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Spatial and temporal response of grizzly bears to recreational use on trail

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SPATIAL AND TEMPORAL RESPONSE OF GRIZZLY BEARS TO RECREATIONAL USE ON TRAILS

By

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ABSTRACT

Many human activities affect how bears use habitat. The effects of motorized recreational vehicle use on trails have not been formally assessed previously. I used hourly locations from four GPS-collared female bears in the Badger-Two Medicine area in the Lewis and Clark National Forest to assess spatial and temporal distributions of bears relative to trail locations and to recreational use on trails. When availability was defined by circles equal to 95 % of move distances around the previous bear location, all bears used areas near trails less than expected. I iteratively reclassified trail habitat versus non-trail habitat as increasing buffers in 50 m increments around trails until I reached a buffer-width at which bears used areas near trails in proportion to availability. Compositional analysis results showed that bears selected against areas within 250 - 900 m from ATV trails and within 450 - 600 m from single-track trails, which had some motorbike use. The distance from trails at which bear use approximated availability varied by individual bear, by time of day, and by type of trail. Log-ratio differences were used to assess selection. Because log-ratio difference vectors were not normally distributed, I also used Friedman's test, a non-parametric method that is subject to the unit-sum constraint to estimate the distance at which selection of non-trail habitat became statistically insignificant. Friedman's test yielded similar results, but with lower effect sizes, which is a consequence of the more conservative nature of non-parametric tests.

ACKNOWLEDGMENTS

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Dr. Christopher Servheen gave me the opportunity to take on this project. He helped me to find sufficient funding and provided endless encouragement and the chance to see many hatfuls of scat as well as many live bears. I greatly appreciate his guidance and support. Dr. Don Christian provided helpful suggestions, thought-provoking ideas, and excellent editing. I thank Dr. Elizabeth Crone for challenging me to conduct the most appropriate analyses and for her support on my committee. Dr. Rick Mace provided fresh perspective and great ideas for rounding out my thesis. I'd like to thank Dr. Jon Graham for the enthusiasm he brought to the statistics courses I took from him and for answering both "quick" and not-so-quick statistical questions. I would also like to thank Dr. Mark Lindberg for stressing the importance of biological significance from the beginning of my project. Thanks also to all of the graduate students who gave me advice and support on my project, especially John Waller, who shared an office, data, and his expertise in analysis of bears and habitat use with me.

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I thank all of my field assistants, Megan Puchlerz, Julie Fuller, Jill Schoemaker, Kamille Rogers, and Bill Long, who persevered through flat tires, motion sickness, and dead batteries and helped me to collect the data to show that indeed, there weren't very many people out there! It was fun. Ruth Roberson and Kelsey Chapman helped to collect and process the trail data layer used in the analysis. Lauren Caldwell and Sundai Brown assisted with data entry.

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Finally, I'd also like to thank all the people who recreate in the Badger-Two Medicine for sharing their perspectives and knowledge of the area and for their interest in my project. I enjoyed talking to you all.

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I. GENERAL INTRODUCTION AND THESIS FORMAT

The range of grizzly bears (*Ursus arctos*) in North America has decreased dramatically since the arrival of European humans. After the grizzly bear was listed as threatened under the Endangered Species Act in 1975, many studies focused on bear habitat use. In the early 1980's managers and researchers realized that human activities can significantly influence habitat use by bears, and developed cumulative effects models to better inform management decisions (Waller 1999). These models include the impacts of recreation on grizzly bears. Because nobody has studied the effects of motorized recreational use on trails on grizzly bear habitat use (Claar et al. 1999), models currently base estimated effects on results from studies completed on effects of roads and non-motorized recreational use on grizzly bears.

The overall objective of this study was to evaluate multiple aspects of grizzly bear habitat use and human recreation. Specific objectives of this research were to:

I. Measure the extent and distribution of recreation in the Badger-Two Medicine area of western Montana

II. Monitor the spatial and temporal distribution of adult female grizzlies relative to trails in the Badger-Two Medicine area

III. Examine whether recreation affects grizzly bear distribution

IV. Describe the spatial and temporal patterns of recreation effects on grizzly bear distribution within their home range.

Grizzly bears and motorized recreational use overlap in the summer and fall in the study area. In preparation for revision of the Lewis and Clark Forest Plan, Forest managers wanted to better understand the amounts and types of recreation in the study area on the forest, whether this use affects bear habitat use, and if so, the extent and type of impact.

This thesis is organized in three sections: 1) this brief overall introduction, 2) a review of relevant literature, and 3) a manuscript presenting the results of this project formatted for submission to the Wildlife Society Bulletin.

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Waller, J.S. 1999. Using Resource Selection Functions to Model Cumulative Effects in the Northern Continental Divide Ecosystem: Report to the NCDE Managers Subcommittee of the Interagency Grizzly Bear Committee. U.S. Fish & Wildlife Service, Grizzly Bear Recovery Coordinator's Office, University of Montana, Missoula.

II. LITERATURE REVIEW

The range of grizzly bears in North America has decreased dramatically since the arrival of European humans. Population size decreases, primarily from loss of habitat and human-caused direct mortality, led to the listing of the grizzly bear as threatened under the Endangered Species Act in 1975 (USFWS 1993). As more people move to areas where grizzlies are currently present, there are increased conflicts and displacement of bears. Such human impacts have the potential to affect grizzly bear conservation and recovery. One of the key results of human presence is displacement from and avoidance of high quality habitat, either temporally or spatially. This can affect reproduction and survival and result in fewer bears. Within public land, motorized and non-motorized recreation occurs primarily along established trails or routes. Use of such human travel routes increases access to previously remote areas, potentially increasing human/bear conflicts and thus bear mortality. When humans recreate on motorized vehicles such as all terrain vehicles (ATVs, 4-wheelers) and motorbikes, impacts to bears may be higher than other forms of recreation because of the higher speeds and increased noise and fumes associated with motorized vehicles.

A brief look at previous studies of spatial relationships of bears to trails, the influences of habitat and habituation on bear response to recreation, technological limitations and biases of previous studies, and some promising new techniques will help to frame discussion of results from this study.

Studies of spatial relationships of bears to trails

Several studies have examined effects of recreation on grizzlies, but few directly address whether bears avoid trails. No research has examined whether bears avoid trails with motorized recreational use. In the Gallatin Range of Yellowstone National Park, visitors traveling off-trail were more likely to observe a grizzly bear than visitors traveling on trails, but the difference decreased when seasonal habitat use of bears converged with trail locations (Chester 1980).

Only Mace and Waller (1996) have analyzed daytime spatial use by grizzly bears in relationship to trails with non-motorized recreation. Bears they studied were found an average of 200 to 500 m farther from trails than expected based on the average available distance from trails. In their study area, the habitat is steep and densely forested, and recreational use levels are high (approximately 90 people visit per day based on trailhead counts; Mace and Waller 1996).

Habitat influences on bear distribution within their home range

Bears may respond to many characteristics of habitat besides the presence of humans on trails. If bear food or cover differs relative to distance from trails, then bear distribution relative to distance from trails may be influenced by variation in food or cover. This variation may confound estimates of response to trails. Factors such as increased visual cover near trails may reduce the response of bears to trails. This possibility requires inclusion of habitat characteristics in any analysis to separate causes of variation in metrics like bear distance to nearest trail. Adding factors such as visual cover requires a larger sample size of bear locations to detect differences in the parameter of interest (e.g., bear distance from trails).

Researchers in Pelican Valley in Yellowstone National Park observed openings in the valley during daylight hours to examine the effect of restricted human use on grizzly bears. Grizzly bears moved farther from tree cover and made more frequent use of areas > 500 m from tree cover when human use in the area was prohibited or restricted than when it was open (Gunther 1991). Bears were sighted within 400 m of campsites 67% less often when they were occupied than when sites were unoccupied. Researchers noted that the area is a large open valley with little visual cover and that the impacts of recreational activity on grizzly bears may be less pronounced in areas with more security cover.

In a study of grizzly bear habitat use that included portions of the study area for this project, researchers found that approximately 75% of all bears (daytime locations) were located within 100 m of cover during daylight hours (Aune and Kasworm 1989). Bears observed at greater distances from cover were usually traveling or accessing carrion.

In a study on bear reactions to various types of disturbance, McLellan and Shackleton (1989) found that presence of visual cover was related to reduced bear responses to hikers and moving vehicles. Bears were never recorded fleeing from moving vehicles while they were in cover. The strongest responses to all stimuli were at distances < 75 m from the stimulus, but increased flight distance in remote areas was associated with human activity, and sometimes occurred at distances > 150 m.

In Yellowstone, movements of reproductive-age female bears in response to approach by humans were greater in areas of less visual cover and when bears were less habituated to humans (Haroldson and Mattson 1985). These authors developed a model of four factors (prior experience with humans, status of an individual, foraging strategy, and physiological state) to account for various behavioral responses by grizzly bears to human presence. They also theorized that greater numbers of bears would be more likely to be affected by human use of more productive habitats, because more bears use highly productive habitats.

These studies all found that visual cover influenced the distance at which bears respond to human disturbance. The maximum distances at which bears reacted to disturbance varied between 100 m and 500 m, suggesting a range of distances resulting from previous experience, visual cover, type of disturbance and other factors, at which bears may respond to trails.

Habituation influences on bear distribution

Responses of bears to trails may be based in large part on previous experience. In Glacier National Park, Jope (1985) identified factors that influence the responses of grizzly bears to hikers and explored implications of habituation to hiker safety. Trails with ≤ 1.5 hiker groups per hour had more full charges by grizzlies than trails with > 3 hiker groups per hour. Fewer charges occurred in late summer, which Jope (1985) speculated might be caused by increased habituation as the summer progressed. If this occurs, bears may move farther from trails later in the summer and fall.

Technological limitations and biases

Improvements in technology allow us to address many potential sources of bias in previous studies and to analyze bear locations at finer spatial scales. Radiotelemetry locations can have very large error polygons (White and Garrott 1990). These vary with operator error, differences in receiving antenna designs, topography, animal movement, distance from animal, number of readings taken, and temporal differences in transect readings, but can be as large as 1 km^2 (Samuel and Fuller 1996). If a bear uses a 100-m-wide opening in a forest but the width of the error polygon is 500 m, the habitat type the bear is using may be interpreted as forested rather than open. The same bias could occur with other small, scattered habitat types.

The presence of researchers may be another source of bias. If a bear is aware of a researcher, and chooses to move into denser cover, estimates of habitat use would be biased against open areas. This behavior has been recorded in some bears by McLellan and Shackleton (1989). When bear locations are determined from airplanes or helicopters the same bias may result if the bear seeks visual cover upon hearing the aircraft (Klein 1974, Quimby 1974, Harding and Nagy 1980).

Because grizzly bears inhabit mainly large tracts of public land, ground-based researchers rarely choose random locations from which to begin looking for bears. Instead they begin from roads or trails, where they can move more quickly, which may lead to more locations of bears when they are close to roads or trails (McLellan and Schackleton 1989). Such logistical constraints may bias results of earlier studies.

Most fieldwork on grizzly bears has occurred during daylight hours, and few studies of bear habitat use include many night locations. McLellan's (1989) 9-year study included 2844 daytime locations of bears and only 121 night locations, the highest number of nighttime locations in any study I found. Most studies reviewed did not have any night locations. This is a major potential source of bias, especially if bears respond to human disturbance by using those areas more at night when humans are not present.

New global positioning system (GPS) collars, and satellite imagery interpretation techniques now permit us to reduce such biases. GPS collars record locations at set intervals without the researcher influencing the movements of bears. The collars continue to record points at night and over the entire area used by the bear, and the error polygons on the collar locations are reported to be 10-15 m^2, which allows correct interpretation of habitat use on a finer scale. GPS collars record locations at time intervals programmed to cater to research questions and provide from hundreds to thousands more locations for each bear than VHF radiotelemetry techniques. The ability of GPS units to obtain a fix and the accuracy of the GPS locations may be reduced in areas with taller trees (Rempel and Rodgers 1997, Dussault et al. 1999), high tree basal area (Rempel et al. 1995, Moen et al. 1996, Edenius 1997), and potentially areas with topographic features that reduce the amount of visible sky. Therefore habitat analyses that do not account for this bias may underestimate use of mature tree stands or areas in steep draws relative to other habitat types (Dussault et al. 1999). Because the factors that correlate with biases have been estimated for only a few study areas, the capability of the GPS units must be evaluated under field conditions at a study site before estimating habitat use.

Mapping habitat at the scale that bears move has been incredibly expensive, difficult, and inaccurate. Satellite images can now be classified into landcover types over large areas and at a much finer resolution than previous mapping efforts, so we can examine habitat use and availability based on a map with a 30 m minimum mapping unit. The two primary drawbacks to maps derived from satellite images are that they may not show the variables of interest (e.g. bear food or horizontal visual cover) and that they may map areas incorrectly if they are based on few vegetation plots or if the wavelengths emitted by two cover types are very similar and thus cannot be properly identified.

In previous analyses, habitat availability has been measured at the scale of the entire home range of an individual or on the entire study area. Such methods carry the assumption that all habitats in the area are equally available to the individual for a given time interval. This may not be appropriate for animals with large home ranges because an individual may not be able to reach all of its home range before the next sampling interval (Arthur 1996). By defining availability based on the distance a bear can move between location attempts, a more appropriate comparison of bear habitat use to availability can be obtained.

Conclusions

New technologies now permit us to address spatially explicit questions on finer scales, with less bias, and with more power to detect relatively small effects. These are particularly useful for large, highly mobile carnivores like grizzly bears that inhabit complex environments. Advances in statistics allow us to compute less biased probabilities of use and availability and to incorporate multiple factors, including many habitat characteristics. In combination with detailed data on levels of recreation, these advantages provide an opportunity to learn how motorized recreation use on trails affects grizzly bear habitat use.

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III. Spatial and Temporal Response of Grizzly Bears to Motorized Recreational Use on Trails

INTRODUCTION

Many types of human developments affect habitat use by grizzly bears (*Ursus arctos*), including roads (Mace et al. 1996), trails (Mace and Waller 1996), and developed sites, but no studies have examined how motorized recreation on trails affects grizzlies (Claar et al. 1999). Several studies have examined how non-motorized human presence on trails affects grizzlies (Chester 1980, Jope 1985, McLellan and Shackelton 1989, Gunther 1991), but few have tried to estimate trail avoidance directly. Only Mace and Waller (1996) have analyzed overall grizzly spatial locations in relationship to trails with non-motorized recreational use. However, they did not estimate recreational use on trails in detail, did not work in an area with motorized recreational use, and were not able to address variation in bear distribution within days. In this study, we determined whether bears use areas near trails less than expected and the distance from trails at which selection was no longer detected.

STUDY AREA

The study area (elevation 1470 - 2550 m) was in the Badger-Two Medicine area in the northern portion of the Lewis & Clark National Forest in northwestern Montana (Figure 1). This area has motorized and non-motorized trail use. Motorized recreation in the area consists of motorcycles and all terrain vehicles (ATVs). Non-motorized use includes hiking, bicycling, and horse riding. The area has two livestock allotments with 107 cattle (cow/calf pairs) from early June to mid-September each year. People primarily use the area for general recreation and hunting in the fall, although some people use the area to check on cattle, maintain trails, and monitor forest resources. Monthly average precipitation is 2.4 - 8 cm and monthly average temperature is -10.2 - 13.7 degrees C (Summit, Montana weather station). In the western third of the area, overstory vegetation consists predominantly of lodgepole pine (*Pinus contorta*) stands, with some subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) stands, and a few whitebark pine (*Pinus albicaulis*) stands (Johnson and Goldan 1987). Small meadows are scattered throughout these forest stands. In the eastern and central portions of the study area, open talus slopes and larger side hill meadows dominate a drier landscape.

METHODS

Bear Location Data

Three teams trapped and collared grizzly bears in or adjacent to the study area between late May and July of 1999, 2000, and 2001. Bears were caught primarily with Aldrich snares (Jonkel 1993), but some were captured from a tree stand using tranquilizing darts (Carney, personal communication). Bears were handled according to Jonkel (1993) and fitted with Telonics (Telonics Inc., Mesa, Ariz.,USA) Generation II Global Positioning System (GPS) collars. Collars were programmed to record a GPS location every 60 min from the time of deployment until mid-October, when they were programmed to release. Collars were retrieved and data were downloaded using Telonics and Trimble Pathfinder Office software (Sunnyvale, CA, USA). Locations were differentially corrected with local GPS base station data before export to geographic information system (GIS) software (Arcview 3.2 and ArcGis 8.0 ESRI, Redlands, CA, USA) for analysis. Bears were located twice weekly from an airplane using VHF equipment to check for mortality signals and to ensure we would still have data if the GPS collars failed.

Recreation Data

Trail locations were recorded using Trimble Geoexplorers accurate to within 10 m or Trimble Pathfinder units accurate to 85 cm. Exported files were downloaded, differentially corrected, and exported using Trimble Pathfinder Office software. Trail files were then converted in Arcview 3.2 to UTM coordinates for analysis.

Because we wished to analyze bear response to trails with different levels and types of recreation within the study area, we sampled recreation on representative trail segments, defined as a length of trail between two intersections or destinations, throughout the study area. We designed a stratified sampling plan with different sampling methods for high-use trails (hereafter, primary trails) and low-use trails (hereafter, secondary trails) based on previous knowledge of trail use levels (Figures 2, 3, and 4) and seasonal trail use regulations (spring = May 1- June 30, summer = July 1-August 31, fall = September 1-October 21).

In spring, motorized recreational use is prohibited and recreational use is low. Because one of four primary trails was relatively inaccessible due to high water in spring, we focused on the other three primary trails. We sampled along the main trail and all trails branching off the main trail by raking 2-3 m-long sections of trail clear of tracks (hereafter, track plot, Figure 2). We recorded the time and location that the trail segment was raked and left a foot print to help assess age of tracks. We returned in 1-3 days to record the number and type of tracks (animals, hikers, horses, mountain bikes, ATVs, and motorcycles) and re-rake the trail.

We thought recreation on primary trails in summer would be too high to accurately measure with the track plot method, so we chose 13 primary trail intersections to sample more precisely in summer 2000. We grouped several secondary trails with each of the primary intersections into a route (Figure 3). Each route was randomly assigned three weekend days (defined as Friday-Sunday) and three weekdays for sampling. On the assigned day, we observed each intersection for 4 h, between 10:30 and 14:30 when possible, recording the number of people on each trail segment, type of transportation, time and direction of travel, and exact times the intersection was observed. Because the forest was closed to recreation in late summer 2000, we were not able to sample each intersection three times, so in fall 2000 and summer and fall 2001, we observed only seven intersections. We used track plots, set in the morning and checked in the afternoon, to sample secondary trails.

Active infrared counters (Cuesta Systems Corp., San Luis Obispo, CA, USA) recorded hourly trail use on five primary trail segments (Figure 3). Counts at intersections nearby were used to calibrate counters. Motion- and light- activated cameras with date-time stamps were rotated between counter sites to record the number of counts caused by animals each hour.

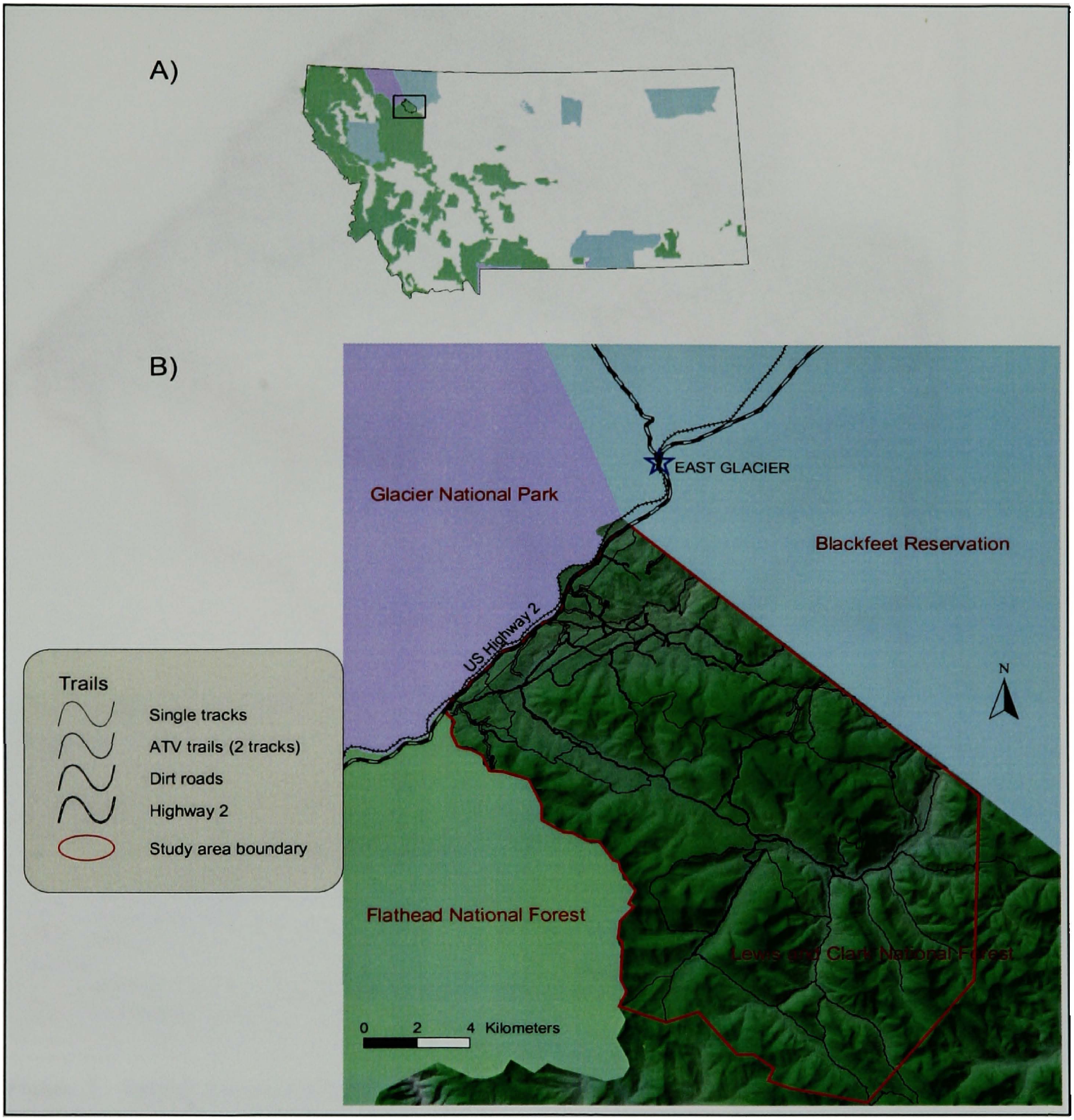


Figure 1: Study area. A) Box illustrates location within northwestern Montana, USA. B) Close-up of study area with trail types.

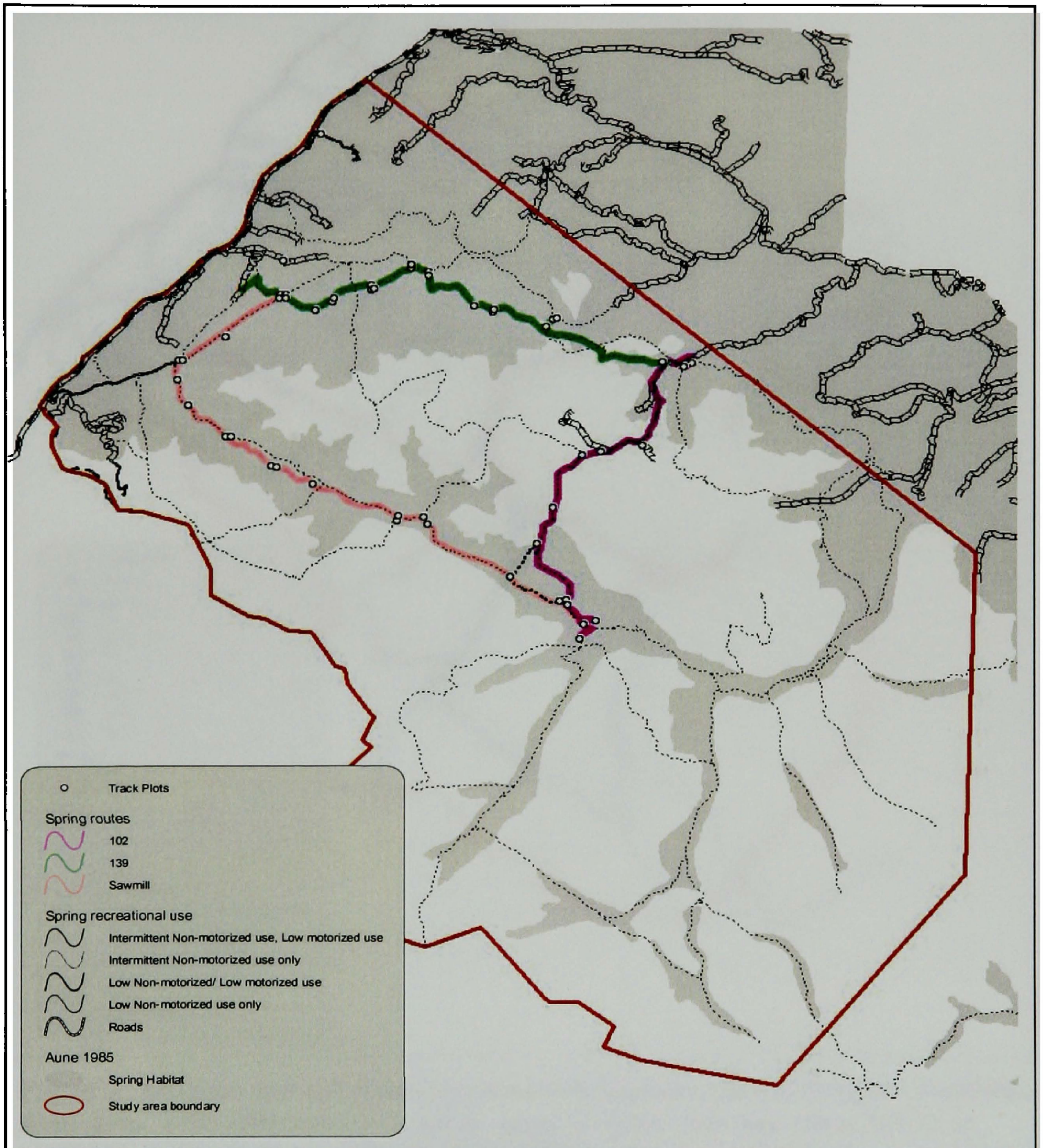


Figure 2. Spring recreation sampling routes with track plot locations in the Badger- Two Medicine study area, 2000 and 2001. Spring recreational use as perceived by land managers as of January 2000. Spring bear habitat as identified by Aune (1985) is also shown. Non-motorized use categories are intermittent <6 people per week, low = 6 to 20 people per week, and high > 20 people per week. Motorized use categories are low < 1 vehicle per day, moderate 1-12 vehicles per day, and high > 12 vehicles per day.

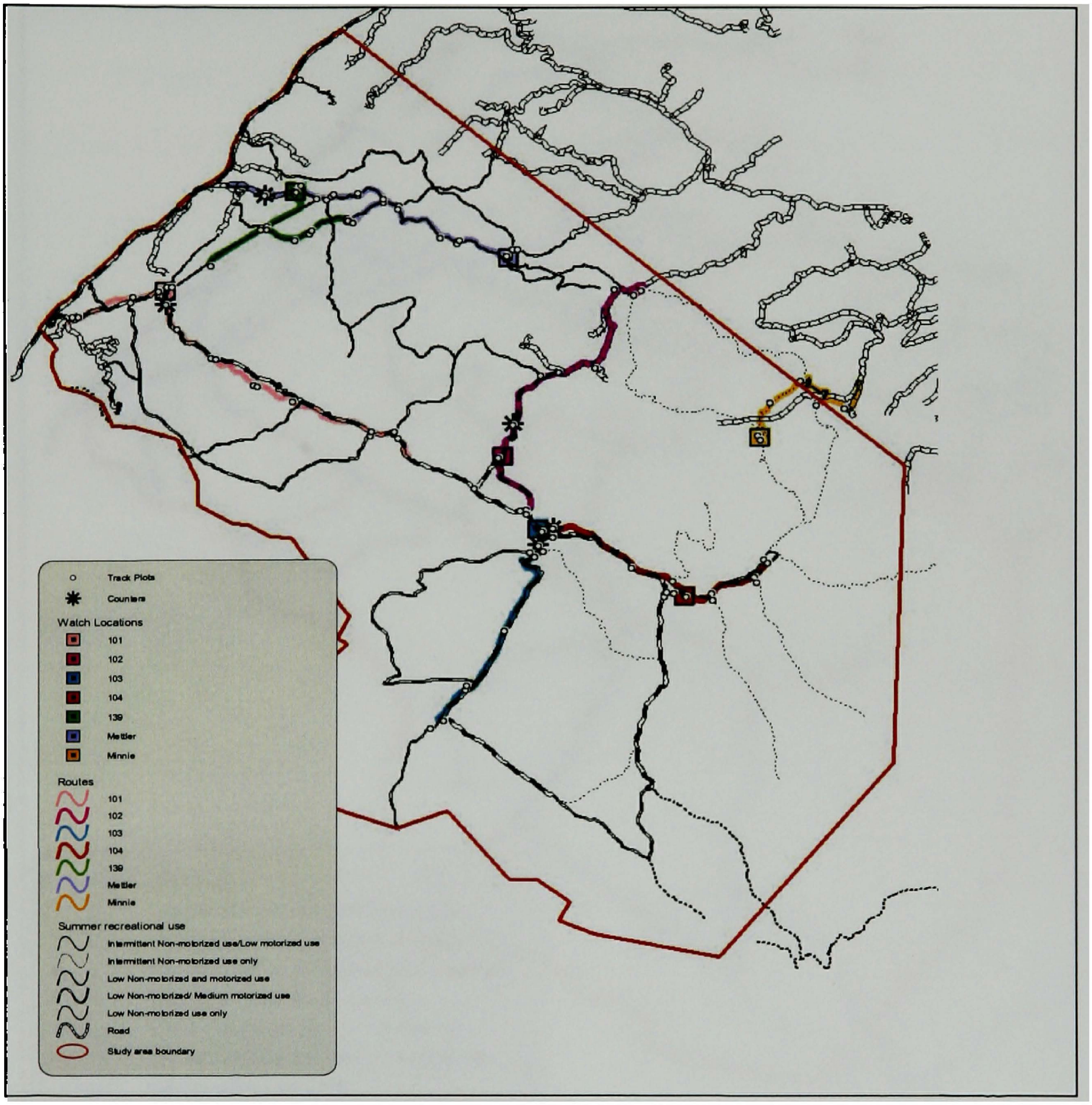


Figure 3. Summer and fall recreation sampling locations for the Badger-Two Medicine study area. Dots represent track plots. Large squares represent observations at intersections for Summer 2001 and Fall 2000 and 2001. Sampling routes are represented by thick colored lines. Counter locations are represented by asterisks. We defined 157 trail segments in the study area. Summer recreational use as perceived by land managers as of January 2000 is shown. Non-motorized use categories are intermittent <6 people per week, low = 6 to 20 people per week, and high > 20 people per week. Motorized use categories are low < 1 vehicle per day, moderate 1-12 vehicles per day, and high > 12 vehicles per day.

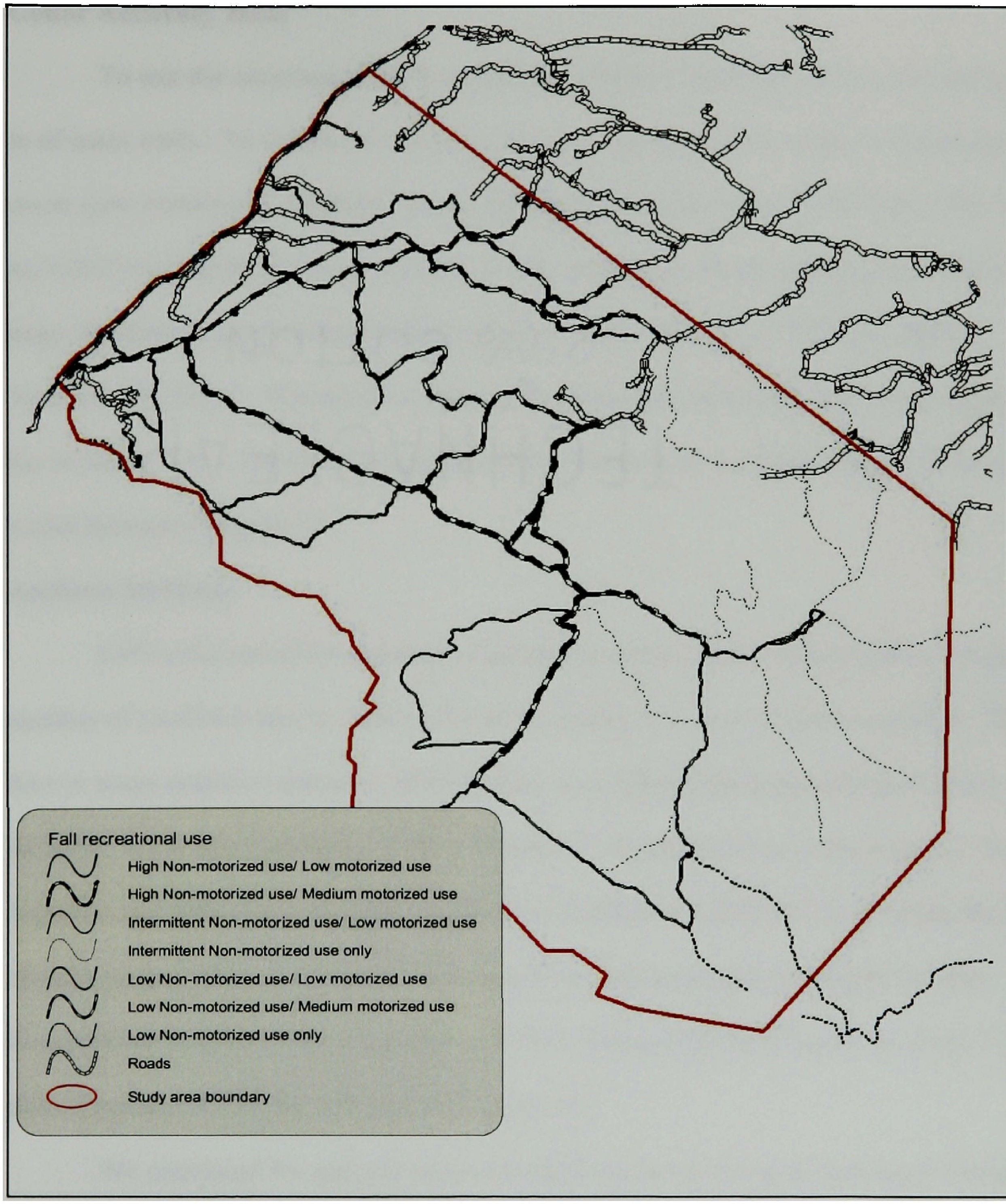


Figure 4. Fall recreational use as perceived by land managers as of January 2000. Non-motorized use categories are intermittent <6 people per week, low = 6 to 20 people per week, and high > 20 people per week. Motorized use categories are low < 1 vehicle per day, moderate 1-12 vehicles per day, and high > 12 vehicles per day.

Collar Accuracy Data

To test the accuracy of GPS collars we randomly sampled 45 test sites within 250 m of main trails. To ensure our accuracy estimates reflected the range of elevation and cover type conditions, selection was stratified based on elevation (<1700 m, 1701-1850 m, >1850 m) and cover type (meadow, shrub, deciduous, small diameter at breast height, large diameter at breast height) using the SILC3 cover type map (Wildlife Spatial Analysis lab, 2001). We placed collars at the test sites a minimum of 4 h and recorded the location with a Trimble Geoexplorer GPS unit to estimate the accuracy of the GPS collar locations (Figure 5).

Analysis Methods

GPS units record the number of satellites used to obtain each location. A greater number of satellites used to define a location results in a more accurate location. When four or more satellites define a GPS location, it is called a three-dimensional (3-D) location; when three satellites define a location, it is called a two-dimensional (2-D) location; and with less than three satellites no location is identified or recorded for that 60-min period. We calculated the distance from true locations (averaged Trimble Geoexplorer locations) that encompassed 95% of the GPS collar locations (95% Circular Error Probable, CEP) for 2-D and 3-D locations.

We estimated the percent of counts caused by animals each hour by dividing the number of animals counted by the total number of counts each hour. Then we subtracted the percent of counts caused by animals from the total counts to estimate the percent of recreational use per hour for each season. We estimated daily use for each day a trail was sampled based on the percent of the daily recreational use we sampled. So, if we observed 2 people at an intersection observation and 50% of recreation occurred during the time period sampled, we would estimate 4 people used the trail segment that day.

Because we only had high numbers of locations for four bears, we analyzed data from each bear separately in all analyses. We examined use versus availability at two spatial scales (Figure 6) to address whether bears use areas near trails less than expected and to compare a traditional analysis technique with a newer technique having different assumptions. Four habitat types were defined for these analyses: ATV trails versus non-ATV trails and single-track trails versus non-single-track trails. Each trail habitat type included the location of the trail plus a 10 m buffer on each side to incorporate the reported error of the Trimble Geoexplorer units. Because buffer zones of ATV and single-track trails overlapped at intersections and we did not wish to assume larger effects for either type of trail *a priori*, we tested each trail type versus non-trail habitat separately for all analyses. Although bears used areas outside the study area (Figure 7) all analyses were confined to the study area, because precise trail location and trail use data were not available outside the study area.

To investigate the extent of bias in traditional, relatively simple analysis methods, we calculated selection based on two levels of availability, a constant home range level of availability and changing availability based on the previous location of the bear. To incorporate GPS error, we defined use as the area of each type of habitat (ATV trail versus non-ATV trail or single-track trail versus non-single-track trail) at the bear location buffered by the 95th CEP for all analyses. At the home range level, because this

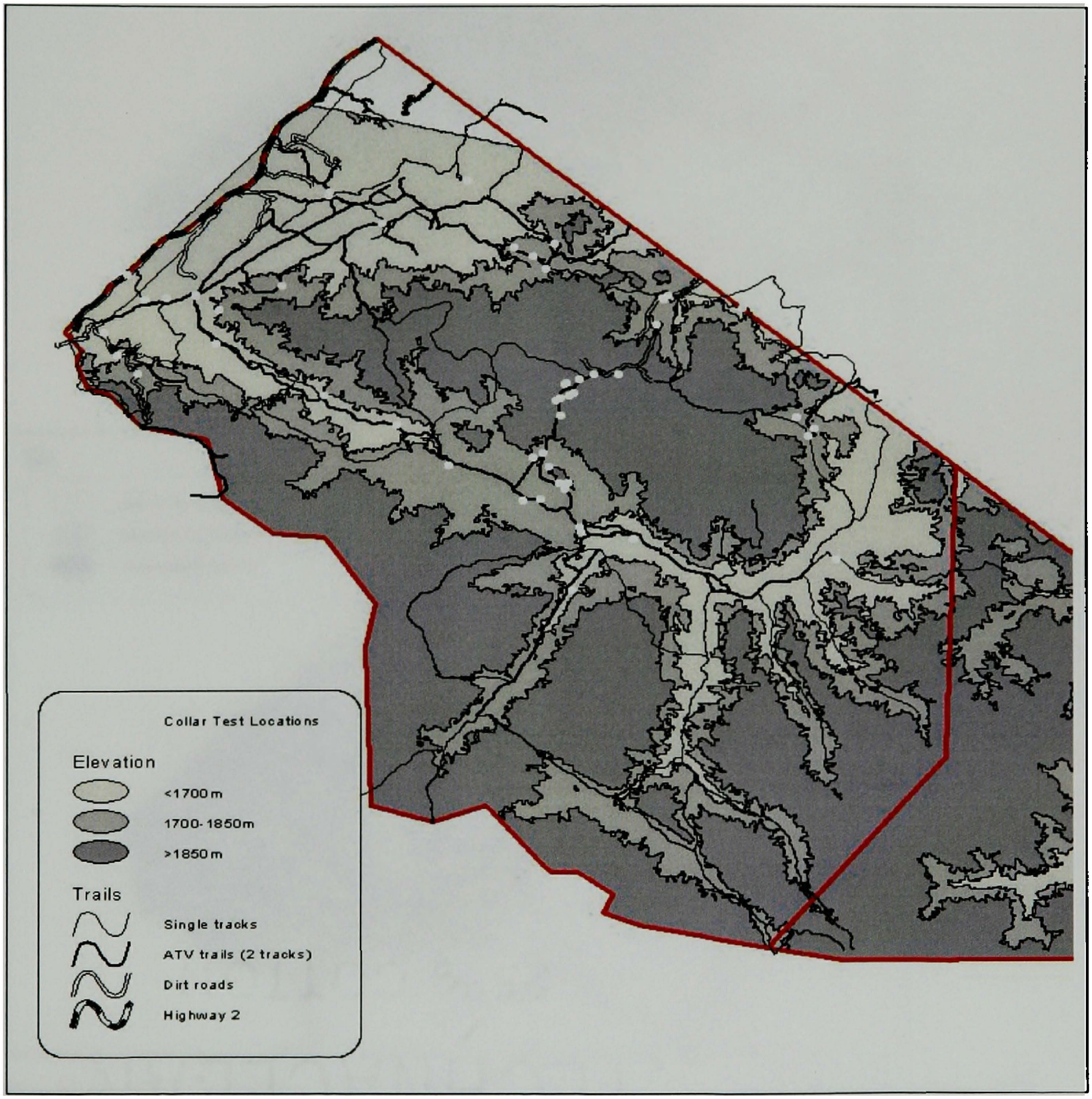


Figure 5. Sampling locations for collar tests in the Badger-Two Medicine study area. These tests were used to calculate the accuracy of GPS collar locations.

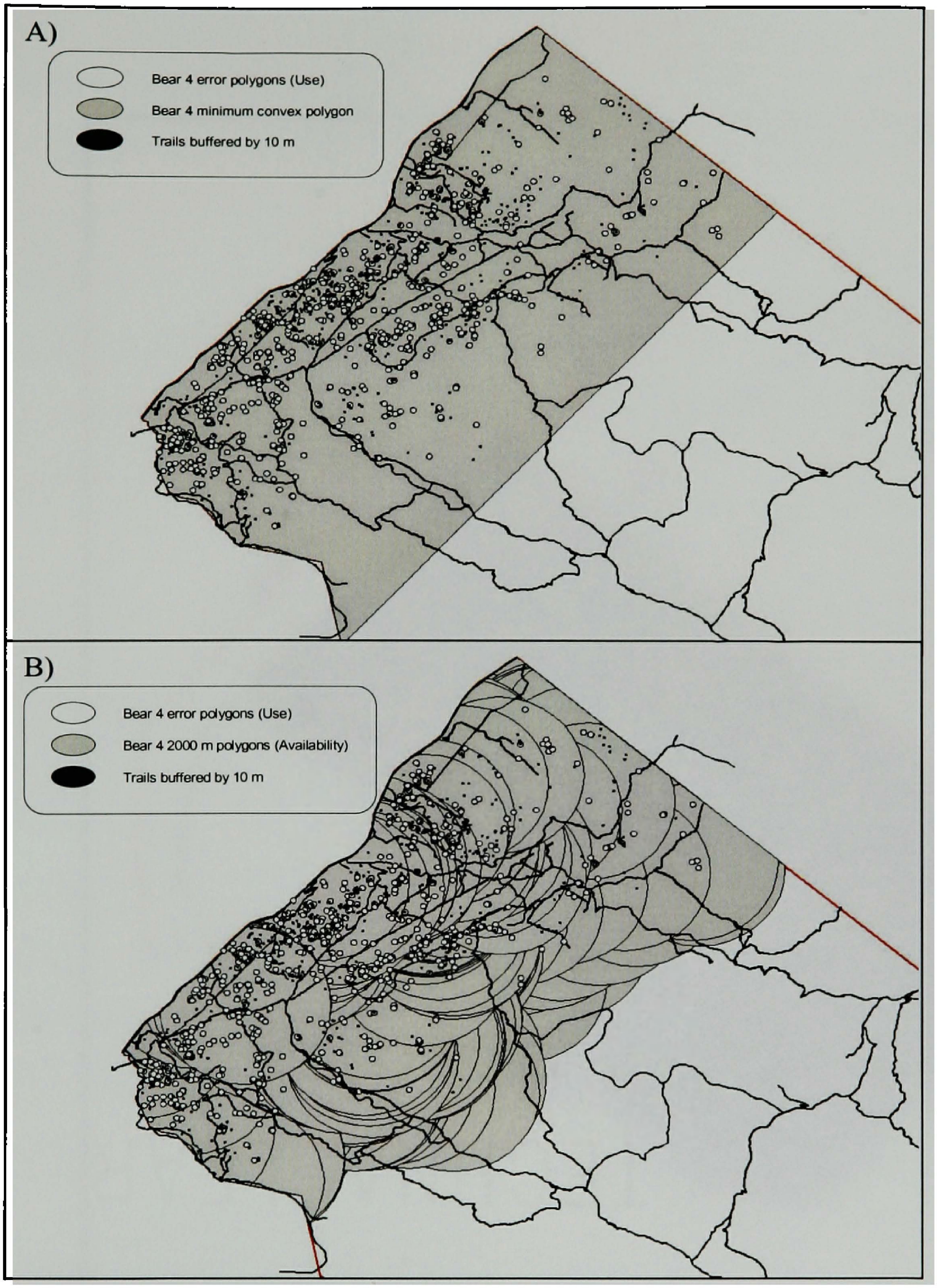


Figure 6. A) Availability when defined as the home range within the study area. B) Availability when defined as circles (2000m buffers) around the bear's previous location.

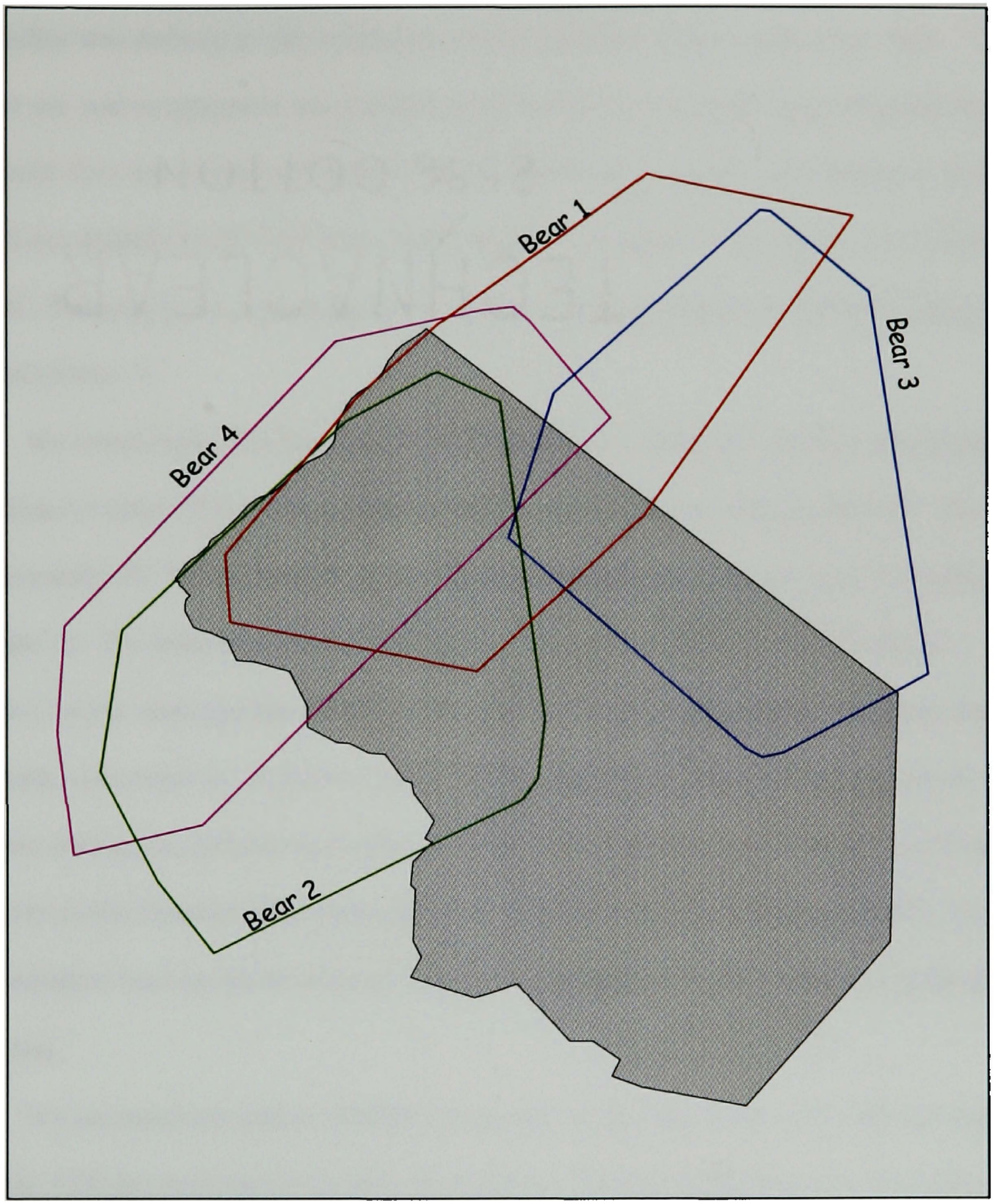


Figure 7. Minimum convex polygon home ranges for bears 1-4. Study area is in gray. Note that home ranges for bears 1,2, and 4 overlap substantially.

technique requires independence of locations, only locations from 10 am were used, and availability was defined as the minimum convex polygon home range of the bear. The percent use was compared to the percent available for each habitat type using the log-likelihood ratio test (Sokal and Rohlf 1995). One of the assumptions implicit in the home range level analysis is that the entire home range is available to the bear for the sampling interval. Because bears have large home ranges we thought this assumption might be violated (Table 1).

We conducted a second analysis with availability based on the previous location of the bear (Arthur 1996). We defined availability by a circle with a radius that was approximately the 99^{th} percentile of movements by bears during hour-long intervals, 2000 m (Table 2). We used the same size circle for all bears so that we could compare selection on the same spatial scale (Arthur 1996). To test whether bear locations were temporally correlated on an hourly basis with distance to closest trail, we regressed two variables testing for periodicity (cosine of 2*pi*Julian hour/24 and sine of 2*pi*Julian hour/ 24) on the distance from the bear location to the nearest trail (Cryer 1986). We tested whether bear locations were temporally correlated on a daily basis using the Box-Ljung test.

We summed use and availability areas across the day (6:00 to 21:00) and night (22:00 to 5:00 the next day) to reduce the effects of temporal dependence (Thomas and Taylor 1990). Day was defined based on when the remote counters recorded the most recreational use. Treating each day or night as a data point (analogous to an animal in Aebischer et al. 1993), we conducted compositional analysis using Resource Selection

Analysis Software (Leban 2002). A p-value of < 0.05 was used to determine whether selection of the non-trail habitat type was statistically significant.

We reclassified trail habitat by buffering the trails at 50 m increments and repeated the entire compositional analysis for each increment for each bear to estimate the distance at which selection of non-trail habitat became statistically insignificant. Beyond this distance bears use the habitat near trails in proportion to its availability, thus are not affected by the trails. We assessed how likely it was for bears to use areas near trails compared to non-trail areas (e.g., one-tenth as likely to use areas near trails as non-trail areas versus one-hundredth as likely to use areas near trails as non-trail areas, etc.) by comparing the back-transformed log-ratio differences (use minus availability) between buffers (Table 15). For easier interpretation, we also computed the number of hours out of 1000 hours that the bear would use areas within each buffer zone if trail and non-trail habitats were equally available.

Compositional analysis assumes normality of the log-ratio differences, so we tested this assumption with the Kolmogrov-Smirnov test statistic for bears with > 50 days or nights of observations in the study area or with the Shapiro-Wilk test statistic for bears with < 50 days or nights of observations in the study area. Because data violated this assumption we also analyzed the data with Friedman's test (Conover 1980), which tests if each rank ordering of the difference in use and availability are equally likely. The Friedman method assumes that the difference between proportional use and availability is the same for all habitats (Alldredge and Ratti 1992). As a non-parametric test, Friedman's test is very conservative, because it incorporates the direction of selection but not the size of the selection effect. It also does not address the unit-sum constraint, so we compared results from compositional analysis and Friedman's test to see if the methods agreed on the direction of the effects and to examine the range of effect sizes.

RESULTS

Bear Location Results

Trapping teams from this study and the Highway 2 study adjacent to this area caught 40 grizzly bears in May-June 1999, 2000, and 2001. Twenty-five grizzly bears received GPS collars and we retrieved information successfully from 17 of these bears. Nine grizzly bears used the study area where we collected recreation data: four female bears used the area extensively (hereafter, bears 1-4), four male bears spent only a few days each in the area, and one female bear was removed from the area for management purposes a short time after she was collared. The number of locations within the study area and the percentage of 3-D locations varied greatly (Table 3). All analyses include only bears 1-4.

Bears did not consistently move to higher elevations in any season (Table 4). Mean bear move distances (Table 5) and mean distance from bear location to nearest trail of any type (Table 6), nearest single-track trail (Table 7), and nearest ATV trail (Table 8) varied by season, by weekday versus weekend, and by day versus night.

Recreation Results

The maximum number of people we saw in one day was 33. Based on counts at intersections in the summer and fall of 2001, 60.6% of people ride ATVs, 15.9% ride motorbikes, 11.0% ride horses, 12.1% hike, and 0.4% ride bicycles. The highest levels of recreation occurred on trails on which ATV use was permitted (Figures 8 and 9). The trails with the lowest levels of recreation were dead-end secondary trails located far from main access points. Almost all recreation occurs during daylight hours, but the distribution throughout the day changes slightly by season, with people recreating approximately an hour later in the fall (Figure 10). Recreation use was highly variable within and between weeks (Figure 11). Based on pictures taken with remote cameras, the percent of animals triggering counters ranged between 0 and 26% and varied by location and by hour of day (Table 9).

GPS Accuracy Results

The GPS collar tests demonstrated larger error widths than the reported error of 15 m. The 95% CEP was 22.441 m for 3-D locations and 67.7486 m for 2-D locations.

Use-Availability Results

When availability was defined as the entire home range, bears 2, 3, and 4 used ATV trails significantly less than expected and bear 1 used ATV trails significantly more than expected (Table 10). Bears 1, 2, and 4 used single-track trails significantly less than expected, while bear 3 used single-track trails significantly more than expected. When availability was defined based on the previous location of the bear, all bears used both trail types significantly less than expected.

The distance from trails at which selection was no longer statistically significant varied by bear (1-4), by trail type (ATV or single-track), by method of analysis (compositional analysis or Friedman's test), and by time of day (Tables 11 and 12). Based on the compositional analysis, buffer widths of trails that bears used less than

Table 1. Distances between bear locations in meters for one-day increments (10 am).

	Bear ID			
	1	2	3	4
Maximum move distance	9657.51	12,668.07	12,541.31	9306.72
Maximum distance across home range in study area	15,998	19,213	16,677	16,411
Percent maximum move distance of maximum home range width	60.3%	65.9%	75.2%	56.7%

Table 2. Distances between bear locations in meters for one-hour increments. The size of the availability circle when we assumed availability changed was slightly larger than the 95th percentile of distance moved.

	Bear ID			
	1	2	3	4
Mean distance moved	517.18	457.61	438.29	313.48
Median distance moved	223.50	262.17	163.02	146.33
95th percentile distance moved	1982.45	1540.43	1661.715	1109.80
Maximum distance moved	5027.92	2898.01	5006.45	5043.94
Percent maximum move length of maximum home range width	31.4%	15.1%	30.0%	30.7%

Table 3. Collar success rates of bears living in the Badger-Two Medicine study area.

Bear ID	Technical Bear ID	Year	Position Attempts	Successful fixes (percent of attempts)	Successful fixes in study area (percent of time in study area)	Percent of 3-D fixes in study area	Days bear was in study area
1	F921	1999	2718	1890 (70%)	781 (41%)	93.0%	64
2	F922	2000	3487	2872 (82%)	1376 (48%)	60.5%	78
3	F293	2000	2590	2052 (79%)	561 (27%)	48.5%	42
4	F37	2001	3160	2563 (81%)	1842 (72%)	51.9%	101

Table 4. Mean and standard deviation of elevation (m) of bear locations by season. Includes all bear locations. Seasons are spring = May 1- June 30, summer = July 1-August 31, fall = September 1-October 21.

	Bear ID											
	1			2			3			4		
Season	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Spring	5508	406	303	1813	121	597				1674	139	451
Summer	5102	382	839	1708	165	1153	1610	118	970	1645	127	1185
Fall	4895	536	429	1763	150	989	1645	292	909	1737	143	922

Table 5. Mean and standard deviation of move distances (m) per hour by season, weekday/weekend, and day/night. Includes all bear locations. Seasons are spring = May 1- June 30, summer = July 1-August 31, fall = September 1-October 21. Weekends are Friday –Monday. Day is 600 to 2100.

		Bear I.D.											
		1			2			3			4		
Time Period		Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Spring													
Weekday	Day	362	598.78	116	483	622.07	109				290	323.01	155
	Night	284	445.02	67	429	712.31	70				318	434.97	68
Total weekday		333	547.56	183	462	657.39	179				298	360.06	223
Weekend	Day	422	671.38	73	523	585.83	85				196	295.65	147
	Night	238	355.21	46	346	543.87	45				274	412.98	80
Total weekend		351	575.52	119	462	575.78	130				224	342.75	227
Total Spring		340	557.86	302	462	623.38	309				261	353.03	450
Summer													
Weekday	Day	541	700.32	261	436	500.61	258	414	284.00	155	321	362.20	440
	Night	526	662.63	201	292	381.39	170	416	418.15	64	280	367.18	260
Total weekday		535	683.49	462	379	461.93	428	415	319.83	219	306	364.33	700
Weekend	Day	491	570.73	215	382	467.47	171	705	300.34	129	392	388.78	297
	Night	432	703.32	162	468	607.18	115	667	458.97	41	394	436.97	188
Total weekend		466	630.92	377	416	528.78	286	696	339.21	170	393	407.69	485
Total Summer		504	660.89	839	394	489.79	714	574	358.53	389	341	384.89	1185
Fall													
Weekday	Day	456	670.84	133	586	646.66	102	788	362.65	60	297	315.95	352
	Night	270	354.91	83	407	655.51	55	704	362.71	20	102	226.28	172
Total weekday		385	576.73	216	523	653.29	157	763	363.85	80	233	303.55	524
Weekend	Day	298	485.77	135	379	489.57	111	706	297.79	82	233	289.03	263
	Night	369	625.29	78	421	650.47	72	663	264.68	23	155	341.32	135
Total weekend		324	540.68	213	396	557.09	183	695	289.97	105	207	309.56	398
Total Fall		355	559.29	429	454	605.86	340	733	334.87	185	222	306.28	922
Total		432	619.94	1570	424	553.04	1363	682	350.35	574	284	356.85	2557

Table 6. Mean and standard deviation of distance of bear location from the nearest trail (m), by season, weekday/weekend, and day/night. Includes all bear locations in the Badger-Two Medicine study area. Seasons are spring = May 1- June 30, summer = July 1-August 31, fall = September 1-October 21. Weekends are Friday –Monday. Day is 600 to 2100.

		Bear I.D.											
		1			2			3			4		
Time Period		Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Spring													
Weekday	Day	288	242.19	92	476	317.51	109				227	150.12	196
	Night	279	264.18	57	376	295.06	70				133	136.26	89
Total weekday		284	249.98	149	437	311.91	179				197	152.04	285
Weekend	Day	185	260.92	74	669	487.35	84				198	143.90	110
	Night	254	247.27	46	690	466.57	45				152	97.74	55
Total weekend		211	256.97	120	676	478.48	129				182	131.84	165
Total Spring		252	255.26	269	537	407.23	308				192	144.99	450
Summer													
Weekday	Day	300	295.30	135	429	426.75	254	414	284.00	155	434	354.33	121
	Night	234	216.99	119	280	181.94	167	416	418.15	64	270	280.73	54
Total weekday		269	263.09	254	369	357.92	421	415	319.83	219	384	341.17	175
Weekend	Day	344	266.82	159	342	243.87	170	705	300.34	129	306	358.22	119
	Night	236	201.70	99	353	349.92	115	667	458.97	41	153	91.40	64
Total weekend		303	249.13	258	346	290.82	285	696	339.21	170	252	302.32	183
Total Summer		286	256.45	512	360	332.44	706	574	358.53	389	316	328.09	358
Fall													
Weekday	Day	420	327.22	12	368	411.02	100	788	362.65	60	239	159.64	377
	Night	291	182.55	18	252	159.87	54	704	362.71	20	185	138.94	219
Total weekday		343	253.47	30	328	348.18	154	763	363.85	80	219	154.42	596
Weekend	Day	47	61.10	2	547	533.31	111	706	297.79	82	260	170.88	269
	Night	303	78.08	5	381	392.65	72	663	264.68	23	189	149.24	163
Total weekend		230	142.28	7	482	488.57	183	695	289.97	105	233	166.45	432
Total Fall		321	239.04	37	411	436.36	337	733	334.87	185	225	159.65	1028
Total		276	255.68	818	413	384.45	1351	682	350.35	574	235	205.33	1836

Table 7. Mean and standard deviation of distance of bear location from the nearest single-track trail (m) by season, weekday/weekend, and day/night. Includes all bear locations in the Badger-Two Medicine study area. Seasons are spring = May 1- June 30, summer = July 1-August 31, fall = September 1-October 21. Weekends are Friday – Monday. Day is 600 to 2100.

		Bear I.D.											
		1			2			3			4		
Time Period		Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Spring													
Weekday	Day	905	381.61	92	778	522.19	109				958	474.17	196
	Night	869	411.30	57	556	334.91	70				778	479.71	89
Total weekday		891	392.26	149	691	469.82	179				902	481.86	285
Weekend	Day	728	515.26	74	890	515.92	84				569	378.33	110
	Night	820	465.10	46	1065	487.36	45				658	467.17	55
Total weekend		763	496.66	120	951	511.19	129				600	412.51	165
Total Spring		834	445.61	269	800	503.37	308				747	471.94	450
Summer													
Weekday	Day	643	444.59	135	739	516.88	254	444	272.67	155	740	493.00	121
	Night	599	410.58	119	712	411.51	167	500	399.54	64	811	395.64	54
Total weekday		623	428.71	254	728	477.54	421	458	307.44	219	766	460.61	175
Weekend	Day	847	539.76	159	581	421.73	170	904	405.89	129	894	538.58	119
	Night	732	494.51	99	788	500.35	115	786	478.17	41	809	388.51	64
Total weekend		803	524.88	258	665	465.49	285	878	423.19	170	862	488.64	183
Total Summer		713	487.52	512	703	473.40	706	696	430.58	389	807	474.72	358
Fall													
Weekday	Day	743	570.70	12	765	601.06	100	796	355.34	60	412	309.70	377
	Night	426	345.47	18	770	305.98	54	704	362.71	20	443	250.24	219
Total weekday		553	467.45	30	767	515.95	154	769	359.13	80	421	292.35	596
Weekend	Day	47	61.10	2	1122	691.76	111	715	289.84	82	551	361.59	269
	Night	340	99.92	5	1003	567.71	72	692	255.51	23	642	453.07	163
Total weekend		256	166.48	7	1075	646.81	183	709	281.38	105	581	395.42	432
Total Fall		496	440.99	37	934	609.46	337	743	328.36	185	480	342.24	1028
Total		743	477.9	818	783	525.60	1351	728	364.71	574	715	465.34	1836

Table 8. Mean and standard deviation of distance of bear location from nearest ATV trail (m) by season, weekday/weekend, and day/night. Includes all bear locations in the Badger-Two Medicine study area. Seasons are spring = May 1- June 30, summer = July 1-August 31, fall = September 1-October 21. Weekends are Friday –Monday. Day is 600 to 2100.

		Bear I.D.											
		1			2			3			4		
Time Period		Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N
Spring													
Weekday	Day	473	486.95	92	776	470.18	109				612	340.04	196
	Night	508	602.64	57	671	334.34	70				378	351.72	89
Total weekday		486	532.46	149	735	424.39	179				539	359.97	285
Weekend	Day	239	278.29	74	827	500.56	84				532	307.25	110
	Night	308	362.32	46	772	431.59	45				421	314.81	55
Total weekend		265	313.50	120	808	476.66	129				495	313.29	165
Total Spring		388	460.74	269	765	447.75	308				523	343.90	450
Summer													
Weekday	Day	565	461.68	135	766	575.55	254	1258	711.47	155	592	339.74	121
	Night	498	425.30	119	712	329.98	167	1179	840.74	64	585	382.16	54
Total weekday		534	445.40	254	745	493.24	421	1238	741.11	219	590	352.35	175
Weekend	Day	671	495.91	159	645	328.65	170	924	348.09	129	580	417.50	119
	Night	518	424.86	99	827	392.87	115	1100	485.63	41	341	245.41	64
Total weekend		612	474.93	258	719	366.32	285	962	386.82	170	497	383.26	183
Total Summer		573	461.73	512	734	446.27	706	1082	582.39	389	542	370.95	358
Fall													
Weekday	Day	1410	401.98	12	726	411.68	100	1659	659.89	60	591	412.38	377
	Night	1077	234.55	18	752	295.22	54	1675	663.75	20	584	457.24	219
Total weekday		1210	347.85	30	735	374.18	154	1664	659.53	80	588	429.02	596
Weekend	Day	1716	80.99	2	919	529.94	111	1711	773.26	82	571	474.59	269
	Night	809	459.16	5	757	472.08	72	1563	706.18	23	393	319.20	163
Total weekend		1068	581.23	7	855	512.78	183	1675	758.24	105	504	431.12	432
Total Fall		1183	396.20	37	800	458.01	337	1669	703.46	185	553	431.72	1028
Total		540	486.8	818	758	450.07	1351	1480	720.69	574	543	400.20	1836

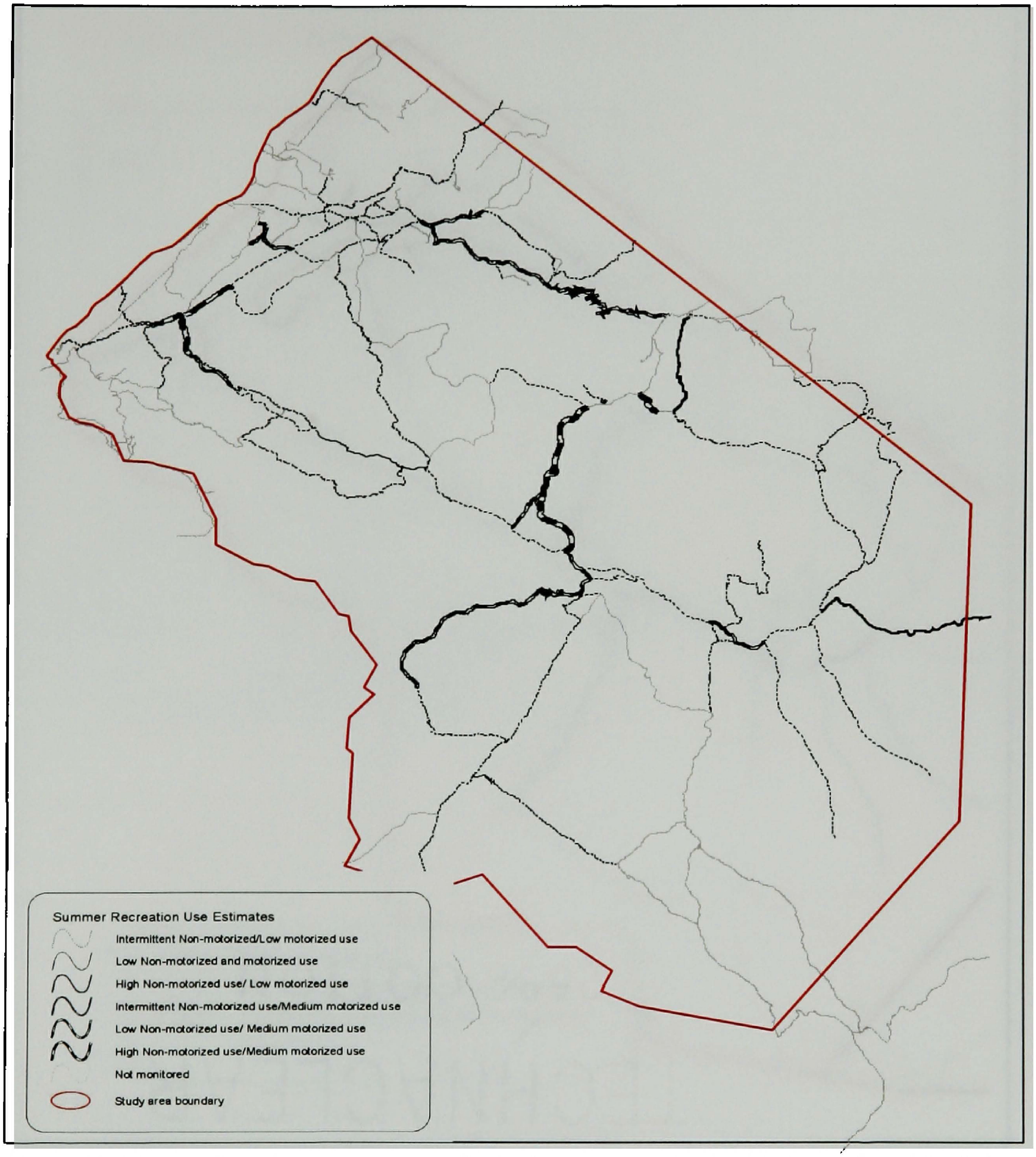


Figure 8. Recreational use estimates for trail segments in the Badger-Two Medicine study area for summer 2001. Estimates are based on either intersection or track plot observations from randomly selected days. Non-motorized use categories are intermittent <6 people per week, low = 6 to 20 people per week, and high > 20 people per week. Motorized use categories are low < 1 vehicle per day, moderate 1-12 vehicles per day, and high > 12 vehicles per day.

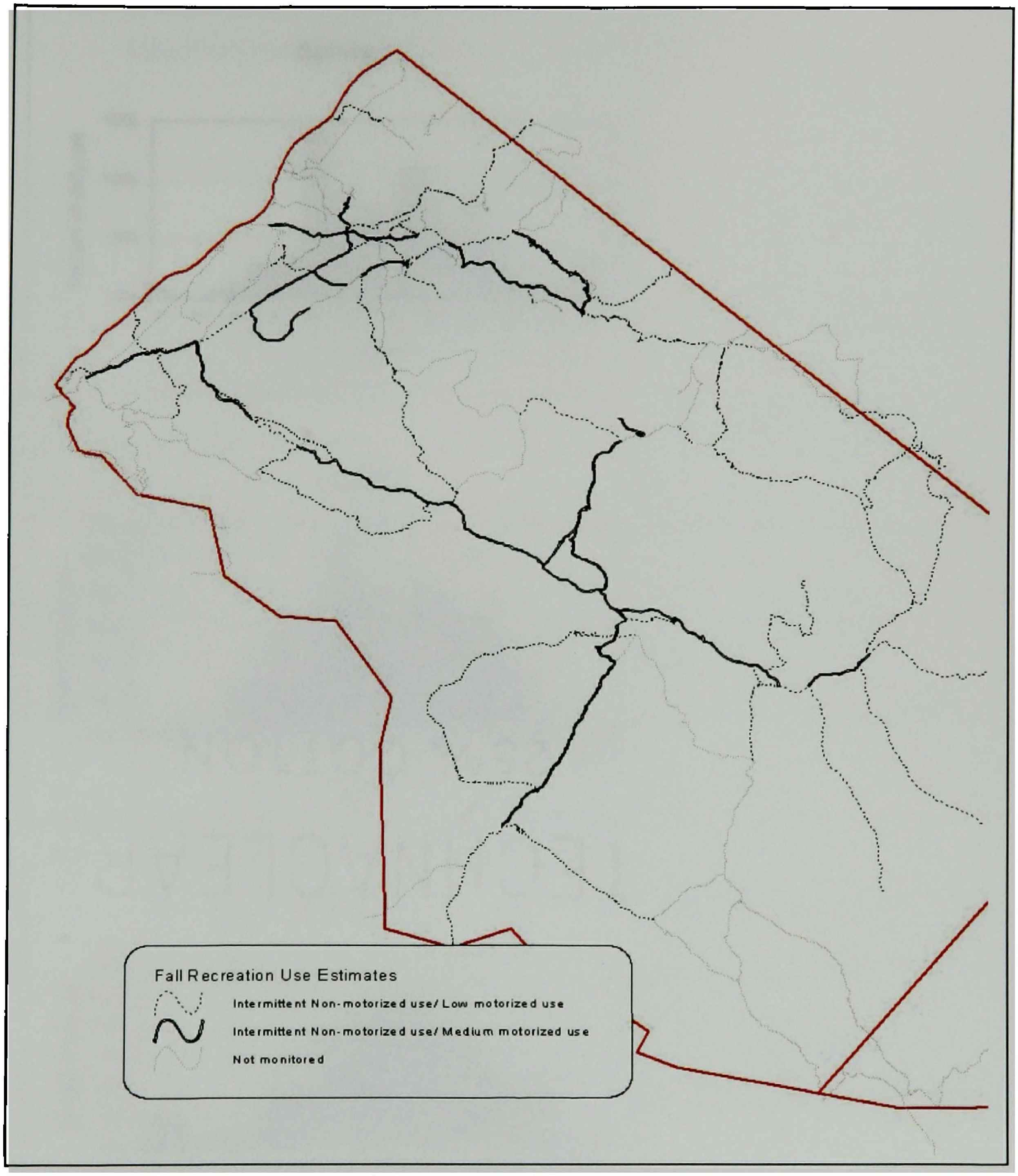


Figure 9. Recreational use estimates for trail segments in the Badger-Two Medicine study area for fall 2001. Estimates are based on either intersection or track plot observations from randomly selected days. Non-motorized use categories are intermittent <6 people per week, low = 6 to 20 people per week, and high > 20 people per week. Motorized use categories are low < 1 vehicle per day, moderate 1-12 vehicles per day, and high > 12 vehicles per day. Fall was defined as September 1-October 15.

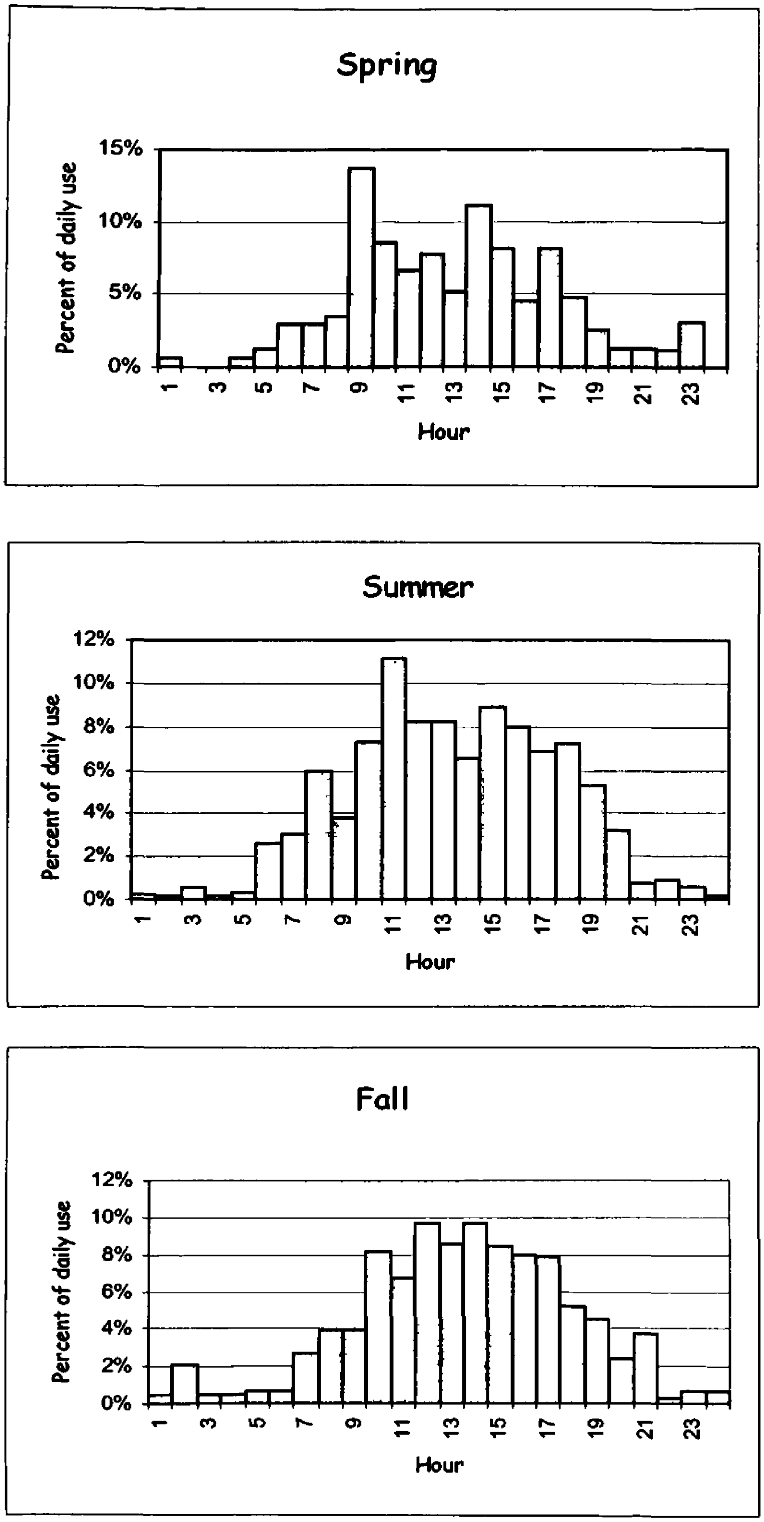
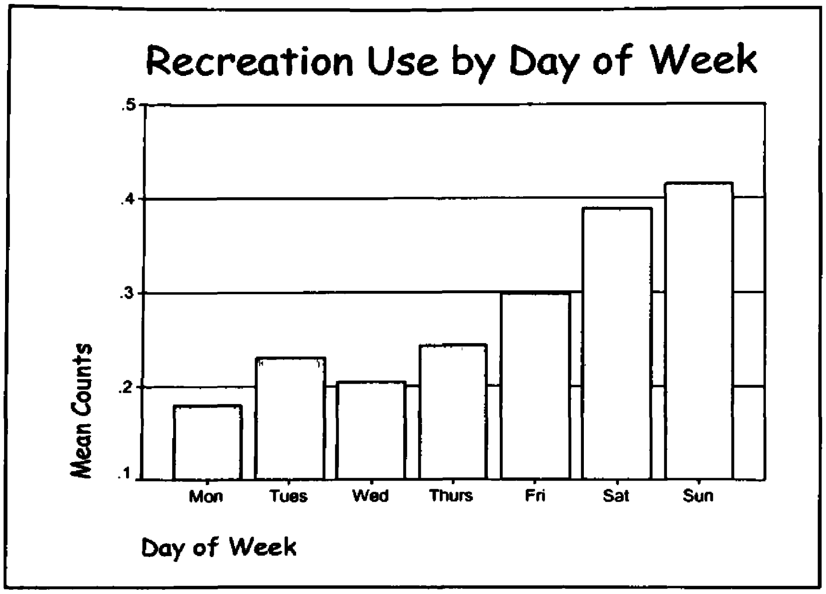


Figure 10. Mean percent of recreation use per hour by season in the Badger-Two Medicine study area in 2001. Includes data from all five counters.



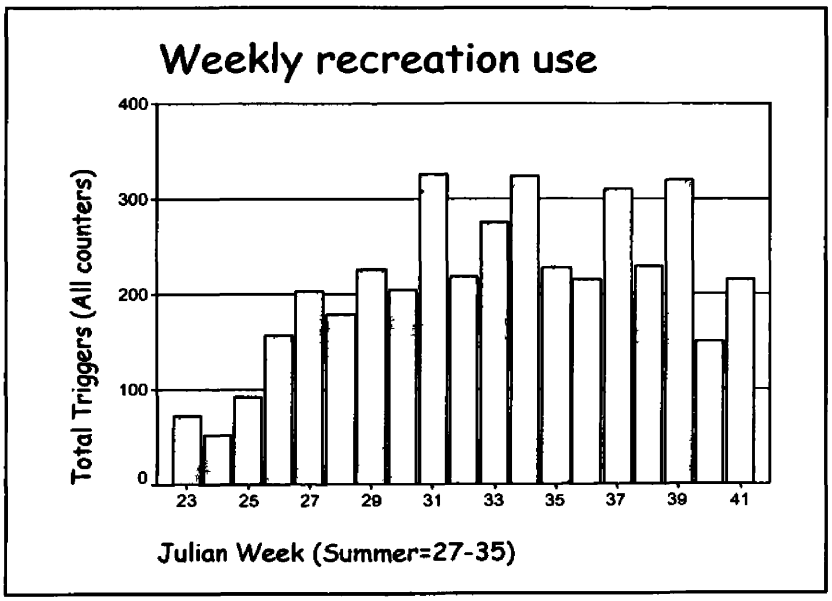


Figure 11. A) Mean number of triggers for five counters by day of week from early June to mid-October 2001. B) Total triggers for all five counters by Julian week from mid-June to mid-October 2001.

Table 9. Percent of animal counts per hour for each counter in the Badger-Two Medicine study area in 2001. See Figure 4 for counter locations.

	C1		C2		C3		C4		C5	
Hour	Percent Animals per Hour	Hours sampled	Percent Animals per Hour	Hours sampled	Percent Animals per Hour	Hours sampled	Percent Animals per Hour	Hours sampled	Percent Animals per Hour	Hours sampled
0	0.0%	29	0.0%	18	0.0%	24	0.0%	32	0.0%	86
1	0.0%	29	0.0%	18	0.0%	24	0.0%	32	0.0%	86
2	0.0%	29	0.0%	18	0.0%	23	0.0%	32	0.0%	86
3	0.0%	29	0.0%	18	0.0%	23	0.0%	32	0.0%	86
4	0.0%	29	0.0%	18	100.0%	23	0.0%	32	0.0%	86
5	0.0%	29	0.0%	18	0.0%	23	0.0%	32	0.0%	86
6	0.0%	29	0.0%	18	0.0%	23	70.0%	31	0.0%	86
7	0.0%	29	0.0%	18	0.0%	23	40.0%	32	0.0%	86
8	0.0%	29	0.0%	18	0.0%	24	56.3%	32	0.0%	86
9	0.0%	29	0.0%	18	0.0%	23	66.7%	31	0.0%	87
10	0.0%	29	0.0%	19	0.0%	23	12.5%	31	0.0%	87
11	0.0%	29	0.0%	19	0.0%	22	0.0%	31	0.0%	87
12	0.0%	29	0.0%	19	0.0%	22	0.0%	31	0.0%	87
13	0.0%	29	0.0%	18	0.0%	22	0.0%	31	0.0%	88
14	0.0%	29	0.0%	18	0.0%	22	0.0%	31	0.0%	88
15	0.0%	28	0.0%	20	0.0%	22	0.0%	31	3.8%	88
16	0.0%	28	0.0%	19	0.0%	20	0.0%	31	0.0%	87
17	0.0%	30	0.0%	19	52.4%	23	0.0%	32	0.0%	87
18	25.0%	30	0.0%	19	0.0%	24	0.0%	33	0.0%	87
19	0.0%	29	0.0%	19	14.3%	25	57.6%	33	0.0%	87
20	0.0%	29	0.0%	19	0.0%	25	0.0%	32	0.0%	86
21	0.0%	29	0.0%	18	77.8%	25	100.0%	32	40.0%	86
22	0.0%	29	0.0%	18	0.0%	24	0.0%	32	0.0%	86
23	0.0%	29	0.0%	18	0.0%	24	0.0%	32	0.0%	86
Totals	3.6%	696	0.0%	442	10.4%	556	26.0%	761	0.8%	2078

expected ranged from 150 to 1000 m around ATV trails and from 450 to 550 m around single-track trails (Figure 12). The direction and size of effects were consistent between compositional analysis and Friedman's test relative to bear (i.e., bear 3 selected against areas near trails the most in both analyses), trail type and time of day, but Friedman's test detected differences only from 50 to 950 m for ATV trails and from 200 to 600 m for single-track trails. The distance from trails at which non-trail selection became statistically insignificant was lowest for bear 1, which used trails significantly more than expected when availability was defined as the entire home range.

The log ratio difference vectors from the compositional analysis departed significantly from a normal distribution (Table 13). The regression analysis testing for serial correlation of bear distance from trails showed significant correlation between hourly locations (Table 14) for bears 1, 2, and 4, but the R squared adjusted was approximately 0.01 for all three bears indicating that the correlation alone did not explain very much of the variation in bear distance from trails. There was no significant hourly correlation between the periodicity terms and bear distance from trails for bear 3. Bear locations 1 day apart at 10 am were not correlated.

Back-transformed mean log-ratio differences (Table 15) at the last buffer width in which selection was statistically significant ranged from 0.007 times as likely to 0.118 times as likely to be used as non-trail habitat. This is equivalent to a bear using trail habitat 0 - 14 hours out of 1000 hours on average if both trail and non-trail habitat were equally available (Figures 13 and 14). The confidence intervals are very large however.

Table 10. Preferred habitat type when availability is defined as the entire home range in the study area. Trails buffered by 10 m. All selections significant at p<0.0001. Includes all bear locations within study area that were at 10 am.

	Bear I.D.			
Trail Type.	1	2	3	4
Single-track trails	Non-trails	Non-trails	Single-track trails	Non-trails
ATV Trails	ATV Trails	Non-trails	Non-trails	Non-trails

Table 11. Compositional analysis results. Smallest trail buffer distance at which no selection was detected. Buffers were tested at 50 m increments. Day = 6:00 to 21:00, Night = 22:00 to 5:00

		Bear I.D.			
Trail Type	Time	1	2	3	4
Single-track trails	Day	600	500	600	550
	Night	550	600	600	600
ATV trails	Day	300	700	950	450
	Night	200	750	1050	350

Table 12: Friedman's test results. Smallest trail buffer distance at which no selection was detected. Buffers were tested at 50 m increments. Day = 6:00 to 21:00, Night = 22:00 to 5:00. Time periods for which the buffer size increased from compositional analysis are in italics.

		Bear I.D.			
Trail Type	Time	1	2	3	4
Single-track trails	Day	350	400	550	250
	Night	250	450	500	*650*
ATV trails	Day	200	600	900	300
	Night	100	700	1000	250

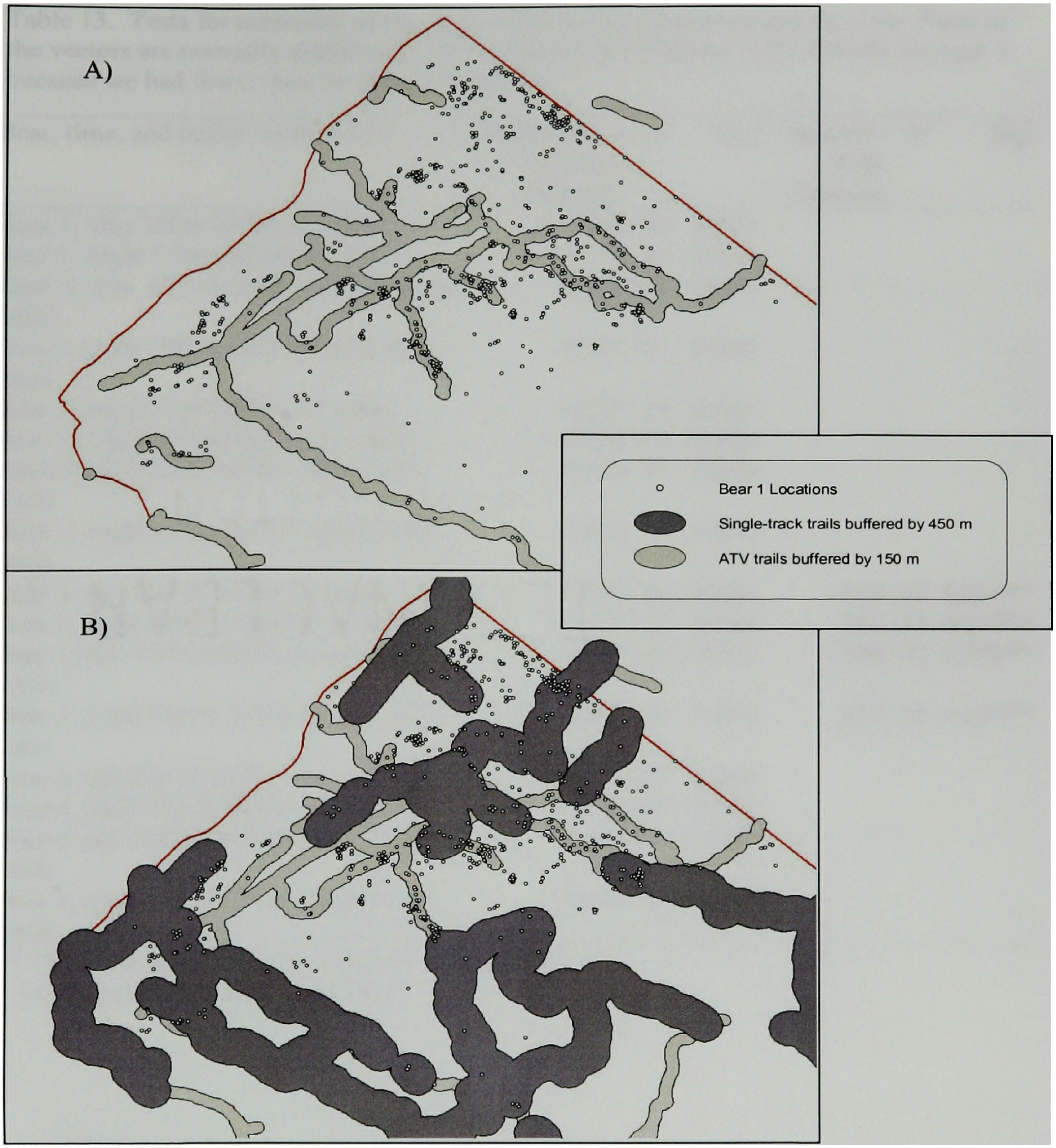


Figure 12. A) ATV trails buffered by 150 meters. B) Single-track trails buffered by 450 meters. When trails are buffered by larger amounts, the trail habitat becomes a larger proportion of the total habitat. At these buffer widths, bear 1 used areas near trails less than expected based on availability.

Table 13. Tests for normality of log-ratio vectors from compositional analysis. None of the vectors are normally distributed. We computed the Shapiro-Wilk statistic for bear 3 because we had fewer than 50 days of locations.

Bear, time, and buffer width tested	Kolmogorov-Smirnov Statistic[a]	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Bear 1_ day 250m buffer atv trails	0.169	64	0.000			
Bear 1_night 150m buffer atv trails	0.172	57	0.000			
Bear 1_day 500 m buffer single-track trails	0.211	64	0.000			
Bear 1_night 500 m buffer single-track trails	0.187	57	0.000			
Bear 2_day 650 m buffer atv trails	0.237	78	0.000			
Bear 2_ night 700 m buffer atv trails	0.192	71	0.000			
Bear 2_day 450 m buffer single-track trails	0.274	78	0.000			
Bear 2_night 550 m buffer single-track trails	0.302	71	0.000			
Bear 3_day 950 m buffer atv trails	0.216	42	0.000	.864	42	0.010**
Bear 3_night 1000 m buffer atv trails	0.179	33	0.009	.866	33	0.010**
Bear 3_day 550 m buffer single-track trails	0.189	42	0.001	.868	42	0.010**
Bear 3_night 550 m buffer single-track trails	0.235	33	0.000	.857	33	0.010**
Bear 4_day 400 m buffer atv trails	0.195	101	0.000			
Bear 4_night 300 m buffer atv trails	0.183	93	0.000			
Bear 4_day 500 m buffer single-track trails	0.214	101	0.000			
Bear 4_night 550 m buffer single-track trails	0.218	93	0.000			

** This is an upper bound of the true significance.

[a] Lilliefors Significance Correction

Table 14. ANOVA testing for hourly serial correlation and of means of distance from bear location to nearest trail for bear 1.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2469859.139	2	1234929.569	30.225	0.000
	Residual	74892785.243	1833	40858.039		
	Total	77362644.382	1835			

a Predictors: (Constant), TIMESIN, TIMECOS
b Dependent Variable: Distance to closest trail

Distance to nearest trail

	Mean	N	Std. Deviation	Minimum	Maximum
Day	264.3	1192	222.5	.9	1589.1
Night	180.0	644	154.8	.2	1183.4
Total	234.7	1836	205.3	.2	1589.0

Table 15. Back-transformed mean log-ratio differences (use minus availability) for buffer zones around single-track and ATV trails. We back-transformed the mean log-ratio difference with the formula: $e^{(\text{log-ratio difference})}$. These can be interpreted as how many times as likely a bear would be to use the trail habitat versus the non-trail habitat if both were equally available.

Single-track trails

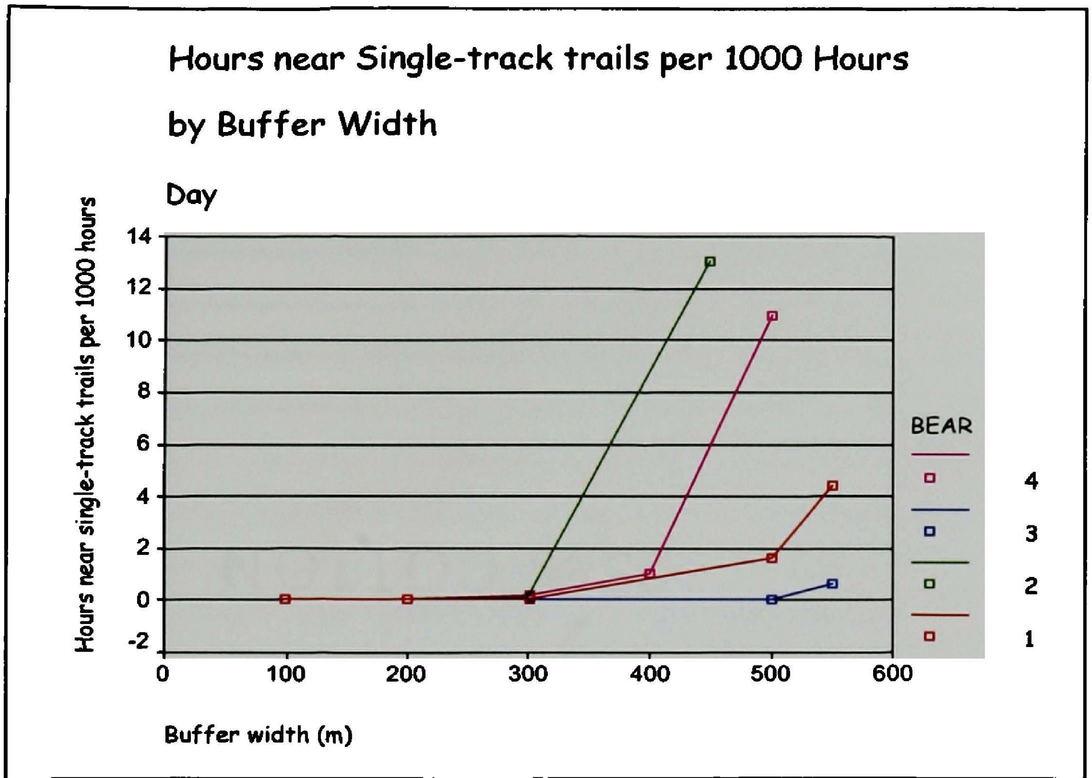
Bear ID	Time	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	900	950	1000
1	Day	<0.001		0.003		0.005				0.040	0.066	*							
	Night	<0.001		<0.001						0.058	*								
2	Day	<0.001		0.001		0.010			0.115	*									
	Night	<0.001		<0.001		<0.001					0.008	*							
3	Day	<0.001		<0.001		<0.001				<0.001	0.025	*							
	Night	<0.001		<0.001		<0.001		0.004		0.003	0.007	*							
4	Day	<0.001		0.002		0.013		0.031		0.105	*								
	Night	<0.001		<0.001		<0.001				0.041	0.040	*							

ATV trails

Bear ID	Time	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	900	950	1000
1	Day	0.006		0.046	0.065	*													
	Night	0.012	0.030	*															
2	Day	<0.001		0.001		0.003				0.032		0.052	0.118	*					
	Night	<0.001		<0.001		<0.001								0.025	*				
3	Day	<0.001		<0.001		<0.001				<0.001				<0.001		<0.001	0.009	0.026	*
	Night	<0.001		<0.001		<0.001				<0.001				<0.001		<0.001	<0.001		0.007**
4	Day	<0.001		0.002		0.012		0.078	*										
	Night	<0.001		0.007		0.066	*												

* Distance of buffer-width around trail at which selection of non-trail habitat became statistically insignificant.

** Distance of buffer-width around trail at which selection of non-trail habitat became statistically insignificant was 1050 m.



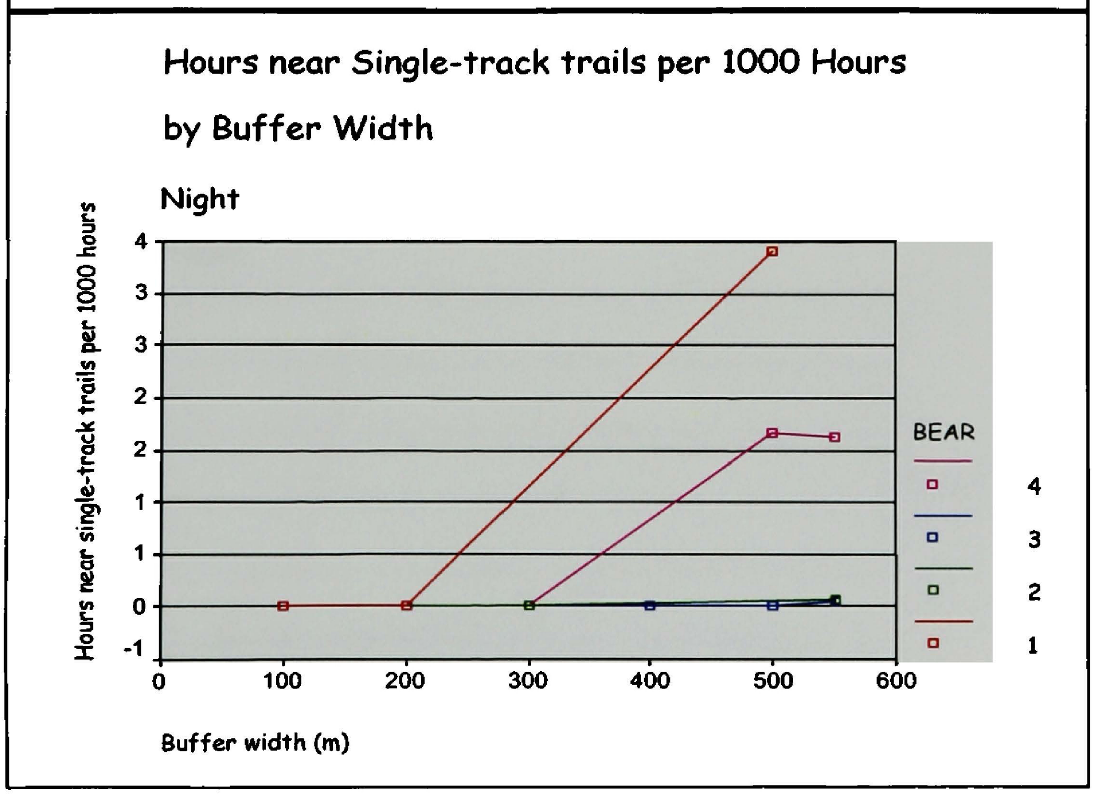
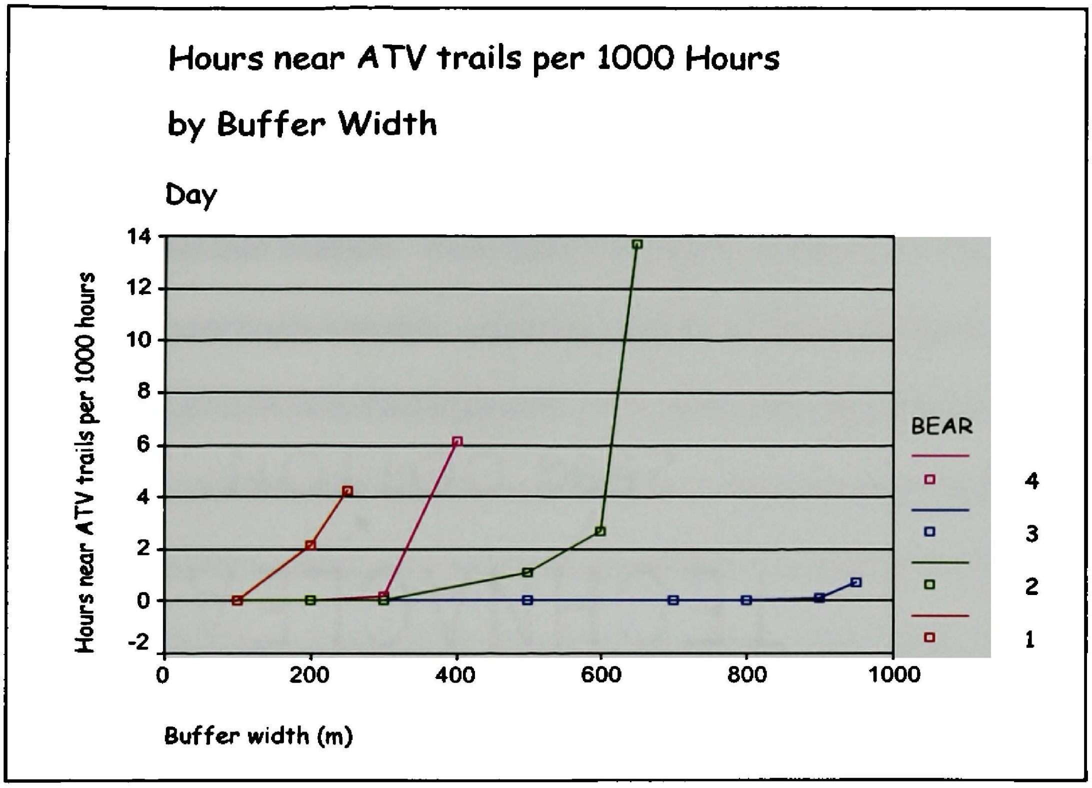


Figure 13. Number of hours out of 1000 hours that bear would spend in areas near single-track trails if single-track trail and non-trail habitat were equally available.



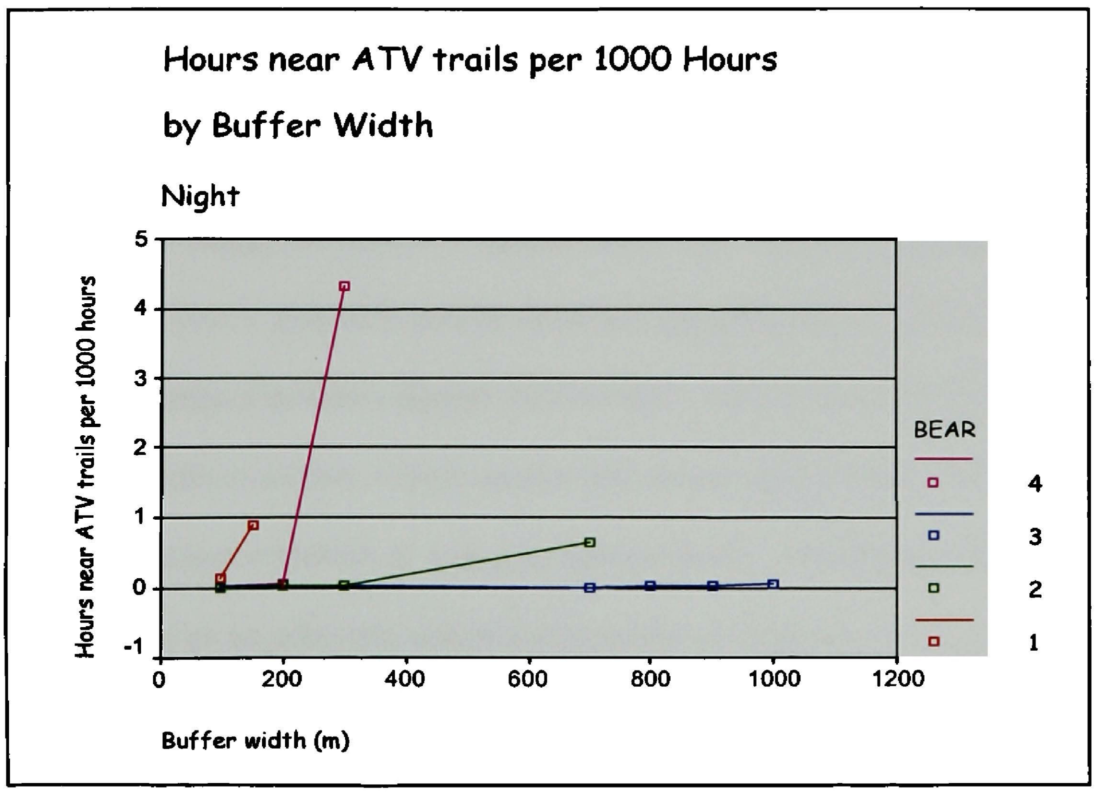


Figure 14. Number of hours out of 1000 hours that bear would spend in areas near ATV trails if ATV trail and non-trail habitat were equally available.

DISCUSSION

When availability was allowed to change, all bears selected non-trails over ATV trails for at least 150 m, and non-trails over single-track trails for at least 450 m, based on the compositional analysis. Even under the more conservative Friedman's test, bears used areas near trails less than expected. Based on locations alone, bears use areas near both kinds of trails less than expected, even with relatively low levels of recreation.

The analyses that allowed availability to change based on the previous location of the bear yielded substantially different results than the analysis with constant availability, in some cases even changing the direction of selection from ATV trails to non-trails. Since the maximum distance bears moved in 1 day was only 56.7% - 75.2% of the maximum distance across the home range within the study area, we can conclude that for 1-day time intervals the entire home range in the study area was not available to the bears, and that the assumption of changing availability was more reasonable for these animals.

The change to selection against areas near trails when availability was allowed to change for bear 1 probably results from her spending most of her time within an area of her home range that had a denser trail system. This choice increased the relative amount of trail habitat available, which means that the analysis that permits availability to change really examines selection at a smaller spatial scale. Although we did not have a sufficient sample size or an adequate sampling technique to rigorously test whether bears select against home ranges with higher density trail systems, qualitatively three of the bears chose areas within their home range that had relatively dense trail systems compared to their entire home range, suggesting they do not select against trails in choosing their home range. The home range of bear 3 had relatively few trails within it, which could mean that it selected against trails at a larger scale. All trails located in the home range of bear 3 have little visual cover adjacent to the trail, which may explain why selection was detected at greater distances from trails (Figure 15).

We met the assumption of independence for all three analyses. We used only locations at one-day intervals for the home range level analysis. Compositional analysis addresses independence by using each animal (in our case each day) as a data point, thereby reducing the degrees of freedom used to determine significance, which would otherwise increase the Type I error (Aebischer et al. 1993). Because we are interested in the effects of trails over the entire day, and because bear locations were recorded at approximately equal sampling intervals, incorporating all locations increases the precision of estimates of proportional habitat use by more closely describing the underlying trajectory (Aebischer et al. 1993). The degrees of freedom in compositional analysis equal the number of habitat types minus one, so the number of observations (days) does not change the degrees of freedom. The degrees of freedom for Friedman's test were reduced to the number of days instead of the number of locations, so we accounted for the serial correlation in this method as well.

We thought that bears might respond temporally to disturbance by shifting their habitat use in disturbed areas to night when fewer humans were present. The buffer distances at which selection became insignificant differed by day and night for all bears, but the direction of the pattern was not consistent (i.e., only two bears were closer to trails at night). The difference between day and night was smaller than the difference between individual bears, indicating that the previous experience of the bear or other individual differences might play a role in determining their response. This inconsistency could also emerge from a difference in the activity patterns of the individual bears, so that the split between night and day did not reflect the perception of night and day for an individual bear. Repeating the entire analysis using each hour as a data point would identify differences in the activity patterns among bears. Other possible explanations include that bears may respond to trails even when humans are not present or may not be active at night.

The results from Friedman's test generally indicated that bears did not select for non-trail areas as much as was indicated in the compositional analysis. The directions of the trends for day/night and ATV/single-track trails are consistent between analyses. With Friedman's test, all bears used areas around ATV trails less than expected for at least 50 m and single-track trails for at least 200 m. The smaller effect sizes probably result from the information lost in ranking the habitat choices and from the unit sum constraint (Alldredge et al. 1998). Very strong selection on one day would count the same as intermediate selection on another day, which overall would decrease the size of the effect detected.

The inconsistency in effect sizes between bears may largely be due to different levels of recreational use on trails. When Bear 1, which had the smallest distances at which selection was detected, spent time near trails, it was mainly near lower-use trails. More consistent selection patterns may emerge from an analysis classifying trails based on recreational use instead of trail type. Because recreation use varies so much from day to day in this study area, bears may have stronger responses than if use was higher and habituation occurred.

In the only other study of grizzly spatial use (daytime only) in relationship to trails, Mace and Waller (1996) found that in fall, selection against trails reached an asymptote at over 2,130 m from trails. Their estimates were based on logistic regression procedures described by Manley et al. (1993, formula 8.6, p. 127). Bears they studied were found an average of 200 to 500 m farther from trails than expected based on the average available distance from trails. In their study area, only non-motorized recreation is permitted, the habitat is steep and densely forested, and recreation is high (approximately 90 people visit per day based on trailhead counts; Mace and Waller 1996).

With so much variance in the distances at which bear use of areas near trails becomes less than expected, and the lack of a perfect analysis, it is difficult to assess the biological significance of the effects of recreational use on trails. A complication to interpretation results because bears do not completely avoid trails. Bears sometimes will even walk along trails, so interpretation should include assessment of how much less likely it is for bears to use areas around trails (Figures 13 and 14). If the habitat that bears use less than expected is highly productive, the effects on bears will likely be greater. Habitat impacts may be important in some seasons because areas near trails are often in river bottoms, which contain high concentrations of bear foods, especially in spring (Figure 2). Bear home ranges overlap and bears have a complex social system about which little is known. This social system and the relationship between bears in an area also affects where bears live on the landscape.

This work provides some intriguing information on how to assess recreational impacts on grizzly bears. Further work is necessary to clarify and refine what appears to be happening. Future analyses should examine whether habitat differs substantially within and outside areas near trails where selection occurs to determine whether areas near trails are high quality (similar to other highly selected areas) or whether other habitat characteristics correlate with and could explain the selection pattern of the bears. Future studies would be more valuable if they sample more bears and examine areas with higher levels of motorized recreation.

Caveats

This study has a number of limitations and should be interpreted with great caution. We analyzed only four female bears that were not randomly selected from the population, so the scope of inference is very limited, and extrapolations should also be limited. The study was designed to examine how bears live with the recreational use on landscape and thus describes only correlation, not causation. Other factors such as location of bear foods, visual cover, water sources, other bears, and recreational use off-trails could be causing the distribution patterns of the bears in this study. In addition to the assumptions described in the text, all of the analysis methods we used assumed that we defined use correctly, that the bears showed the same habitat selection behavior across seasons, and that if a habitat is more available, animals will use it more.

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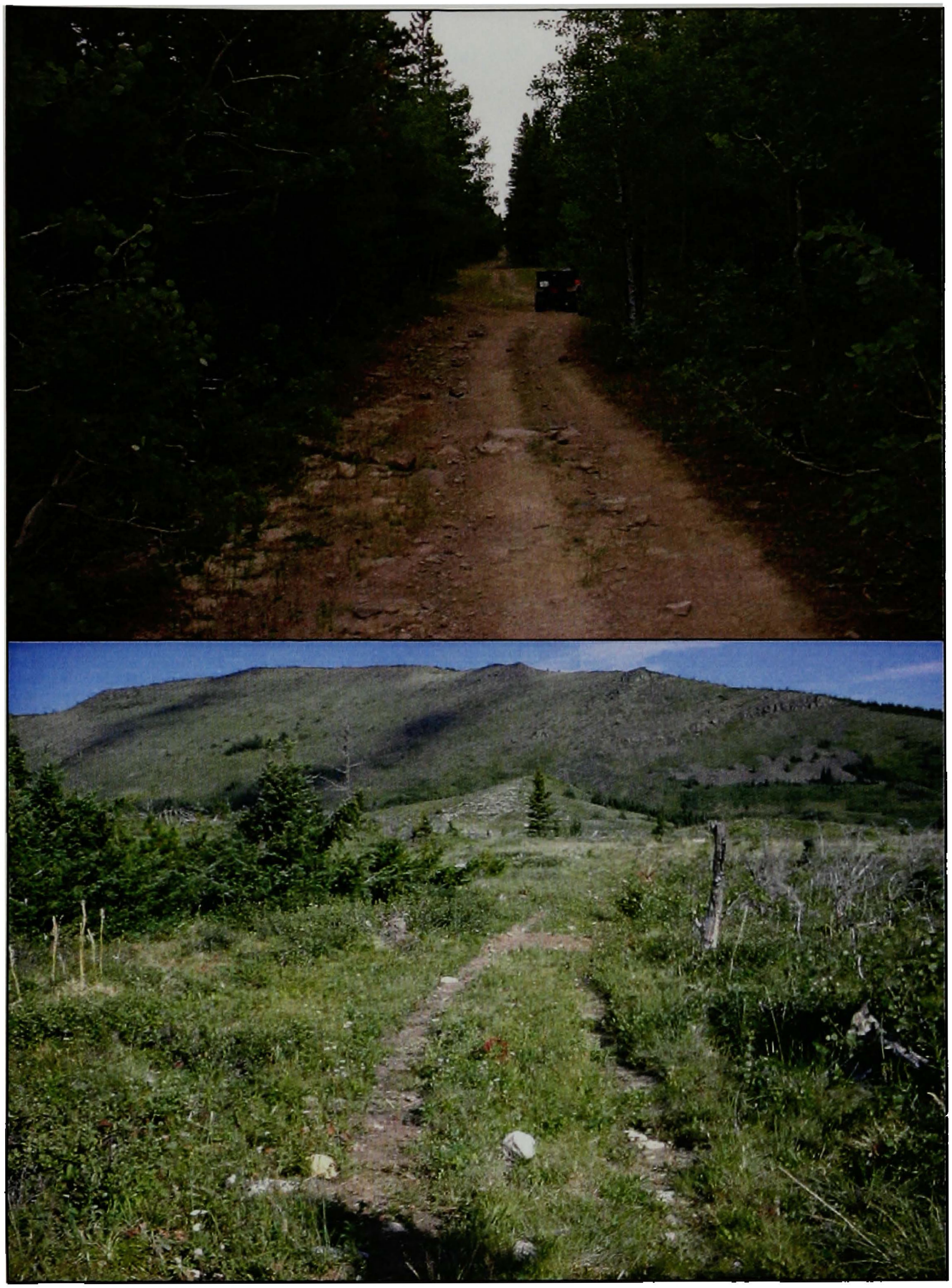

Figure 15. The top picture shows forest to the edge of trail 101 in the home range of bears 1, 2, and 4. The bottom picture shows the more open habitat near trails 169 and 172 in the home range of bear 3.

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