0	0.9394	1	0	0.0016	0.8605	1.0183
330	1/30/2005-3/1/2005	32	0	0.9394	0	0	0.0017	0.8593	1.0195
360	3/2/2005-3/21/2005	32	0	0.9394	1	0	0.0017	0.8593	1.0195

[1] using Pollock et al. 1989

Appendix G2. Annual survival rate[1], all marked Dall's sheep, White Mountains, March 2005-March 2006.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2005	31	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2005-4/22/2005	31	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2005-5/23/2005	31	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2005-6/23/2005	31	1	0.9677	0	0	0.0010	0.9066	1.0289
120	6/24/2005-7/24/2005	30	0	0.9677	0	0	0.0010	0.9055	1.0299
150	7/25/2005-8/25/2005	30	0	0.9677	0	0	0.0010	0.9055	1.0299
180	8/26/2005-9/26/2005	30	0	0.9677	0	0	0.0010	0.9055	1.0299
210	9/27/2005-10/27/2005	30	1	0.9355	0	3	0.0019	0.8505	1.0205
240	10/28/2005-11/28/2005	32	0	0.9355	1	0	0.0018	0.8532	1.0178
270	11/29/2005-12/29/2005	31	1	0.9053	0	0	0.0025	0.8072	1.0034
300	12/30/2005-1/29/2006	30	1	0.8751	0	0	0.0032	0.7645	0.9858
330	1/30/2006-3/1/2006	29	1	0.8450	1	0	0.0038	0.7239	0.9660
360	3/2/2006-3/21/2006	27	0	0.8450	0	0	0.0041	0.7195	0.9705

[1] using Pollock et al. 1989

Appendix G3. Annual survival rate[1], all marked Dall's sheep, White Mountains, March 2006-March 2007.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2006	27	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2006-4/22/2006	27	1	0.9630	0	0	0.0013	0.8931	1.0329
60	4/23/2006-5/23/2006	26	1	0.9259	0	0	0.0024	0.8291	1.0228
90	5/24/2006-6/23/2006	25	0	0.9259	0	0	0.0025	0.8271	1.0247
120	6/24/2006-7/24/2006	25	0	0.9259	0	0	0.0025	0.8271	1.0247
150	7/25/2006-8/25/2006	25	0	0.9259	2	0	0.0025	0.8271	1.0247
180	8/26/2006-9/26/2006	23	1	0.8857	0	0	0.0039	0.7633	1.0081
210	9/27/2006-10/27/2006	22	1	0.8454	3	4	0.0050	0.7065	0.9843
240	10/28/2006-11/28/2006	22	0	0.8454	0	0	0.0050	0.7065	0.9843
270	11/29/2006-12/29/2006	22	0	0.8454	3	3	0.0050	0.7065	0.9843
300	12/30/2006-1/29/2007	22	0	0.8454	0	0	0.0050	0.7065	0.9843
330	1/30/2007-3/1/2007	22	0	0.8454	3	9	0.0050	0.7065	0.9843
360	3/2/2007-3/21/2007	28	0	0.8454	0	0	0.0039	0.7223	0.9685

[1] using Pollock et al. 1989

Appendix G4. Annual survival rate[1], all marked Dall's sheep, White Mountains, March 2007-March 2008.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2007	28	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2007-4/22/2007	28	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2007-5/23/2007	28	0	1.0000	2	0	0.0000	1.0000	1.0000
90	5/24/2007-6/23/2007	26	0	1.0000	0	0	0.0000	1.0000	1.0000
120	6/24/2007-7/24/2007	26	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2007-8/25/2007	26	0	1.0000	0	0	0.0000	1.0000	1.0000
180	8/26/2007-9/26/2007	26	0	1.0000	0	0	0.0000	1.0000	1.0000
210	9/27/2007-10/27/2007	26	0	1.0000	2	5	0.0000	1.0000	1.0000
240	10/28/2007-11/28/2007	29	0	1.0000	0	0	0.0000	1.0000	1.0000
270	11/29/2007-12/29/2007	29	0	1.0000	0	0	0.0000	1.0000	1.0000
300	12/30/2007-1/29/2008	29	0	1.0000	0	0	0.0000	1.0000	1.0000
330	1/30/2008-3/1/2008	29	0	1.0000	0	0	0.0000	1.0000	1.0000
360	3/2/2008-3/21/2008	29	0	1.0000	0	0	0.0000	1.0000	1.0000

[1] using Pollock et al. 1989

Appendix G5. Annual survival rate[1], all marked Dall's sheep, White Mountains, March 2008-March 2009.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2008	29	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2008-4/22/2008	29	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2008-5/23/2008	29	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2008-6/23/2008	29	0	1.0000	1	0	0.0000	1.0000	1.0000
120	6/24/2008-7/24/2008	28	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2008-8/25/2008	28	0	1.0000	4	0	0.0000	1.0000	1.0000
180	8/26/2008-9/26/2008	24	0	1.0000	16	0	0.0000	1.0000	1.0000
210	9/27/2008-10/27/2008	8	0	1.0000	9	0	0.0000	1.0000	1.0000

[1] using Pollock et al. 1989

Appendix G6. Annual survival rate[1], female marked Dall's sheep, White Mountains, March 2004-March 2005.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2004-4/22/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2004-5/23/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2004-6/23/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
120	6/24/2004-7/24/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2005-8/25/2004	1	0	1.0000	0	0	0.0000	1.0000	1.0000
180	8/26/2004-9/26/2004	1	0	1.0000	1	8	0.0000	1.0000	1.0000
210	9/27/2004-10/27/2004	8	0	1.0000	0	18	0.0000	1.0000	1.0000
240	10/28/2004-11/28/2004	26	1	0.9615	0	1	0.0014	0.8891	1.0340
270	11/29/2004-12/29/2005	26	0	0.9615	0	0	0.0014	0.8891	1.0340
300	12/30/2004-1/29/2005	26	1	0.9246	0	0	0.0025	0.8269	1.0222
330	1/30/2005-3/1/2005	25	0	0.9246	0	0	0.0026	0.8250	1.0241
360	3/2/2005-3/21/2005	25	0	0.9246	0	0	0.0026	0.8250	1.0241

[1] using Pollock et al. 1989

Appendix G7. Annual survival rate[1], female marked Dall's sheep, White Mountains, March 2005-March 2006.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2005	25	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2005-4/22/2005	25	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2005-5/23/2005	25	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2005-6/23/2005	25	1	0.9600	0	0	0.0015	0.8847	1.0353
120	6/24/2005-7/24/2005	24	0	0.9600	0	0	0.0015	0.8832	1.0368
150	7/25/2005-8/25/2005	24	0	0.9600	0	0	0.0015	0.8832	1.0368
180	8/26/2005-9/26/2005	24	0	0.9600	0	0	0.0015	0.8832	1.0368
210	9/27/2005-10/27/2005	24	1	0.9200	0	3	0.0028	0.8159	1.0241
240	10/28/2005-11/28/2005	26	0	0.9200	1	0	0.0026	0.8200	1.0200
270	11/29/2005-12/29/2005	25	1	0.8832	0	0	0.0036	0.7649	1.0015
300	12/30/2005-1/29/2006	24	1	0.8464	0	0	0.0046	0.7137	0.9791
330	1/30/2006-3/1/2006	23	0	0.8464	1	0	0.0048	0.7108	0.9820
360	3/2/2006-3/21/2006	22	0	0.8464	0	0	0.0050	0.7078	0.9850

[1] using Pollock et al. 1989

Appendix G8. Annual survival rate[1], female marked Dall's sheep, White Mountains, March 2006-March 2007.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2006	22	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2006-4/22/2006	22	1	0.9545	0	0	0.0019	0.8695	1.0396
60	4/23/2006-5/23/2006	21	1	0.9091	0	0	0.0036	0.7919	1.0263
90	5/24/2006-6/23/2006	20	0	0.9091	0	0	0.0038	0.7890	1.0292
120	6/24/2006-7/24/2006	20	0	0.9091	0	0	0.0038	0.7890	1.0292
150	7/25/2006-8/25/2006	20	0	0.9091	0	0	0.0038	0.7890	1.0292
180	8/26/2006-9/26/2006	20	1	0.8636	0	0	0.0051	0.7239	1.0034
210	9/27/2006-10/27/2006	19	1	0.8182	2	3	0.0064	0.6613	0.9751
240	10/28/2006-11/28/2006	19	0	0.8182	0	0	0.0064	0.6613	0.9751
270	11/29/2006-12/29/2006	19	0	0.8182	1	1	0.0064	0.6613	0.9751
300	12/30/2006-1/29/2007	19	0	0.8182	0	0	0.0064	0.6613	0.9751
330	1/30/2007-3/1/2007	19	0	0.8182	3	8	0.0064	0.6613	0.9751
360	3/2/2007-3/21/2007	24	0	0.8182	0	0	0.0051	0.6786	0.9578

[1] using Pollock et al. 1989

Appendix G9. Annual survival rate[1], female marked Dall's sheep, White Mountains, March 2007-March 2008.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2007	24	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2007-4/22/2007	24	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2007-5/23/2007	24	0	1.0000	1	0	0.0000	1.0000	1.0000
90	5/24/2007-6/23/2007	23	0	1.0000	0	0	0.0000	1.0000	1.0000
120	6/24/2007-7/24/2007	23	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2007-8/25/2007	23	0	1.0000	0	0	0.0000	1.0000	1.0000
180	8/26/2007-9/26/2007	23	0	1.0000	0	0	0.0000	1.0000	1.0000
210	9/27/2007-10/27/2007	23	0	1.0000	2	1	0.0000	1.0000	1.0000
240	10/28/2007-11/28/2007	22	0	1.0000	0	0	0.0000	1.0000	1.0000
270	11/29/2007-12/29/2007	22	0	1.0000	0	0	0.0000	1.0000	1.0000
300	12/30/2007-1/29/2008	22	0	1.0000	0	0	0.0000	1.0000	1.0000
330	1/30/2008-3/1/2008	22	0	1.0000	0	0	0.0000	1.0000	1.0000
360	3/2/2008-3/21/2008	22	0	1.0000	0	0	0.0000	1.0000	1.0000

[1] using Pollock et al. 1989

Appendix G10. Annual survival rate[1], female marked Dall's sheep, White Mountains, March 2008-March 2009.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERCL
0	3/22/2008	22	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2008-4/22/2008	22	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2008-5/23/2008	22	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2008-6/23/2008	22	0	1.0000	1	0	0.0000	1.0000	1.0000
120	6/24/2008-7/24/2008	21	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2008-8/25/2008	21	0	1.0000	4	0	0.0000	1.0000	1.0000
180	8/26/2008-9/26/2008	17	0	1.0000	10	0	0.0000	1.0000	1.0000
210	9/27/2008-10/27/2008	7	0	1.0000	7	0	0.0000	1.0000	1.0000
240	10/28/2008-11/28/2008	7	0	1.0000	0	0	0.0000	1.0000	1.0000
270	11/29/2008-12/29/2008	7	0	1.0000	0	0	0.0000	1.0000	1.0000
300	12/30/2008-1/29/2009	7	0	1.0000	0	0	0.0000	1.0000	1.0000
330	1/30/2009-3/1/2009	7	0	1.0000	0	0	0.0000	1.0000	1.0000
360	3/2/2009-3/21/2009	7	0	1.0000	0	0	0.0000	1.0000	1.0000

[1] using Pollock et al. 1989

Appendix G11. Annual survival rate[1], male marked Dall's sheep, White Mountains, March 2004-March 2005.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPERC
180	8/26/2004-9/26/2004	3	0	1.0000	0	0	0.0000	1.0000	1.0000
210	9/27/2004-10/27/2004	3	1	0.6667	0	3	0.0494	0.2311	1.1022
240	10/28/2004-11/28/2004	5	0	0.6667	0	1	0.0296	0.3293	1.0040
270	11/29/2004-12/29/2005	6	0	0.6667	0	2	0.0247	0.3587	0.9747
300	12/30/2004-1/29/2005	8	0	0.6667	0	0	0.0185	0.3999	0.9334
330	1/30/2005-3/1/2005	8	0	0.6667	0	1	0.0185	0.3999	0.9334
360	3/2/2005-3/21/2005	9	0	0.6667	0	0	0.0165	0.4152	0.9181

[1] using Pollock et al. 1989

Appendix G12. Annual survival rate[1], male marked Dall's sheep, White Mountains, March 2005-March 2006.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPER(
0	3/22/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
30	3/23/2005-4/22/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
60	4/23/2005-5/23/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
90	5/24/2005-6/23/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
120	6/24/2005-7/24/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
150	7/25/2005-8/25/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
180	8/26/2005-9/26/2005	9	0	1.0000	0	0	0.0000	1.0000	1.0000
210	9/27/2005-10/27/2005	9	0	1.0000	0	4	0.0000	1.0000	1.0000
240	10/28/2005-11/28/2005	13	0	1.0000	0	0	0.0000	1.0000	1.0000
270	11/29/2005-12/29/2005	13	0	1.0000	0	0	0.0000	1.0000	1.0000
300	12/30/2005-1/29/2006	13	0	1.0000	0	0	0.0000	1.0000	1.0000
330	1/30/2006-3/1/2006	13	1	0.9231	0	0	0.0050	0.7839	1.0622
360	3/2/2006-3/21/2006	12	0	0.9231	0	0	0.0055	0.7782	1.0679

[1] using Pollock et al. 1989

Appendix G13. Annual survival rate[1], male marked Dall's sheep, White Mountains, March 2006-March 2007.

WEEK	DATES	# RISK	# DEATHS	SURVIVAL	# CENSORED	# ADDED	VAR(SURV)	LOWERCL(95%)	UPPER
0	3/22/2006	12	0	1.0000	0	0	0.0000	1.0000	1.000(
30	3/23/2006-4/22/2006	12	0	1.0000	0	0	0.0000	1.0000	1.000(
60	4/23/2006-5/23/2006	12	0	1.0000	0	0	0.0000	1.0000	1.000(
90	5/24/2006-6/23/2006	12	0	1.0000	0	0	0.0000	1.0000	1.000(
120	6/24/2006-7/24/2006	12	0	1.0000	0	0	0.0000	1.0000	1.000(
150	7/25/2006-8/25/2006	12	0	1.0000	2	0	0.0000	1.0000	1.000(
180	8/26/2006-9/26/2006	10	0	1.0000	6	0	0.0000	1.0000	1.000(
210	9/27/2006-10/27/2006	4	0	1.0000	2	1	0.0000	1.0000	1.000(
240	10/28/2006-11/28/2006	3	0	1.0000	0	0	0.0000	1.0000	1.000(
270	11/29/2006-12/29/2006	3	0	1.0000	2	0	0.0000	1.0000	1.000(
300	12/30/2006-1/29/2007	1	0	1.0000	0	0	0.0000	1.0000	1.000(
330	1/30/2007-3/1/2007	1	0	1.0000	0	0	0.0000	1.0000	1.000(
360	3/2/2007-3/21/2007	1	0	1.0000	0	0	0.0000	1.0000	1.000(

[1] using Pollock et al. 1989

Appendix H-1. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, March, September/October, 2004.

	Rocky Mountain[1]	All Regions[2]
Plants	March	Sept/Oct
Arctagrostis	0.6	2.9
Calamagrostis purpurascens	35.3	18.9
Festuca	5.5	0.5
Hierochloe	2.7	3.1
Poa	6.6	0.9
Trisetum	1.3	
Unknown Grasses	1.6	0.9
Total Grasses:	53.6	27.2
Carex	4.4	11.3
Eriophorum	1.1	2.7
Luzula	3.0	2.9
Total Sedge/Rushes:	8.5	16.9
Antennaria	0.3	
Artemisia		
Astragalus		
Cerastium		
Draba	0.3	
Epilobium		
Equisetum	0.8	8.1
Erigeron		
Hedysarum		
Lesquerella		
Lupinus	8.9	
Minuartia		
Oxytropis		
Pedicularis		
Phlox		
Potentilla		0.1
Pyrola		
Saxifraga		
Silene spp.		
Solidago		
Stellaria spp.	0.3	0.5
Flower		
Unknown Forbs	1.1	0.4
Total Forbs:	11.7	9.1

Appendix H-1 continued. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, March, September/October, 2004.

	Rocky Mountain[1]	All Regions[2]
Aulacomnium Moss	1.1	0.3
Classic Moss	10.2	3.3
Lycopodium		
Polytrichum Moss	0.8	
Sphagnum Moss		0.4
Total Mosses:	12.1	4.0
Cetraria/Dactylina	2.8	4.1
Cladina/Cladonia	4.9	27.4
Peltigera	3.0	4.6
Stereocaulon		0.4
Total Lichens:	10.7	36.5
Alnus stem		
Betula stem		
Cassiope		1.2
Dryas	1.9	0.5
Empetrum		0.9
Empetrum stem		
Ledum		
Populus leaf		0.4
Populus stem		
Rhododendron leaf		
Salix leaf	0.9	2.9
Salix stem	0.3	0.4
Vaccinium leaf		
Thorn		
Unknown Shrub leaf		
Unknown Shrub stem	0.3	
Total Shrubs:	3.4	6.3
Picea		
Total Conifers	0.0	0.0
Ferns:	0.0	0.0
TOTAL	100.0	100.0

[1] Includes Cache Mountain

[2] Limestone Ridge, Rocky Mountain, Cache Mountain, Pridle Mountain, and Mount Schwatka

Appendix H-2. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, July, 2005.

Plants	Limestone Ridge	Rocky Mountain[1]	Mount Prindle	Mount Schwatka	Victoria Mountain
Arctagrostis		1.9	3.2	2.4	6
Calamagrostis purpurascens	13.6	10.5	5.9	10.9	7.7
Festuca	3.0	2.9	3.2	1.7	1.2
Hierochloe	0.9	1.7	1.6	1.4	0.8
Poa	3.6	7.4	4.0	5.6	3.8
Trisetum	0.6	0.4		0.7	0.5
Unknown Grasses	1.1	1.9	0.9	1.4	0.5
Total Grasses:	22.8	26.7	18.8	24.1	20.5
Carex	25.1	40.5	51.4	25.8	38.65
Eriophorum	3.6	4.3	0.4	2.4	1.25
Luzula	3.4	7.8	10.1	1.0	2.85
Total Sedge/Rushes:	32.1	52.6	61.9	29.2	42.75
Antennaria	1.5	0.8		2.1	0.6
Artemisia	1.5	0.2	0.2	1.0	1.85
Astragalus	0.4		0.4	2.3	
Cerastium	1.1			0.2	
Draba					
Epilobium				0.9	0.45
Equisetum	3.2				0.45
Erigeron					
Hedysarum					0.6
Lesquerella				1.2	
Lupinus	1.6	0.2	1.5	6.9	4.8
Minuartia					
Oxytropis				1.4	1.85
Pedicularis					
Phlox				1.4	
Potentilla	0.6	1.4	0.3	0.3	1.2
Pyrola	1.3				
Saxifraga	1.3		0.4	1.2	
Silene spp.	2.8				0.75
Solidago				0.5	
Stellaria spp.	0.6				0.45
Flower					
Unknown Forbs	2.8	0.4	2.7	1.4	3.8
Total Forbs:	18.7	3.0	5.5	20.8	16.8

Appendix H-2 continued. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, July, 2005.

Plants	Limestone Ridge	Rocky Mountain[1]	Mount Prindle	Mount Schwatka	Victoria Mountain
Aulacomnium Moss	1.1	0.2	1.1	0.5	0.15
Classic Moss	5.8	1.0	2.5	4.7	2.65
Lycopodium				0.5	0.3
Polytrichum Moss		0.2			
Sphagnum Moss			0.5		
Total Mosses:	6.9	1.4	4.1	5.7	3.1
Cetraria/Dactylina	2.1	0.4	1.8	0.5	1.85
Cladina/Cladonia	7.9	5.8	4.0	2.8	4.95
Peltigera	1.7	1.9	1.8	0.9	0.75
Stereocaulon	1.9	0.6			0.45
Total Lichens:	13.6	8.7	7.6	4.2	8
Alnus stem					
Betula stem					
Cassiope		1.7	0.4		
Dryas	2.1	3.1		5.0	0.45
Empetrum	0.4			2.3	0.75
Empetrum stem					
Ledum					
Populus leaf					0.65
Populus stem				0.3	
Rhododendron leaf				1.9	0.15
Salix leaf	2.1	1.4	0.5	6.0	4.15
Salix stem		0.8	0.7	0.5	1.35
Vaccinium leaf	0.9	0.2			
Thorn					0.15
Unknown Shrub leaf					0.45
Unknown Shrub stem		0.4			0.3
Total Shrubs:	5.5	7.6	1.6	16.0	8.4
Picea	0.4		0.5		0.45
Total Conifers	0.4	0.0	0.5	0.0	0.45
Ferns:	0.0	0.0	0.0	0.0	0
TOTAL	100.0	100.0	100.0	100.0	100.00

Appendix H-3. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, June and July, 2006.

Plants	Limestone Ridge	Rocky Mountain[1]	Prindle Mountain	Mount Schwatka	Victoria Mountain
Arctagrostis	2.3	0.5	2.7	4.5	5.8
Calamagrostis purpurascens	8.2	10.2	10.8	6.5	6.8
Festuca	1.4	3.9	2.6	1.9	2.7
Hierochloe	1.3	0.9	0.6	1.0	1.4
Poa	4.6	3.8	1.2	2.5	3.8
Trisetum	0.3	0.2	0.3	0.2	0.4
Unknown Grasses	0.3	1.1	1.1	0.9	1.2
Total Grasses:	18.4	20.5	19.3	17.5	22.1
Carex	17.6	36.7	54.7	33.3	46.1
Eriophorum	5.9	1.5	1.4	2.3	2.1
Luzula	3.4	3.3	4.6	3.1	8.5
Total Sedge/Rushes:	26.9	41.4	60.7	38.7	56.7
Antennaria	0.9	0.7		4.3	
Artemisia	0.1		1.1	0.8	4.5
Astragalus	0.3	0.2	0.3	1.2	
Cerastium	1.6			0.3	
Draba	0.1				
Epilobium		0.5		2.7	
Equisetum	0.3				
Erigeron					
Hedysarum				0.8	
Lesquerella				0.9	
Lupinus	4.8	0.5	0.3	2.9	0.5
Minuartia				0.2	
Oxytropis				0.7	1.6
Pedicularis					
Phlox	0.5			0.5	
Potentilla	1.6	1.8	1.6	3.0	0.8
Pyrola					
Saxifraga				0.9	0.5
Silene spp.	3.9			0.4	
Solidago					
Stellaria spp.			0.3		0.9
Flower					
Unknown Forbs	1.5	2.2	1.2	1.4	1.2
Total Forbs:	15.6	5.8	4.8	21.0	10.0

Appendix H-3 continued. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, June and July, 2006.

Plants	Limestone Ridge	Rocky Mountain[1]	Prindle Mountain	Mount Schwatka	Victoria Mountain
Aulacomnium Moss	2.4	0.4	0.4	0.3	0.3
Classic Moss	11.6	4.4	2.3	5.7	1.5
Lycopodium				0.1	
Polytrichum Moss	1.3	0.8			
Sphagnum Moss			0.3		
Total Mosses:	15.3	5.5	3.0	6.1	1.8
Cetraria/Dactylina	1.6	2.2	3.0	0.7	0.3
Cladina/Cladonia	11.3	11.1	1.2	3.4	3.1
Peltigera	2.3	3.5	0.9	0.5	0.2
Stereocaulon	0.5	1.1		0.2	
Total Lichens:	15.7	17.9	5.1	4.8	3.6
Alnus stem					
Betula stem	0.3	0.7		0.2	1.4
Cassiope		0.5			
Dryas	3.5	3.6	0.9	2.7	
Empetrum				0.3	
Empetrum stem					
Ledum					
Populus leaf					
Populus stem					
Rhododendron leaf					
Salix leaf	1.3	2.2	1.3	5.6	3.9
Salix stem	2.3	1.5	4.9	2.4	0.3
Vaccinium leaf		0.2			
Thorn					
Unknown Shrub leaf	0.3	0.2		0.4	
Unknown Shrub stem	0.4	0.2		0.3	
Total Shrubs:	8.1	8.9	7.1	11.8	5.6
Picea					
Total Conifers	0.0	0.0	0.0	0.0	0.0
Ferns:	0.0	0.2	0.0	0.1	0.2
TOTAL	100.0	100.0	100.0	100.0	100.0

[1] Includes Cache Mountain

Appendix H-4. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, February, 2007.

Plants	Limestone Ridge	Rocky Mountain[1]	Prindle Mountain	Mount Schwatka	Victoria Mountain
Arctagrostis		7.5	2.3	2	2.7
Calamagrostis purpurascens	19.5	9.9	28.9	4.05	13.3
Festuca	5.2	11.4	4.9	0.9	3.4
Hierochloe	0.8	1.8	1.5	0.3	3.1
Poa	5.5	12.9	7.5	1.7	7.1
Trisetum	1.6	0.8	0.9	1.3	2.7
Unknown Grasses		1.0	2.8	1.2	0.4
Total Grasses:	32.6	45.3	48.8	11.45	32.7
Carex	9.2	9.4	5.5	25.85	7.4
Eriophorum	6.3	3.7		5.2	3.0
Luzula	1.9	1.0	3.8	3.35	2.4
Total Sedge/Rushes:	17.4	14.1	9.3	34.4	12.8
Antennaria		0.2		0.15	0.6
Artemisia				0.3	0.1
Astragalus		0.6		1.75	1.8
Cerastium			0.3	0.5	0.6
Draba				0.15	0.3
Epilobium				0.5	
Equisetum	0.7	0.2		1.05	0.4
Erigeron				0.1	
Hedysarum					
Lesquerella				3.15	
Lupinus	8.8	5.1		9.5	14.4
Minuartia				0.15	
Oxytropis				0.3	0.9
Pedicularis				0.15	0.6
Phlox		0.5	0.4	0.15	
Potentilla		0.6	0.4	0.4	0.1
Pyrola					
Saxifraga	0.3				0.9
Silene spp.		0.2		0.95	
Solidago					
Stellaria spp.		0.3		1	0.3
Flower					0.3
Unknown Forbs	1.0	0.9	0.6	1.7	1.2
Total Forbs:	10.8	8.6	1.7	21.95	22.5

Appendix H-4 continued. Percent occurrence of plant species and parts in microhistological samples of fecal pellets from Dall's sheep, by study area in the White Mountains, Alaska, February, 2007.

	Limestone Ridge	Rocky Mountain[1]	Prindle Mountain	Mount Schwatka	Victoria Mountain
Aulacomnium Moss	1.8	1.3	2.0	1.35	1.8
Classic Moss	11.4	14.4	15.2	10.2	16.6
Lycopodium					
Polytrichum Moss	3.2	0.3	1.9		
Sphagnum Moss		0.6		0.1	
Total Mosses:	16.4	16.6	19.1	11.65	18.4
Cetraria/Dactylina	1.8	1.5	2.3	3.1	1.9
Cladina/Cladonia	13.1	9.4	5.8	8.15	5.8
Peltigera	3.7	1.6	3.9	1.4	1.0
Stereocaulon	0.5		0.1	0.25	0.3
Total Lichens:	19.1	12.5	12.1	12.9	9.0
Alnus stem				0.15	
Betula stem			2.5	0.1	
Cassiope		0.3		0.15	0.4
Dryas		0.8	0.3	1.85	
Empetrum	0.7		2.3	0.25	
Empetrum stem			0.4		
Ledum	0.2		0.7		
Populus leaf					
Populus stem			0.3	0.65	
Rhododendron leaf				0	
Salix leaf	0.2			1.25	0.7
Salix stem	0.6	0.7	1.6	1	0.7
Vaccinium leaf	1.5		0.3		
Thorn					
Unknown Shrub leaf					0.6
Unknown Shrub stem	0.5	0.6	0.6	1.4	2.1
Total Shrubs:	3.7	2.4	9.0	6.8	4.5
Picea		0.5		0.85	
Total Conifers	0.0	0.5	0.0	0.85	0.0
Ferns:	0.0	0.0	0.0	0	0.1
TOTAL	100.0	100.0	100.0	100	100.0

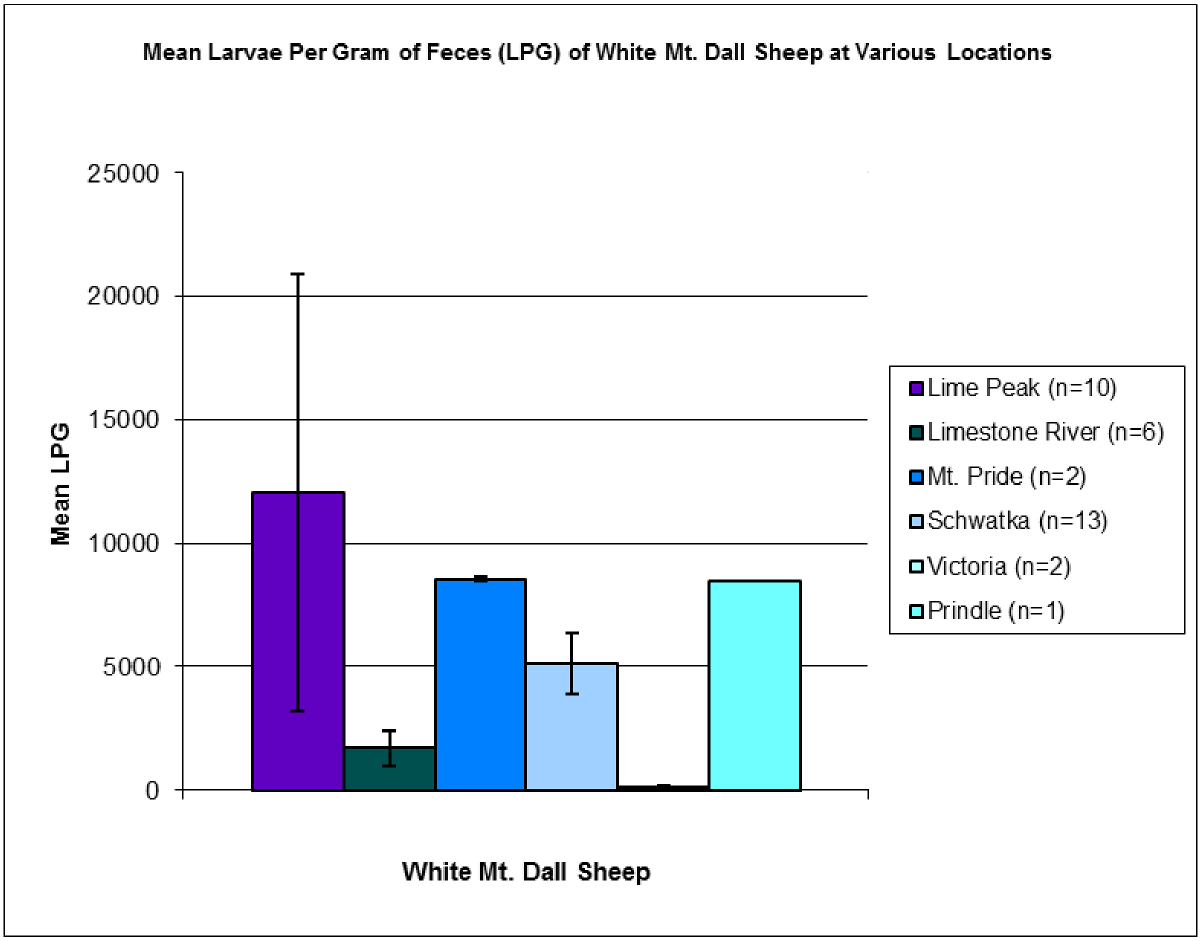
[1] Includes Cache Mountain

Appendix I-1. Summary of samples for larvae per gram of lungworm (Protostrongylus stilesi) in captured Dall's sheep by region, sex and age in the White Mountains, Alaska 2004.

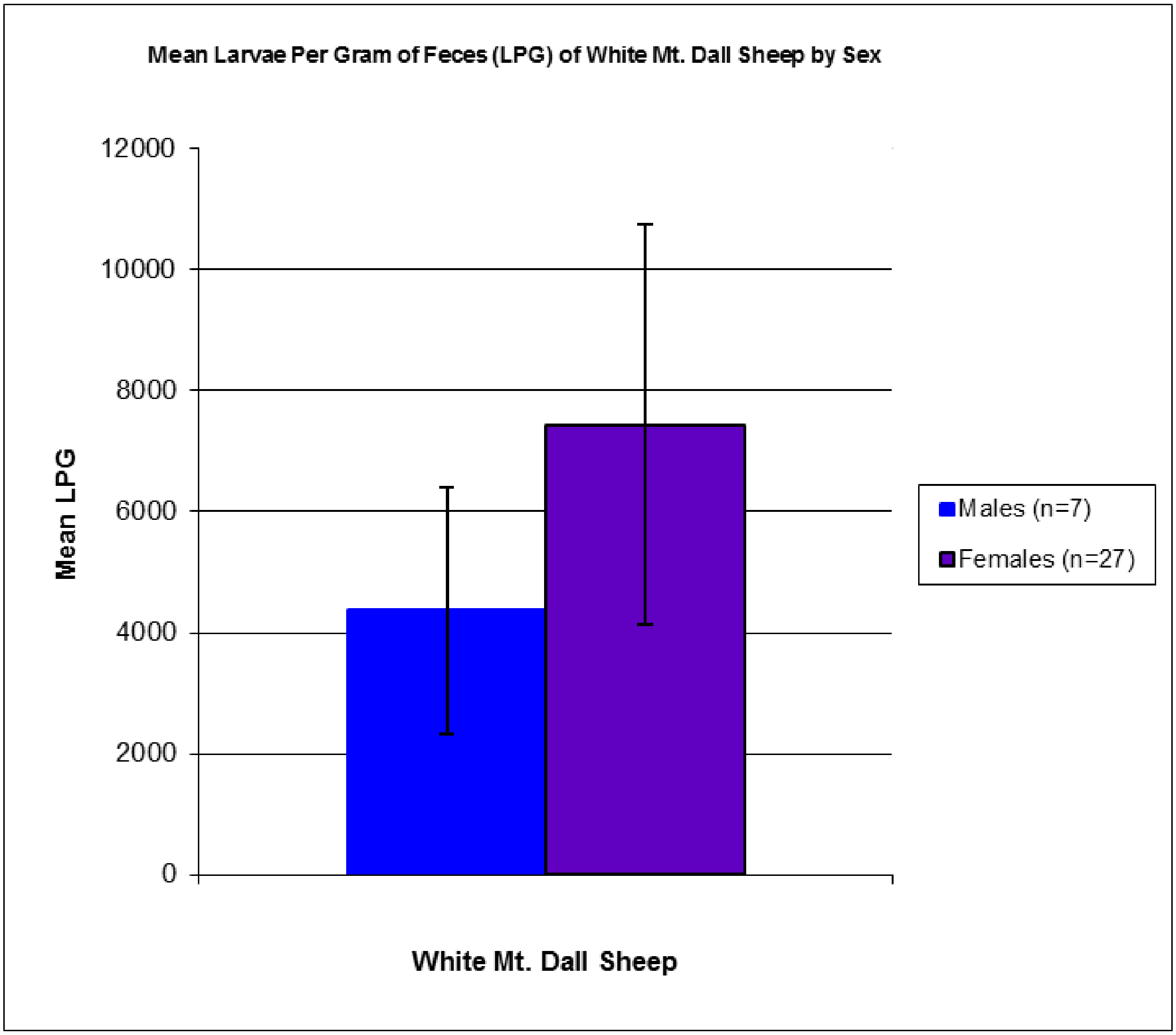
Region	Capture date	ID	Sex	Age	F.Wt. (g)	T.V. (mL)	Count 1	Count 2	Count 3	Mean larva/ aliquot (L1)	Total L1	LPG
Limestone Ridge	9/25/2004	12	Female	9	5	2.3	21	7	21	16.33	3756.67	751.33
Limestone Ridge	9/25/2004	13	Female	9	5	1.98	124	85	127	112.00	22176.00	4435.20
Limestone Ridge	9/25/2004	14	Female	8	5	1.38	54	66	26	48.67	6716.00	1343.20
Limestone Ridge	9/25/2004	15	Female	7	5	1.63	4	1	2	2.33	380.33	76.07
Limestone Ridge	10/17/2004	16	Male	2	5	1.48	118	111	107	112.00	16576.00	3315.20
Limestone Ridge	9/25/2004	18	Male	2	3.8	1.65	9	5	8	7.33	1210.00	318.42
Mount Prindle	9/22/2004	19	Female	6	5	1.97	720	377	403	500.00	42274.68	8454.94
Mount Prindle	9/22/2004	21	Female	3	1.4	1.78	100	48	56	68.00	12104.00	8645.71
Mount Prindle	10/20/2004	23	Female	11	3.3	1.68	317	368	312	332.33	55832.00	16918.79
Mount Schw atka	10/17/2004	24	Male	3	2.4	1.73	109	98	112	106.33	18395.67	7664.86
Mount Schw atka	10/17/2004	25	Female	8	4.7	1.33	5	9	5	6.33	842.33	179.22
Mount Schw atka	10/18/2004	26	Female	6	1.4	N/A	0	0	0	0.00	0.00	0.00
Mount Schw atka	10/18/2004	29	Female		4	1.78	191	185	222	199.33	35481.33	8870.33
Mount Schw atka	10/18/2004	30	Male		2.2	1.98	14	27	18	19.67	3894.00	1770.00
Mount Schw atka	10/18/2004	32	Female	8	2	1.73	68	54	48	56.67	9803.33	4901.67
Mount Schw atka	10/18/2004	33	Female	10	3.8	1.69	44	12	18	24.67	4168.67	1097.02
Mount Schw atka	10/18/2004	34	Female	7	5	0.83	450	398	437	428.33	35551.67	7110.33
Mount Schw atka	10/18/2004	35	Female	6	2.7	0.82	58	55	47	53.33	4373.33	1619.75
Mount Schw atka	10/18/2004	36	Female	9	4.8	1.53	41	32	37	36.67	5610.00	1168.75
Mount Schw atka	10/18/2004	37	Female	9	2	1.81	128	124	85	112.33	20332.33	10166.17
Mount Schw atka	10/17/2004	38	Female	7	2.5	1.78	107	120	123	116.67	20766.67	8306.67
Mount Schw atka	10/18/2004	39	Female	4	1.1	1.83	77	79	92	82.67	15128.00	13752.73
Rocky Mountain[1]	3/22/2004	4	Male	6	5.1	1.33	634	494	629	585.67	77893.67	15273.27
Rocky Mountain[1]	3/22/2004	5	Female	6	5.1	5.53	848	815	838	833.67	#######	90395.62
Rocky Mountain[1]	9/22/2004	6	Female	7	5.1	1.93	31	44	46	40.33	7784.33	1526.34
Rocky Mountain[1]	9/22/2004	7	Female	9	2.6	1.88	16	31	18	21.67	4073.33	1566.67
Rocky Mountain[1]	9/22/2004	8	Male	1	3.7	1.78	27	19	20	22.00	3916.00	1058.38
Rocky Mountain[1]	9/22/2004	9	Female	7	5	1.61	0	2	3	1.67	268.33	53.67
Rocky Mountain[1]	9/22/2004	10	Female	9	5	1.63	18	14	18	16.67	2716.67	543.33
Rocky Mountain[1]	9/22/2004	11	Male	3	2	1.7	19	13	12	14.67	2493.33	1246.67
Rocky Mountain[1]	11/9/2004	N04-023	Female	6	5	2.33	185	196	111	164.00	38212.00	7642.40
Rocky Mountain[1]	11/9/2004	N04-024	Female	4	1.29	1.73	10	9	7	8.67	1499.33	1162.27
Victoria Mountain		41	Female	6	0.8	1.23	2	0	0	0.67	82.00	102.50
Victoria Mountain	10/16/2004	17 mort	Female	7	2.6	1.48	3	3	4	3.33	493.33	189.74

[1] includes Cache Mountain

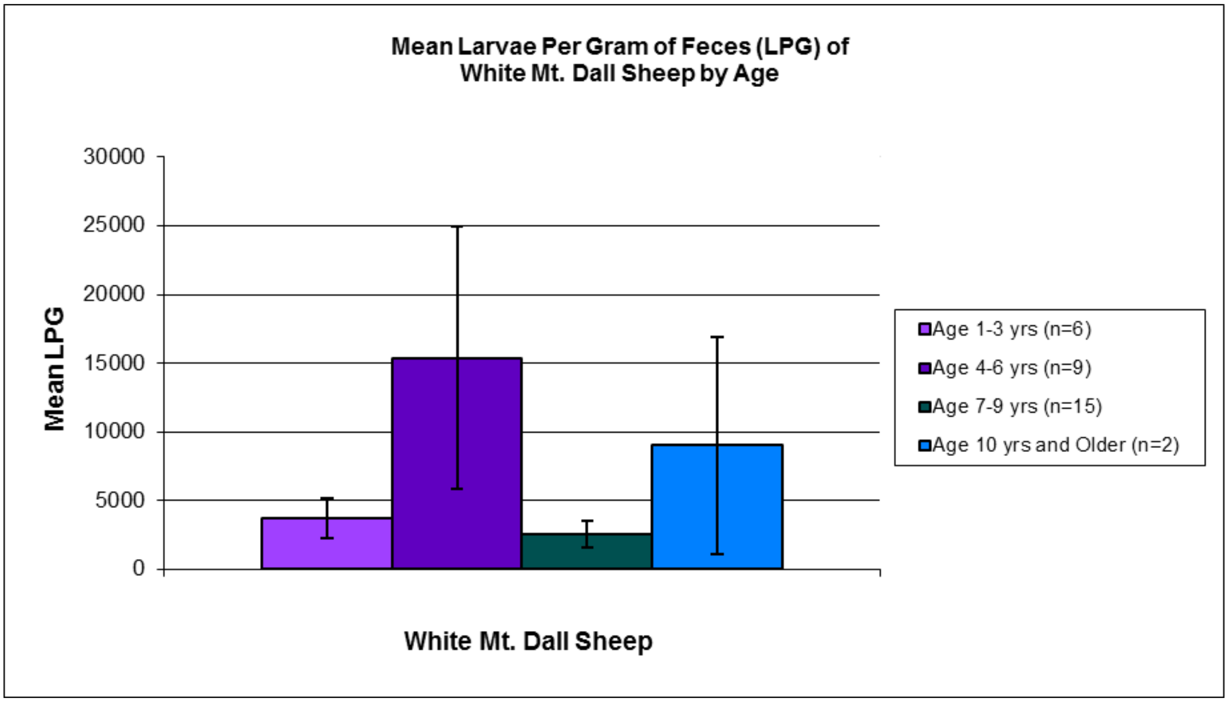
Appendix I-2. Mean larvae per gram of White Mountain Dall Sheep by region, 2004.



Appendix I-2 continued. Mean larvae per gram of White Mountain Dall Sheep by sex, 2004.



Appendix I-2 continued. Mean larvae per gram of White Mountain Dall Sheep by age, 2004.



Appendix J. Final report on trace minerals in White Mountains Dall's sheep hair, serum and whole blood by Sarah Moses; including summary of interpretations by Dr. Kimberlee Beckmen.

TO: KIMBERLEE BECKMEN (ALASKA DEPARTMENT OF FISH AND GAME)
FROM: SARA MOSES (UNIVERSITY OF ALASKA FAIRBANKS WILDLIFE TOXICOLOGY LABORATORY)
SUBJECT: TRACE MINERALS IN WHITE MOUNTAINS DALL'S SHEEP HAIR, SERUM AND WHOLE BLOOD
DATE: SEPTEMBER 1, 2006
CC: TODD O'HARA, KATRINA KNOTT, RHONDA SWOR (UAF WTL)

Summary

Trace minerals in hair (*n* = 39), serum (*n* = 28) and whole blood (*n* = 24) samples from Dall's sheep were analyzed at the Wildlife Toxicology Laboratory (WTL) at the University of Alaska Fairbanks (UAF). Hair was analyzed for cadmium (Cd), copper (Cu), iron (Fe), total mercury (THg) and selenium (Se). Serum was analyzed for Cd, Cu, Fe, and zinc (Zn). Whole blood was analyzed for Se only. The samples were collected from the White Mountains region of Alaska by the Alaska Department of Fish and Game (ADF&G) and other agencies throughout 2004. All samples were digested using a closed microwave digestion method and analyzed via atomic absorption spectrometry (AA) or cold vapor atomic fluorescence spectrometry (CVAFS; Hg only). Samples were analyzed according to strict internal QA/QC standards. A summary of the results are shown in Table I below. An additional six hair (Cd, Cu, Fe, Se, Zn), three serum (Cd, Cu, Fe, Zn) and three whole blood (Se) samples from Dall's sheep were analyzed for comparison to animals collected at other locations or times.

Table I: Range and arithmetic mean (± standard deviation) of trace minerals in hair (*n* = 39), serum (*n* = 28) and whole blood (*n* = 24) samples from White Mountains Dall's sheep on a fresh weight basis

Element	Hair Concentration		Serum/Whole Blood Concentration[1]	
	Range	Mean (±SD)	Range	Mean (±SD)
Cadmium (ppb)	10.94-932.88	72.62 (±147.14)	All BDL[2]	All BDL[2]
Copper (ppm)	1.40-12.60	4.45 (±1.98)	0.84-2.23	1.37 (±0.27)
Iron (ppm)	60.37-1494.10	356.8 (±269.0)	5.29-28.71	9.54 (±4.76)
Total Mercury (ppb)	BDL[2]-16.35	6.96 (±3.79)[4]	NA[3]	NA[3]
Selenium (ppb)	70.90-2558.45	351.03 (±394.67)	82.62-399.41	172.53 (±77.78)
Zinc (ppm)	NA[3]	NA[3]	0.291-1.149	0.62 (±0.17)

[1] Selenium was determined in whole blood. All other elements were determined in serum.
[2] BDL = Below Detection Limit (approximately 2ppb for THg in hair and 0.5 ppb for Cd in serum)
[3] Total mercury in serum and zinc in hair were not analyzed
[4] Mean and standard deviation for THg calculated by assigning all samples BDL = 2ppb, the detection limit

Method Overview

Prior to digestion, all hair samples were washed three times with Ultrapure water to remove any external contamination and allowed to dry completely prior to digestion. Hair, serum and whole blood samples were then digested by a closed microwave (Multiwave 3000, Anton Paar) procedure using a combination of nitric acid and hydrogen peroxide. Cu, Fe and Zn concentrations were determined in the digests using a flame ionization technique for atomic absorption spectrometry (AA; Perkin Elmer, AAnalyst 800). Cd concentrations were determined using an AA furnace technique. Se concentrations were determined using a mercury hydride system/flow injection analysis system (MHS/FIAS) AA technique. Finally, the concentration of THg was determined using a "purge and burn" technique via cold vapor atomic fluorescence spectrometry (CVAFS; Brooks Rand; method modified from EPA Method 1631) after stabilizing the mercury in the digests through the addition of hydrochloric acid. Detailed SOPs are available upon request.

All reported values are on a "fresh weight" basis, calculated as a concentration. For hair, fresh weight should be approximately equivalent to "dry weight" since the water content in minimal, although percent moisture was not determined in hair samples. For whole blood and serum, fresh weight is equivalent to "wet weight". Each sample was run in triplicate and the arithmetic mean is reported here.

Quality Assurance/Quality Control (QA/QC)

Internal QA/QC checks included method blanks, method blank spikes, sample spikes and duplicate sample analysis. Exercises with the Texas A&M University Trace Element Research Laboratory (TAMU TERL) are also conducted as part of our ongoing QA/QC effort.

Results and Discussion

Trace mineral (Cd, Cu, Fe, THg, Se, Zn) concentrations in White Mountains Dall's sheep hair, serum and whole blood are detailed in Appendix A. A summary has been provided above (Table I).

An additional six hair (Cd, Cu, Fe, Se, Zn), three serum (Cd, Cu, Fe, Zn) and three whole blood (Se) samples from Dall's sheep were analyzed for comparison to animals collected at other locations or times. The detailed results are provided in Appendix B. A summary appears in Table II below.

Table II: Range and arithmetic mean (± standard deviation) of trace minerals in hair (*n* = 6), serum (*n* = 3) and whole blood (*n* = 3) samples from Dall's sheep comparison animals on a fresh weight basis

Element	**Hair Concentration**		**Serum/Whole Blood Concentration**[1]	
	Range	**Mean (±SD)**	**Range**	**Mean (±SD)**
Cadmium (ppb)	BDL[2]-548.49	106.1 (±217.4)	All BDL[2]	All BDL[2]
Copper (ppm)	1.87-6.27	3.67 (±1.48)	0.61-1.09	0.90 (±0.26)
Iron (ppm)	51.8-443.6	285.1 (±292.3)	6.50-9.22	7.75 (±1.37)
Selenium (ppb)	94.31-283.58	155.27 (±71.41)	44.24-275.76	131.75 (±125.67)
Zinc (ppm)	28.96-94.24	49.53 (±23.37)	0.56-1.09	0.86 (±0.27)

[1] Selenium was determined in whole blood. All other elements were determined in serum.
[2] BDL = Below Detection Limit (approximately 0.5ppb for Cd in hair and serum)

Trace mineral concentrations in White Mountains Dall's sheep were compared to reference values available for domestic sheep (Puls 1994), shown in Table III and IV below.

Table III: Reference values for mineral levels in the wool of domestic sheep, ppm dry weight (Puls 1994)[1]

	Cadmium	**Copper**	**Iron**	**Selenium**	**Zinc**
Deficient	NA	0.5 – 2.5	NA	0.03 – 0.30	< 70
Marginal	NA	2.0 – 4.0	NA	0.06 -0.20	80 – 100
Adequate	NA	2.8 – 10	NA	0.20 – 4.00	70 – 130
Normal	0.20 – 1.22	NA	17 – 22	NA	NA
High	NA	NA	NA	NA	102-115
Toxic	> 20	NA	NA	NA	100-145

[1] No reference values are available for total mercury.

Table IV: Reference values for mineral levels in the serum (Cd, Cu, Fe, Zn) and whole blood (Se) of domestic sheep, ppm wet weight (Puls 1994) [1]

	Cadmium	Copper	Iron	Selenium[2]	Zinc
Deficient	NA	0.10 – 1.00	< 1.60	0.006 – 0.030	0.22 – 0.45
Marginal	NA	0.40 – 1.00	NA	0.030 – 0.060	0.40 – 0.80
Adequate	NA	0.70 – 2.00	1.66 – 2.22	0.080 – 0.400	0.80 – 1.20
Normal	NA	NA	NA	NA	NA
High	NA	1.00 – 5.00	NA	NA	4.00 – 5.00
Toxic	NA	3.30 – 20.0	NA	> 3.00	30.0 – 50.0

[1] No reference values are available for total mercury.
[2] Selenium reference value is for whole blood. All other mineral reference values are for serum.

All White Mountains Dall's sheep hair samples were within or below the normal range for cadmium in wool. No reference values are available for cadmium in sheep serum, but all Dall's sheep were below the instrumental detection limit for cadmium in serum.

Copper in Dall's sheep hair ranged from deficient to above adequate for individual samples, with the mean falling in the adequate range. 36 of the 39 hair samples were at or above the adequate level for copper. Copper in serum samples ranged from adequate to high, with the mean falling in the adequate range. 27 of 28 samples were within the adequate range for Cu in serum.

All hair and serum samples had Fe concentrations above the reference adequate range for iron.

Hair was marginal to adequate for selenium. 26 of the 39 hair samples were in the adequate range for Se and the rest were marginal. Whole blood selenium ranged from marginal to adequate. Nine of 24 whole blood samples were within the adequate range for Se, whereas the remaining 15 were within the marginal range.

Zinc was not analyzed in hair. Serum samples ranged from deficient to adequate in zinc. Six of 28 serum samples were adequate, but the rest were only marginal to deficient in zinc.

References

Puls, R. 1994. *Mineral levels in animal health: Diagnostic data (2nd ed.)*. Sherpa International, Clearbrook, British Columbia, Canada.

APPENDIX A

Individual Sample Trace Mineral Concentrations
(Table A.1 – Table A.6)

Contents

Table A.1: Cadmium (Cd) concentration (ppb fresh weight) of White Mountains Dall's sheep hair (*n* = 39) and serum (*n* = 28) samples (not analyzed in whole blood)

ADF&G Animal ID (WM-_)	Hair Cadmium Concentration (ppb)	Serum Cadmium Concentration (ppb)
3	NA[1]	BDL[2]
4	35.29	NA[1]
5	15.27	BDL[2]
6	65.09	BDL[2]
7	23.02	BDL[2]
8	179.19	BDL[2]
9	11.89	BDL[2]
10	23.92	BDL[2]
11	11.32	BDL[2]
12	11.21	BDL[2]
13	35.02	BDL[2]
14	161.01	BDL[2]
15	39.48	BDL[2]
16	31.65	BDL[2]
17	41.25	BDL[2]
18	55.21	NA[1]
19	66.26	NA[1]
20	18.50	BDL[2]
21	38.46	BDL[2]
22	26.02	NA[1]
23	121.15	BDL[2]
24	35.43	BDL[2]
25	121.87	NA[1]
26	33.29	NA[1]
29	932.88	BDL[2]
30	72.94	BDL[2]
31	58.75	NA[1]
32	19.83	BDL[2]
33	10.94	BDL[2]
34	33.59	BDL[2]
35	36.73	BDL[2]
36	102.16	NA[1]
37	111.00	BDL[2]
38	57.96	BDL[2]
39	18.99	BDL[2]
40	38.98	NA[1]
41	45.47	BDL[2]
N04-24	11.50	NA[1]
2004-102	53.36	NA[1]
N04-23	26.20	NA[1]

[1] NA = Samples not available
[2] BDL = Samples below detection limit

Table A.2: Copper (Cu) concentration (ppm fresh weight) of White Mountains Dall's sheep hair (*n* = 39) and serum (*n* = 28) samples (not analyzed in whole blood)

ADF&G Animal ID (WM-_)	Hair Copper Concentration (ppm)	Serum Copper Concentration (ppm)
3	NA[1]	1.56
4	3.75	NA[1]
5	4.29	2.23
6	3.85	1.81
7	4.00	1.46
8	4.17	1.55
9	4.37	1.58
10	12.60	1.51
11	4.19	1.67
12	4.70	1.42
13	3.30	1.40
14	5.54	1.59
15	4.13	1.31
16	3.91	1.42
17	4.96	1.32
18	4.50	NA[1]
19	2.31	NA[1]
20	1.40	1.26
21	2.87	1.40
22	2.94	NA[1]
23	3.79	1.01
24	3.60	1.10
25	2.38	NA[1]
26	4.47	NA[1]
29	8.61	1.16
30	5.61	1.28
31	4.24	NA[1]
32	3.40	1.17
33	2.90	0.84
34	4.53	1.13
35	6.77	1.42
36	8.92	NA[1]
37	5.46	1.20
38	3.72	1.43
39	3.40	1.06
40	4.38	NA[1]
41	4.24	1.19
N04-24	3.64	NA[1]
2004-102	4.71	NA[1]
N04-23	2.88	NA[1]

[1] NA = Samples not available

Table A.3: Iron (Fe) concentration (ppm fresh weight) of White Mountains Dall's sheep hair (*n* = 39) and serum (*n* = 28) samples (not analyzed in whole blood)

ADF&G Animal ID (WM-_)	Hair Iron Concentration (ppm)	Serum Iron Concentration (ppm)
3	NA[1]	8.05
4	210.70	NA[1]
5	294.79	19.98
6	428.03	9.50
7	240.71	6.59
8	199.57	7.16
9	296.04	13.79
10	243.19	5.91
11	356.22	6.33
12	1494.10	5.29
13	93.66	6.15
14	341.98	8.04
15	310.69	7.61
16	344.20	6.15
17	383.63	9.75
18	408.49	NA[1]
19	185.62	NA[1]
20	183.07	8.47
21	345.38	10.71
22	249.89	NA[1]
23	187.78	7.25
24	172.55	8.42
25	60.37	NA[1]
26	351.52	NA[1]
29	1180.07	8.94
30	238.53	11.25
31	323.68	NA[1]
32	136.91	8.98
33	220.25	12.26
34	713.98	8.80
35	317.03	8.37
36	439.69	NA[1]
37	549.31	7.19
38	480.61	28.71
39	329.32	9.57
40	558.12	NA[1]
41	238.48	7.94
N04-24	213.20	NA[1]
2004-102	442.92	NA[1]
N04-23	149.92	NA[1]

[1] NA = Samples not available

Table A.4: Total mercury (THg) concentration (ppb fresh weight) of White Mountains Dall's sheep hair (*n* = 37) (not analyzed in serum or whole blood)

ADF&G Animal ID (WM-_)	Hair Total Mercury Concentration (ppb)
4	BDL[2]
5	7.82
6	16.35
7	10.59
8	6.54
9	9.94
10	10.00
11	7.04
12	3.45
13	6.79
14	12.16
15	2.88
16	4.94
17	7.42
18	BDL[2]
19	BDL[2]
20	BDL[2]
21	9.42
22	6.40
23	8.29
24	10.75
25	6.60
26	13.86
29	NA[1]
30	NA[1]
31	6.97
32	6.30
33	8.68
34	8.38
35	4.55
36	5.09
37	BDL[2]
38	9.45
39	BDL[2]
40	7.98
41	2.07
N04-24	15.00
2004-102	4.71
N04-23	4.99

[1] NA = Not Available (Analytic error. No sample available to reanalyze)
[2] BDL = Samples below detection limit

Table A.5: Selenium (Se) concentration (ppb fresh weight) of White Mountains Dall's sheep hair (*n* = 39) and whole blood (*n* = 24) samples (not analyzed in serum)

ADF&G Animal ID (WM-_)	Hair Selenium Concentration (ppb)	Whole Blood Selenium Concentration (ppb)
2	NA[1]	82.62
4	368.05	223.26
5	169.61	83.36
6	183.34	170.11
7	153.95	NA[1]
8	179.30	89.09
9	144.28	126.02
10	139.64	103.89
11	165.55	NA[1]
12	213.87	123.96
13	135.99	141.79
14	184.27	125.36
15	112.98	112.00
16	164.21	138.82
17	256.71	NA[1]
18	586.66	178.09
19	209.41	NA[1]
20	298.55	NA[1]
21	459.29	NA[1]
22	537.06	NA[1]
23	271.30	229.67
24	488.80	231.48
25	204.20	85.05
26	365.37	NA[1]
29	296.42	224.00
30	240.53	203.75
31	2558.45	NA[1]
32	359.41	NA[1]
33	427.07	399.41
34	234.24	141.82
35	320.22	241.85
36	553.78	155.58
37	385.94	NA[1]
38	776.43	NA[1]
39	436.22	221.64
40	396.12	308.11
41	327.72	NA[1]
N04-24	218.20	NA[1]
2004-102	96.01	NA[1]
N04-23	70.90	NA[1]

[1] NA = Not Available

Table A.6: Zinc (Zn) concentration (ppm fresh weight) of White Mountains Dall's sheep serum (*n* = 28) (not analyzed in hair or whole blood)

ADF&G Animal ID (WM-_)	Serum Zinc Concentration (ppm)
3	0.524
5	0.603
6	0.559
7	0.682
8	0.526
9	0.549
10	0.533
11	0.566
12	0.586
13	0.509
14	0.546
15	0.891
16	0.466
17	0.458
20	0.414
21	0.676
23	0.827
24	0.589
29	0.497
30	0.595
32	0.445
33	0.436
34	0.976
35	0.960
37	0.647
38	0.909
39	0.611
41	0.906

APPENDIX B

Trace Mineral Concentrations of Comparison Animal Samples
(Table B.1 – Table B.5)

Contents

Table B.1: Cadmium (Cd) concentration (ppb fresh weight) of hair (*n* = 6) and serum (*n* = 3) samples (not analyzed in whole blood) from Dall's sheep comparison animals

ADF&G Animal ID	Hair Cadmium Concentration (ppb)	Serum Cadmium Concentration (ppb)
WM42	42.16	NA[1]
WM43	33.81	BDL[2]
WM44	BDL[2]	BDL[2]
N04-205	548.49	NA[1]
LCDS05-01	4.77	BDL[2]
LCDS05-02	7.49	NA[1]

[1] NA = Samples not available
[2] BDL = Samples below detection limit

Table B.2: Copper (Cu) concentration (ppm fresh weight) of Dall's sheep hair (*n* = 6) and serum (*n* = 3) samples (not analyzed in whole blood) from Dall's sheep comparison animals

ADF&G Animal ID	Hair Copper Concentration (ppm)	Serum Copper Concentration (ppm)
WM42	4.12	NA[1]
WM43	3.04	1.09
WM44	3.67	0.61
N04-205	6.27	NA[1]
LCDS05-01	3.07	1.01
LCDS05-02	1.87	NA[1]

[1] NA = Samples not available

Table B.3: Iron (Fe) concentration (ppm fresh weight) of Dall's sheep hair (*n* = 6) and serum (*n* = 3) samples (not analyzed in whole blood) from Dall's sheep comparison animals

ADF&G Animal ID	Hair Iron Concentration (ppm)	Serum Iron Concentration (ppm)
WM42	152.83	NA[1]
WM43	443.56	6.50
WM44	157.64	7.54
N04-205	811.50	NA[1]
LCDS05-01	93.21	9.22
LCDS05-02	51.79	NA[1]

[1] NA = Samples not available

Table B.4: Selenium (Se) concentration (ppb fresh weight) of Dall's sheep hair (*n* = 6) and whole blood (*n* = 3) samples (not analyzed in serum) from Dall's sheep comparison animals

ADF&G Animal ID	Hair Selenium Concentration (ppb)	Whole Blood Selenium Concentration (ppb)
WM42	283.58	NA[1]
WM43	94.31	75.26
WM44	138.61	275.76
N04-205	189.57	NA[1]
LCDS05-01	101.64	44.24
LCDS05-02	123.89	NA[1]

[1] NA = Samples not available

Table B.5: Zinc (Zn) concentration (ppm fresh weight) of Dall's sheep serum (*n* = 3) (not analyzed in hair or whole blood) from Dall's sheep comparison animals

ADF&G Animal ID	Hair Zinc Concentration (ppm)	Serum Zinc Concentration (ppm)
WM42	52.63	NA[1]
WM43	35.69	0.93
WM44	45.76	0.56
N04-205	94.24	NA[1]
LCDS05-01	39.90	1.09
LCDS05-02	28.96	NA[1]

[1] NA = Samples not available

Appendix J continued.

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

DIVISION OF WILDLIFE CONSERVATION

FRANK H. MURKOWSKI, GOVERNOR

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MEMORANDUM

TO: Tom Seaton, Jim Herriges, Mark Bertram And Jim Lawler

DATE: 9/7/06
TELEPHONE: 907-459-7257

FROM: Dr. Kimberlee Beckmen

SUBJECT: Dall sheep trace mineral analysis

Please find attached the laboratory report from the Wildlife Toxicology Laboratory at UAF containing trace minerals analysis of samples collected during live-capture and post-mortem examinations.

As you'll recall, the reason for this undertaking was to discover if the occurrence of 'stump headed" sheep in the White Mountains was related to a deficiencies of one or more trace minerals. The study was expanded when two spinal fracture/capture myopathy deaths, also typically related to trace mineral/vitamin deficiencies, were detected during the initial live-capture operations. We are hindered by that lack of other Dall Sheep populations to compare to. In these results you'll see some data from a yearling male who died in a disease die-off in Denali in July and samples from two Lake Clark sheep (for which I do not have sex, age, capture date or location data). In this memo I will summarize and give a brief interpretation of the UAF results. I have just received them and thus have not had a chance to apply any statistical analysis or compare to other wild sheep. I will write a project report and sent it along to you later.

Brief summary of UAF data: Sheep hair, blood and serum were analyzed for Copper, Selenium, Cadmium, Mercury, Zinc and Iron. Not all tissues were available from every animal and not all elements were analyzed in every tissue. When comparing the results, note that some are presented in ppb while the reference values are in ppm so the decimal must be moved to 3 places to the right to convert ppm to ppb. Note that the 2004 and 2005 capture data are separate in the report but I combined them for the percentages below. The non-White Mountains (WM) Dall sheep are mentioned separately.

SELENIUM: Sixty-two percent of White Mountains Dall sheep hair samples had marginal levels of selenium (below what is acceptable for healthy domestic sheep wool). In whole blood, 23.8% were marginal. The second lowest concentration in hair and lowest concentration in blood were from one of the capture myopathy cases (N04-23 = WM-2) and the next lowest in hair was from the stumpy 2004-102. I interpret these results to indicate that a significant proportion of White Mountain Dall Sheep have inadequate dietary selenium and clinical disease (susceptibility to capture myopathy) is likely a result of this deficiency. The interpretation of the relationship of trace mineral status and the proximate cause of Stumpy-headedness however is complicated by the fact that the one live captured stumpy, WM31, had the highest level of selenium in hair and no blood sample was available. Fortunately, I just received a liver sample (and hair will be available) from another WM stumpy from this years hunt. I intend to look at all the data with age, sex and capture location once I receive the electronic results. It appears from a visual inspection that sheep captured at Schwatka were less likely to be deficient in Se. The Lake Clark and Carlo Creek sheep were also deficient in selenium in hair. One liver sample from a pregnant Dall sheep near Anchorage (Windy Gap) had a liver selenium level (determined at U of Idaho) of 230ppb which would be in the adequate range. In a study of Bighorn sheep in Wyoming, they found that lambs with nutritional muscular dystrophy, also known as nutritional myopathy or ‘white muscle disease’ (which is histologically nearly indistinguishable from capture myopathy) and lungworm pneumonia were related to selenium in forage and that supplementary salt licks decreased the incidence of disease and shedding of lungworm larvae. In that study, forage analysis showed that it was summer range with very wet conditions that had poor plant uptake of selenium that likely led to the situation.

COPPER: The results from hair reveal that 7.1% of WM sheep were deficient in copper and 40.5% were marginal compared to domestic sheep. Like selenium, copper is essential for immune function and integument (hair, skin, hooves) health. It is important to keep in mind that domestic and wild sheep are very sensitive to copper levels, both deficiencies and toxicities. Additionally, trace elements interact and excess or deficiencies can affect the needs of other elements. In the case of copper and selenium, marginal levels of both may augment the adverse effects to manifest a deficiency at those levels. Again, my interpretations of these results are that about a third of WM sheep are also copper deficient. I’ll be looking at correlations between the various elemental levels in individuals. The two sheep from Lake Clark also had marginal to deficient copper levels in hair while the Carlo Creek and Anchorage area sheep had adequate levels.

Zinc: When compared to domestic sheep, 66.7% of WM Dall sheep are marginal and 15% deficient in Zinc. Zinc is also a trace element important for integument. Certain breeds of animals (i.e. huskies) have higher zinc needs that normal to maintain normal foot health and hair coats. As mentioned above, marginal zinc may contribute to the exacerbation of the other marginal elemental levels. In the Bighorn sheep study mentioned above, those animals were also low on zinc.

Cadmium: All but one WM Dall sheep hair sample and all serum were below normal levels for domestic sheep. We analyzed for this one because of its key interactions with the others.

Mercury: Some good news here, there is no concern for the levels of total mercury in any of the sheep. Liver concentrations of total mercury are below the levels of concern for human consumption.

Iron: Concentrations of iron in hair and serum are above the adequate range.

Note: The 3 WM sheep samples from March 2004 that were analyzed for Vitamin E were all severely deficient.

Recommendations for future analysis and studies:

1. Analyze all available (and continue to collect) sera, blood, liver and hair samples from Dall sheep for Se, Zn, Cu and Vitamin E.
2. Concurrently analyze feces for lungworm shedding (larvae per gram).
3. Get resample blood analysis on the WM sheep that have been given BoSE at capture. (Is there lamb survival data on the radiocollared animals?)
4. Consider forage studies including analysis of summer and winter forage for different population.
5. Consider weather and soil studies in conjunction with forage study.
6. There are a number of larger studies that could be conducted. With a little more information, we could also consider a treatment manipulation (i.e. trace mineral blocks).
7. Be sure to resample hair (and liver, lung, feces if available) when radio collars are picked up from mortalities.
8. Analyze archived serum and fresh blood for other health parameters (serum chemistry, disease serology)

There are 18 sera and 9 blood samples from Lake Clark Dall sheep that should be top priority. Is there funding available for NPS for the trace minerals analysis and parasitology on those samples?

It is too late for this season but perhaps in the future we could require a hair sample from all hunter-harvested sheep (they have to bring in the horns for sealing and a horn core sample is being collected now).

Cc: Judy Putera, Don Young

Appendix K1. Historical summary of sheep surveys on Victoria Mountain-1944 to 2018[1].

	Rams							
Date	Legal	Sublegal	Ewes	Lambs	Yrlg	Unid.	Total	Observers
1944							57	Unknown
8/25/1949							42	R. Scott
6/26/1953				24			95	D. Klein
7/6/1955	33		342	19		15	101	D. Klein
9/1/1957							52	Unknown
7/14/1960							45	F. Jones
7/19/60[3]	18		602	32			110	F. Jones
7/3/1962							61	F. Jones
8/28/1970	0	2	41	17			60	A. Smith
1970	5	10	11	1			27	A. Smith
6/27/1982	0	5	10	1	1	1	18	D. Haggstrom
6/30/1982	0	0	3	2	1		6	D. Haggstrom
6/27-29/86	0	1	19	6			26	E. Crain and B.Lentsch
8/1/1992	1	0	4	3			8	J. Herriges and W. Hobgood
8/4/1994	0	0	21	11			32	M. Bertram and M. Vivion
8/11/1995	0	0	31	19			50	M. Bertram and M. Vivion
8/5/1996	0	0	34	13			47	J. Akaran and Ml. Vivion
7/24/1999	0	2	73	28			103	J. Akaran and M. Vivion
7/29/2000	0	3	24	7			34	J. Akaran and M. Vivion
8/1/2001	0	4	24	5			33	J. Akaran and M. Vivion
7/23/2002	0	0	25	12			37	J. Akaran and M. Vivion
7/19/2003	0	1	66	23			88	M. Bertram and M. Vivion
8/5/2004		7	26	6			39	J. Akaran and M. Vivion
7/23/2005	4	4	40	8			56	M. Bertram and M. Vivion
8/1/2006		6	42	7			55	M. Bertram and N. Guldager
7/5/2007	1	6	49	15			71	J. Akaran and N. Guldager
7/23/2008	4		48	18			70	J. Akaran and N. Guldager
7/14/2011		9	35	15			59	J. Akaran and N. Guldager
7/12/2012		20	13	6			39	B. Lake and N. Guldager
8/7/2013	4	13	22	4			43	B. Lake and M. Hinkes
7/30/2014	2	8	6	3			19	B. Lake and N. Guldager
7/13/2015	1	6	35	10			52	B. Lake and N. Guldager
7/7/2016		1	2	1			4	B. Lake and N. Guldager
7/14/2017		1	13	5			19	B. Lake and N. Guldager
7/25/2018		7	5				12	J. Hughley and N. Guldager

[1] data from Kaye 1982, Eagen 1993, Herriges 1993 to 2002, Seaton 2003.

[2] includes yearlings

[3] Schwatka and Victoria Mountains combined

Appendix K2. Historical summary of sheep surveys on Mt. Schwatka-1929 to 2018[1].

	Rams							
Date	Legal	Sublegal	Ewes	Lambs	Yrlg	Unid.	Total	Obserers
1929							30	J. Mertie
8/25/1949							15	R. Scott
5/1/1957							10	J. Gross
7/14/1960							65	F. Jones
7/3/1962							59	F. Jones
8/28/1970	11	7	55	28			101	A. Smith
1973	5	9	36	12	3		65	ADFG
1974	8	21	40	9	12		90	ADFG
1975	2	14	42	7	3		68	ADFG
8/5-8/77	8	6	31	11			56	A. Smith
7/25/1980	13	5	32	19	5		74	E. Crain and R. Kaye
7/18/1981	1	12	30	20	13		76	E. Crain and R. Kaye
6/30/1982	8	15	34	3	16		78	E. Crain and R. Kaye
6/27/1982	0	7	23	0	9		39	D. Haggstrom
6/30/1982	9	9	52	3	1		74	D. Haggstrom
6/27-29/86	5	9	46	15			75	E. Crain and B. Lentsch
8/4/1989	0	6	51	6		14	77	R. Beasley and B. Lentsch
10/2/1992	1	16	63	19		30	129	S. Watson
8/1/1992	21	3	82	4			110	J. Herriges and W. Hobgood
8/4/1994	0	0	56	14			70	M. Bertram and M. Vivion
8/11/1995	0	12	65	18			95	M. Bertram and M. Vivion
8/5/1996	2	9	91	27			129	J. Akaran and M. Vivion
8/5/1997	2	10	86	22			120	J. Akaran and M. Vivion
7/24/1999	3	22	122	69			216	J. Akaran and M. Vivion
7/29/2000	5	26	129	7			168	J. Akaran and M. Vivion
8/1/2001	9	13	68	13			103	J. Akaran and M. Vivion
7/23/2002	2	30	95	25			152	J. Akaran and M. Vivion
7/19/2003	3	32	82	20			137	M. Bertram and M. Vivion
8/5/2004	4	29	61	21			115	J. Akaran and M. Vivion
7/23/2005	3	30	92	21			146	M. Bertram and M. Vivion
7/29/2006		27	75	12			114	M. Bertram and N. Guldager
7/5/2007	6	16	73	34			129	J. Akaran and N. Guldager
7/23/2008	14	15	90	50			169	J. Akaran and N. Guldager
7/14/2011	6	33	126	29			193	J. Akaran and N. Guldager
7/12/2012	3	38	107	23			171	B. Lake and N. Guldager
8/7/2013	3	24	65	10			102	B. Lake and M. Hinkes
7/30/2014		12	64	19			95	B. Lake and N. Guldager
7/13/2015		9	45	3			57	B. Lake and N. Guldager
7/7/2016	2	12	50	6			70	B. Lake and N. Guldager
7/14/2017	6	13	57	40			116	B. Lake and N. Guldager
7/25/2018	4	5	53	12			74	J. Hughley and N. Guldager

[1] data from Kaye 1982, Eagen 1993, Herriges 1993 to 2002, Seaton 2003.