

Interagency Population Monitoring Plan  
For Grizzly Bears  
in the  
Northern Continental Divide Ecosystem,  
Montana



April 2005

## DOCUMENT PREFACE

This document represents the second and final draft of an interagency plan to monitor grizzly bear population trend in the Northern Continental Divide Ecosystem, Montana. The study design present here was formulated from two meetings with wildlife biologists, research biologists, statisticians, and game managers familiar with wildlife populations and grizzly bear ecology. Final concepts for this monitoring program were solidified during a 2-day workshop in February 2005. A list of those who participated in this program design is provided in Appendix A.

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## INTRODUCTION

The Grizzly Bear (*Ursus arctos*) Recovery Plan (USFWS 1993) sets forth criteria to judge recovery of the species in the Northern Continental Divide Ecosystem (NCDE) (Fig. 1), Montana. These criteria are the minimum number of females with cubs seen each year, the distribution of family groups, and total and female known human-caused mortality. From these data, a minimum estimate of population size is made, and the allowable female mortality rate is calculated.

The above recovery criteria cannot be demonstrated in the NCDE because females with cubs are extremely difficult to observe because dense forest canopies and shrub fields conceal individuals. For this and other reasons, there has been no organized effort to collect sightings of family groups annually in the NCDE, and the size and trend of the grizzly bear population remains unknown. Therefore, the minimum annual counts are likely below actual population size and do not reflect the true status of this population of grizzly bears.

Estimates of population trend or female survival rates are not currently required for grizzly bear recovery in the NCDE. However, should the recovery plan be revised, the ability to calculate these parameters will greatly enhance our knowledge of population status and should help clarify the legal status of the population under the Endangered Species Act.

Our understanding of the population status of grizzly bears in the NCDE should improve dramatically in the next couple of years. In 2004, an interagency field effort was undertaken to enumerate population size of grizzly bears over the entire NCDE. Under this program DNA samples were collected from bear hair entangled on barbed wire corrals placed throughout the Ecosystem. These hair samples will provide a unique genotype and gender for each individual that entered the wire corral. From these data, researchers will estimate population size with confidence limits and relative bear density across the NCDE. This benchmark estimate of population size will not be the only work required for

recovery. A companion program is needed that would track population trend and female vital rates over time and provide ancillary information on other indices of population health. The objectives, field design, and analytical procedures to document population trend are provided below.

### **OBJECTIVES**

- 1) Determine the population trend of grizzly bears in the NCDE by monitoring the survival and reproductive rates of female grizzly bears;
- 2) Document the ratio of reported-to-unreported mortality for female grizzly bears in the NCDE;
- 3) Monitor distribution of bears within and outside of recovery boundaries;
- 4) Serve as a clearinghouse for capture, telemetry, and survival data on grizzly bears in the NCDE; and
- 5) Collect and provide information on other management-oriented and pertinent aspects of grizzly bear ecology.

## BIOLOGICAL CONTEXT

Brown bear (grizzly) populations are notoriously difficult to study at broad landscape scales because they characteristically live in remote and mountainous habitats and exist in low densities. The NCDE is over 22,000 km<sup>2</sup> in size, and over 50% of the Ecosystem is without roads. The species is characterized by low reproductive rates and delayed reproductive maturation (Bunnell and Tait 1981). Previous studies in the NCDE have documented reproductive characteristics of female grizzly bears (Aune and Kasworm 1989, Aune et al. 1994, Mace and Waller 1998). Aune et al. (1994) reported an average cub litter size of 2.14, an interval of 2.69 years, and an age of first reproduction of 5.7 years. It is not known whether these reproductive elements have changed over time. It should be recognized that while female survival rates can be accurately measured over the course of several years if 20-30 individuals are monitored annually, estimating reproductive rates from field data would take much longer. Reproductive rate studies on this species may take 8-10 years to complete. This is because a low percentage of the adult female population may have litters in a given year, cycles among individuals may be staggered, and inter-birth intervals are relatively long (Schwartz et al. 2003). Further, if preliminary analyses suggest that survival and reproductive rates vary across the NCDE, it would take still longer to increase the sample size of radioed females that is needed to more accurately examine these differences. Fortunately, estimates of population trend can be completed in a shorter period if reproductive data are taken from the literature and not estimated from field data.

Mortality records for grizzly bears in the NCDE for the period 1994-2004 show that mortalities are not equally distributed across the Ecosystem (Fig. 2). Of 191 mortalities with known or approximate geographic coordinates, only 8% occurred in either a designated wilderness area or in Glacier National Park. The remaining mortalities occurred on private, tribal, or federal nonwilderness lands.

The skewed nature of these mortalities towards nonwilderness areas, suggests that a source-sink situation may exist in the NCDE.

Source-sink demography may exist if differential survival and reproductive rates exist in a population. Such a source-sink dynamic is not unusual given the complex land management and ownership patterns observed in the NCDE. This variation in rates would manifest themselves as differences in local population trend. Areas or local populations where fecundity exceeds mortality are termed “sources,” and areas that are not demographically viable are termed “sinks” (Pulliam 1998). However, it is difficult to conduct formal source-sink analyses (Doak 1995) unless sample sizes are adequate to estimate trend in both the source and sink areas, and data exist on dispersal distance and direction of subadult bears.

The grizzly bear population in the NCDE is not genetically isolated from bear populations in Canada. Genetic diversity in the NCDE appears high (70.3%) relative to more isolated populations such as the Yellowstone (55.5%) and Kodiak Island, Alaska (26.5%) (Waits et al. 1998).

## METHODS

### **Sample Size of Radio-instrumented Female Grizzly Bears**

Population trend is determined by estimating the survival and reproductive rate of female grizzly bears. These 2 parameters are determined by following the fate of radio-instrumented females and by observing their reproductive cycles. In general, survival rates are determined by tabulating the number of radioed bears that die and the number of years that they are monitored. The length of time that bears are radio-monitored is expressed as “bear-years.” An individual that is monitored for 1 complete year, for example, accumulates 1 bear-year of data. It follows that if 100 females are followed for an entire calendar year, 100 bear-years of data are accumulated.

The estimate of female grizzly bear survival should be as precise as possible. Greater precision is achieved as the number of bear-years of data increases. When only a few females are followed for a short time, confidence in survival estimates, and thus trend, is relatively low. Precision in the estimate of survival is also a function of the survival rate itself. More precision (tighter confidence intervals) is gained when relatively few individuals die. As the survival rate decreases at a given level of radio-years, precision decreases as well. Further, the use of covariates to explain variance in survival rates can increase precision of estimates.

The relationships between bear-years, survival rates, and confidence intervals are illustrated in Fig. 3. For example, if after 100 radio-years of data, survival is estimated to be 89%, then one would be 95% certain that the survival is no lower than 84%. This difference between the mean and lower confidence interval is 5%. Conversely if, after the same number of radio-years, survival is estimated to be 97%, then the lower confidence interval would be 94%, or a difference of 3%.

We propose an adaptive approach for determining the long-term sampling intensity of radioed females. The number of female grizzly bears that will be monitored annually in the NCDE will be a balance between statistical precision, observed survival rates, and staffing and budgetary constraints. We propose to radio-monitor approximately 25 independent female grizzly bears within occupied habitats in Montana and an additional 4 females in Canada. With this sampling intensity, and accounting for loss of some radioed bears due to mortality or collar failure each year, it will take between 5 and 7 years to achieve approximately 100 bear-years of survival data. At that time, the precision in our estimates of female survival will be assessed. This time frame should coincide with the publication of the population estimate for the NCDE from recent DNA studies. At that time, population managers can assess whether more precise estimates are necessary.

## **Spatial Distribution of Radio-instrumented Grizzly Bears**

Female grizzly bears will be captured, radio-instrumented, and monitored throughout the NCDE and into southern British Columbia and Alberta Canada. Over time, bias towards any particular area will be minimized by allocating the sample of females primarily on density of the population and secondarily by ensuring thorough geographic distribution.

The final distribution of study bears will be based on relative density estimates obtained from the USGS ecosystem-wide DNA study that was conducted in 2004. Bear density will be categorized by major geographic zones in the NCDE, which are termed “monitoring zones.” Because grizzly bears may move extensively throughout the NCDE, and will probably occupy several monitoring zones, proportional use of each zone by females will be assessed annually and adjustments made in capture effort during subsequent years. Take for example a monitoring zone that is scheduled to have 1 radioed bear. If 2 females from adjacent zones overlap approximately  $\frac{1}{2}$  of their respective home ranges with the zone in question, then bear use of that zone will be equivalent to 1 bear, and sampling will be deemed adequate.

Some monitoring zones are relatively large compared to others and transcend geo-political boundaries. It is assumed in this case that grizzly bear survival may vary across the extent of the zone. To anticipate possible differences in bear survival, the study will strive, over time, to capture female grizzly bears in different areas of the zone. In monitoring zones where the target is 1 female, we will attempt to alternate the sample of radioed females among jurisdictions over several years. Additionally we know that grizzly bears use habitats outside of the NCDE recovery boundaries. Study bears that leave the Ecosystem will be monitored. Over the long term, some capture operations may be conducted within a 10-mile buffer (Fig. 1) of the NCDE.

The population of grizzly bears in the NCDE intermixes with grizzly bears in Canada. It is necessary, therefore, to include a sample of radioed females from



Canada in our estimates of trend for the NCDE. Fortunately, 2 long-term research projects near the international border in Canada are also monitoring female grizzly bears. We will use survival, reproduction, and movement data from 4 females – 2 each in Alberta and British Columbia, Canada. These bears must reside within 10 miles of the international border and meet the criteria for inclusion as described below.

The preliminary distribution of radioed-collared females is given in Fig. 4. This distribution is based on the first of four DNA capture/recapture sessions conducted in the NCDE during 2004.

### **Delineation of Study Bears**

We will use the methods of Schwartz et al. (2005) to delineate study bears. Females first captured and radioed at a research site with the intention of representing the population become study animals. Bears first captured and radioed at a conflict site by bear managers become members of a “conflict” sub-sample. A conflict bear may become a study bear if captured at a research site. Conversely, study animals that are captured at a conflict site retain their place as a study bear if wearing a functional radio collar at time of conflict capture. Study bears whose collars have failed, fallen off, or were censored from the study sample for some other reason and were later captured at a conflict site are reclassified as part of the conflict sub-sample. Nontarget individuals captured at conflict sites are considered members of the conflict subsample.

The goal of this monitoring program is to sample as many individuals from the population as possible over time. In this regard, we will make no proactive attempts to re-collar specific study animals when they are either convenient to capture or when we suspect that radio failure is imminent. Once a study animal is censored from the study because of collar failure or drop, attempts will be made to replace that individual with a new female from the same monitoring zone. If the previously collared study bear is again captured in a research capture in that area, it will again enter the pool of research bears.

Several specific capture sites will be delineated within each monitoring zone as described in the previous section (Spatial Distribution of Radio-instrumented Grizzly Bears). However, in no case will capture sites for the purpose of trend monitoring be placed directly at known high-conflict sites where trapping is ongoing or is likely to be implemented for control of bear-human conflicts. Examples of places that will not be sampled include grain-spill areas or unsanitary private properties that are known to attract grizzly bears.

### **Capture and Radio-instrumentation Protocol**

Capture and handling methods will adhere to Montana FWP capture protocol and the methods described in “A Manual for Handling Bears for Managers and Researchers” (U.S. Fish and Wildlife Service, Grizzly Bear Recovery Office, 1993). Montana Fish, Wildlife, & Parks has the required federal permit to capture and handle grizzly bears using approved methods.

Grizzly bears will be captured using leg-hold snares or culvert traps. Road-killed deer or other lures will be used to attract bears to sites. Helicopter darting will be used as possible. Bears will be immobilized using either Ketamine/Rompun (ketamine HCL/xylazine HCL) or Telazol (tiletamine HCL/zolazepam HCL). All bears will be ear-tagged and microchipped. Morphological measurements will be taken on all bears. Only female grizzly bears (both subadult and adult) will be radio-instrumented. Cotton spacers and mortality sensors will be used on all radio collars. Radio frequencies will be coordinated with all other research in the NCDE. Tooth and hair samples will be taken for age estimation and DNA genotyping.

Grizzly bears will be fitted with one of 3 types of radio collars, depending on body size and geographic location within the NCDE. Traditional vhf collars with a battery life of 5 years will be placed on subadult females (<100 lbs) and most adult bears.

This program will minimize airplane over-flights in Glacier National Park by using specialized global positioning system (gps) satellite collars (Telonics,

Inc. TGW-3580 GPS/Argos). Using this technology, the most recent telemetry data are uplinked to a satellite, processed by Service Argos, and disseminated to the monitoring team via the Internet each week. These collars are designed to stay on the bear for 2 seasons, after which a mechanism separates the collar belting, and it falls to the ground. After retrieval, the entire set of stored location data are then downloaded from radio collar to computer.

In areas where there is a lack of biological information on the habitat requirements or movement patterns of female grizzly bears, some individuals will be fitted with store-on-board gps collars. This may occur in peripheral areas of the NCDE where movement beyond ecosystem boundaries is expected. Telemetry duty cycles will be set so that a maximum number of locations can be obtained over the 3-year life of the collar.

### **Telemetry Monitoring Schedule**

The status (dead or alive) of radio-instrumented bears will be determined from ground and aerial telemetry, and through visual observations as opportunities arise. With several exceptions, 2 radio-monitoring schedules will be followed based on suspected differential mortality trends across the Ecosystem and based on the status of female reproduction. Historical records show that most mortality occurs in front-country situations where public and private lands interface (Fig. 2). Conversely, female mortality is historically less frequent in wilderness areas and national park lands. Because we suspect the probability of dying is less in remote areas, solitary females in these areas will not need to be monitored as intensively as those in the front-country. Solitary females living in remote environments will be located once per month. Bears living in predominantly front-country areas, those living outside of the NCDE recovery zone, and females with a conflict management history will be monitored every 2 weeks. All females having dependent young will be monitored every 2 weeks in an effort to more accurately monitor survival of dependent young. Further, we will use gps collars with Argos satellite uplink

for females in Glacier National Park. Using this technology, we will monitor the movements of females each week. Collars in mortality mode will be investigated as promptly as possible by ground crews to determine cause of death. All adult bears will be more intensively monitored during the spring den emergence period to document the presence/absence of litters and to count litter sizes.

### **Calculation of Survival Rates (cause-specific mortality rates)**

**Independent Bear Survival:** Annual survival rates for independent females will be estimated using censored telemetry data (White and Garrott 1990) obtained throughout each bear's active season. Encounter history spreadsheets will be developed each year for those management and non-management females that are categorized as "study bears" (see Delineation of Study Bears section). Mortalities will be classified according to terminology given in Cherry et al. (2002) with minor exceptions (Table 1). However, determining the precise cause of death may not be routinely possible given the proposed telemetry schedule, inclement weather, and the fact that carcasses of dead bears may severely decompose within 10 days of death.

The basic temporal unit of survival will be the month. Each bear will be categorized as alive or dead each month. Bears that either die or shed their collar before the 15<sup>th</sup> day of the month will be censored to the end of the last month they were known to be alive. In those cases where the death or loss of collar is suspected after the 15<sup>th</sup> day of a month, data will be censored forward to the first day of the following month. Because the ultimate fate of some bears will be undetermined (do not positively know if they died or not, but radio contact lost), 2 survival rates will be calculated to bound the survival probabilities. First, survival rates will be calculated for those bears that were known to have died. This will provide an estimate of maximum survival rate. Second, and in addition to the known deaths, we will include encounter histories for bears whose deaths were ambiguous (those deaths classified as probable, possible, unresolved, or

unexplained (Table 1). This second procedure should provide a minimum survival rate.

Survival rate analyses will be conducted using the known-fate model in Program MARK (White and Burnham 1999). This method calculates binomial likelihood functions for each month (White and Burnham 1999). Factors that may influence bear survival will be investigated using information theory (AIC) (Burnham and Anderson 1998, Hebblewhite et al. In press) in Program MARK. Covariates that will be initially included to better understand factors affecting female grizzly bear survival are given in Table 2. Bears will be classified according to the general land areas within their home ranges (Mace and Waller 1998). Lands within a 10-mile buffer of the NCDE will be classified as either: designated wilderness, national park, multiple use, or private-tribal lands. Convex home range polygons will be constructed annually for each bear to determine the proportion of home range in each land type. Each bear will be classified as living in designated wilderness, national park, multiple use lands, private-tribal lands, or combinations of the above.

**Dependent Young Survival:** The fate of dependent young will be determined from visual observations of family groups during telemetry flights and from ground observations as possible. Increased emphasis will be placed on trying to observe adult females at their dens during spring to determine presence of dependent young each year. Females that have young will be radio-monitored from the air twice per month in an attempt to determine the fate of their young. There are generally 2 methods to calculate dependent young survival rates. The first is to use the number of radio-days the young were known to be alive. In this instance, radio-days are based on those of the mother, not the cubs, since cubs will not be radio-marked. In the second method, one simply determines the proportion of cubs born to all mothers that survive. Because of the dense vegetation in much of the NCDE, opportunity to visually observe bears is limited for females with young. Because young can only be

sporadically observed, we propose that the method using radio-days not be employed. We propose to estimate survival rate of dependent young as  $(1 - \text{dependent bear deaths} / \text{total number of cubs born})$  following Hovey and McLellan (1996). This will likely bias estimates of survival low.

**Unreported Mortality Rate:** Grizzly bear mortalities will be categorized by cause, certainty, and method of discovery (Table 1). Reported mortalities are those deaths that are reported to agency personnel after being discovered by the public. Unreported deaths are those that are not reported to an agency official by the public, such as a bear illegally shot and left. Unreported deaths are, therefore, those that go undocumented via normal channels. If a significant number of deaths are unaccounted for in agency records, estimates of sustainable mortality levels may be inaccurate. Of particular interest then is the ratio of reported deaths to unreported deaths. The rate of unreported mortality will be estimated for female grizzly bears in the NCDE using the methods of Cherry et al. (2002).

#### **Calculation of Reproductive Rate**

The reproductive rate ( $m$ ) per female will be defined as number of female cubs/inter-birth interval (Hovey and McLellan 1996). In this method, the reproductive rate is calculated for each female and is weighted by the number of years (bear-years) each bear is followed.

**Litter Size:** The number of cubs produced per female will be ascertained using visual observations from aerial telemetry flights as quickly as possible after families emerge from their dens during spring. Additional litter size data will be used from the official tally of unduplicated females with cubs or yearlings in the NCDE, and from management females with litters. These data are intended to supplement data from radioed females (Hebblewhite et al. In press). For this data set, we will use ANOVA procedures to ascertain if there are differences in litter size among month of observation, years, and geographic area. Further, we

will determine if there are observed differences in litter size for females having cubs and those with yearlings and two-year-olds.

**Interbirth Interval:** The interbirth interval will be defined as the period of care given the litter in years, plus any intervening period before the next birth (Hovey and McLellan 1996). These data will be collected from following the reproductive history of radioed females. Supplemental data on this parameter will be obtained from reproductive tracts obtained from females that die in the NCDE.

**Age of First Parturition:** Age of first parturition (a) will be documented for each female using several techniques. Visual observations will be made each year during early spring den flights to determine if younger individuals (ages 3-7 years) have cubs. Nipple coloration is also an indicator of whether a female has produced young in the past and will be recorded for all females at time of capture (LeCount 1986). From these data, the mean age of first reproduction for the population will be calculated using methods of Garshelis et al. 1998.

**Reproductive Senescence:** Maximum age of female reproduction (w) will be ascertained as possible by observing age-specific trends in the reproductive output of older females (>15 years). However, because the sample size of these older females is likely to be small, this parameter may be modeled using information in Schwartz et al. (2003).

### **Calculation of Population Trend**

Advancements in the calculation of population trend in wildlife populations are being made each year. Methods that could be proposed at this time may become obsolete in several years. Further, it would be difficult to anticipate at this time, how complex survival and reproductive matrices may become. This is especially so because a complete suite of relevant covariates cannot be anticipated at this time. As sophistication in methodology increases, and the form and structure of the data become more apparent, the interagency team charged with this monitoring program will utilize state-of-the-art

techniques. Expert bio-statistical advice will be sought to ensure the most appropriate methods are used to calculate population trend.

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**Table 1. Terms and definitions to be used to categorize grizzly bear mortalities (modified from Cherry et al. 2002).**

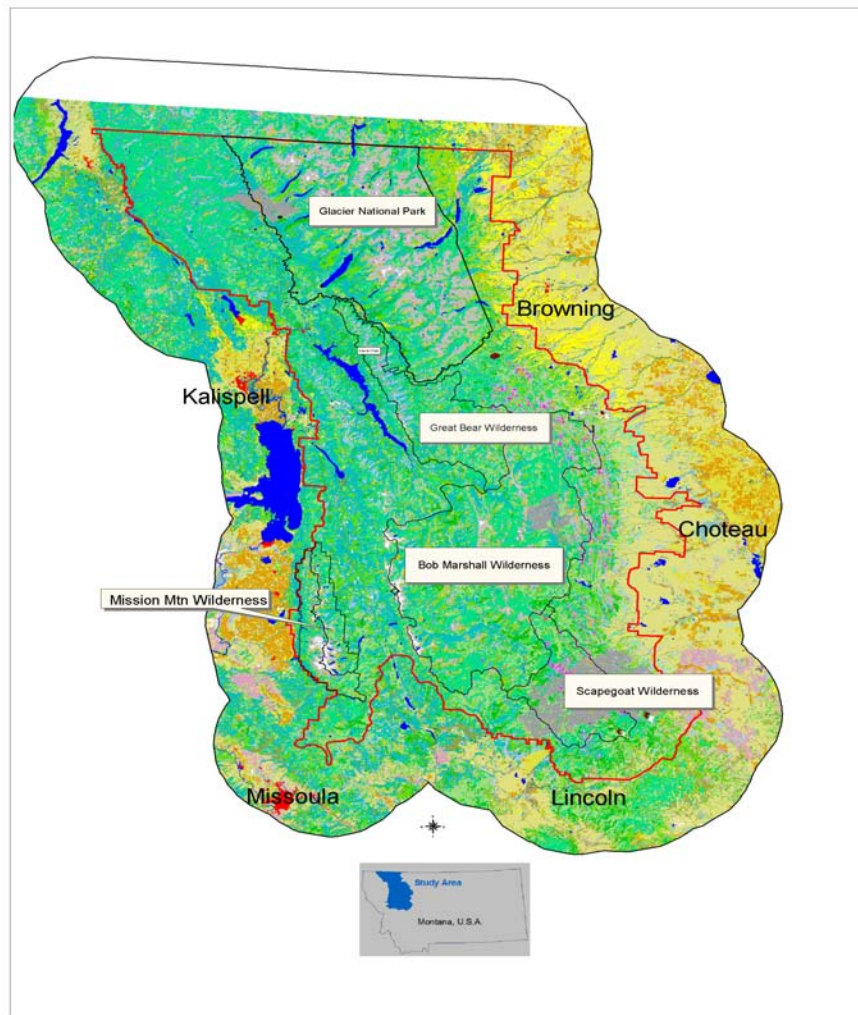
<b>Terms</b>	<b>Definitions</b>
<b>Cause of Mortality</b>	
Natural	Positively or reasonably attributed to natural cause.
Human-caused	Positively or reasonably attributed to humans.
Mistaken ID	Bear illegally killed during a black bear hunting season where no body parts were removed.
Poaching	Bear illegally killed and body parts removed.
Malicious	Bear illegally killed which cannot be attributed to other type of mortality.
Management	Bear legally killed because of management action.
Automobile	Bear struck and killed by automobile.
Train	Bear struck and killed by train.
Defense-of-life	Bear killed by public while defending their life.
Undetermined	Cause could not be determined.
<b>Certainty of Mortality</b>	
Known	A carcass or parts to substantiate death.
Probable	Strong evidence to indicate mortality, but no carcass recovered. Included cases where evidence indicates severe wounding, and observations suggest the bear displayed abnormal behavior.
Possible	Some presumptive evidence of mortality, but no prospects for validation. Includes defense of life situations where shots were fired yet no evidence of significant wounding was found. Hearsay evidence of poaching or malicious death are also included here.
Unresolved	Pulse rate and stationary location of a transmitter indicated a cast-off collar or mortality, and transmitters could not be retrieved due location (i.e., cliff, log-jam in river) or failure; bear never recaptured, so fate was unresolved.
Unexplained	Premature failure of a working transmitter occurred that could not logically be attributed to expected battery life; bear never recaptured, so loss was unexplained.
<b>Discovery of Mortality</b>	
Reported	Mortality of an instrumented or noninstrumented bear discovered without the aid of telemetry.
Unreported	Mortality of an instrumented bear discovered due to telemetry and not reported by the public.
Unexplained	Premature failure of radio collar that could not be attributed to battery life. Bear never encountered again.

**Table 2. List of covariates that will be considered to influence grizzly bear survival rates in the NCDE. Additional covariates may be added as necessary.**

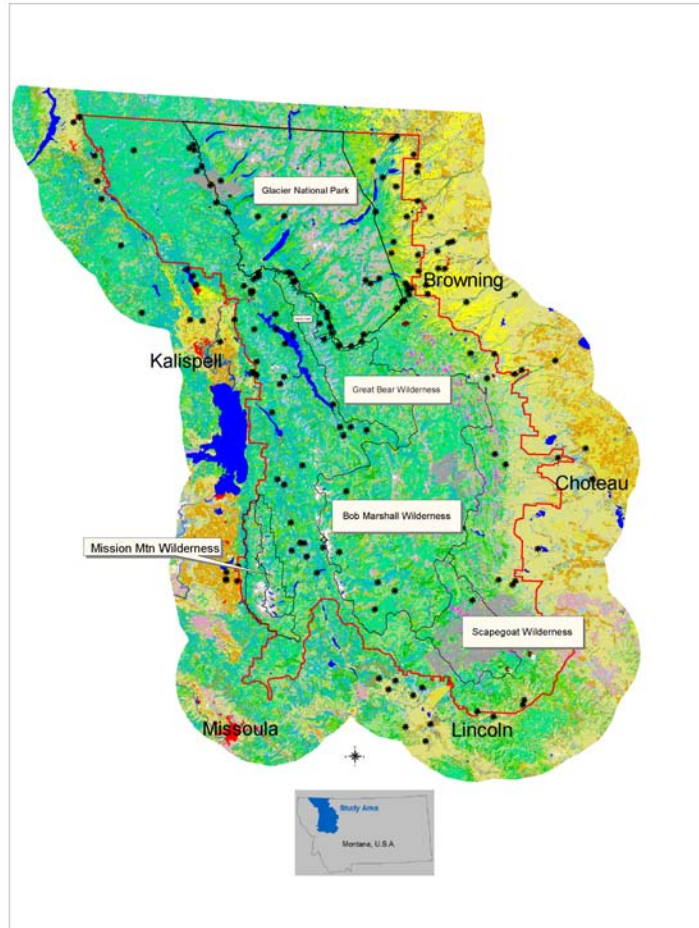
Covariate	Definition
Age	Age determined from tooth cementum, except for cubs and yearling bears which are determined by tooth eruption or body size.
Age Class	Cub, yearling, subadult (2-5 years), adult (>5 years).
Home range location	Each bear will be categorized as living primarily in 1) wilderness, 2) national park, 3) multiple use lands, or 4) private-tribal interface.
Reproductive status	For adult females, whether they have cubs of the year, yearling, dependent 2-year-olds, or are without young.
Management/research capture	Dichotomous variable applied to each bear, each year, based on whether bear was captured from the population at large for monitoring purposes or whether it was captured due to management actions.
Season	Spring (den exit- 15 July) summer (16 July-16 September) autumn (17 September-den entry), denning (period when bears in den). <sup>a</sup>
Bear Management Unit	Bear assigned to predominate BMU.

<sup>a</sup> Mace et al. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. *J. Applied Ecol.* 33:1395-1404.

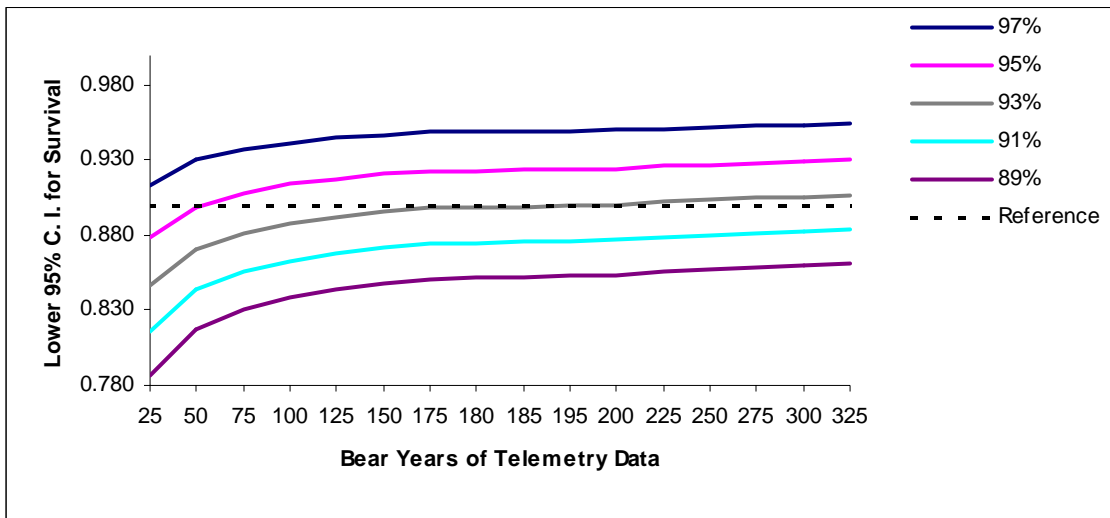
**Figure 1. The Northern Continental Divide Ecosystem in western Montana. The recovery zone boundary is depicted in red. Grizzly bears will be monitored within a 10 mile buffer of the recovery zone as given in the outer line.**



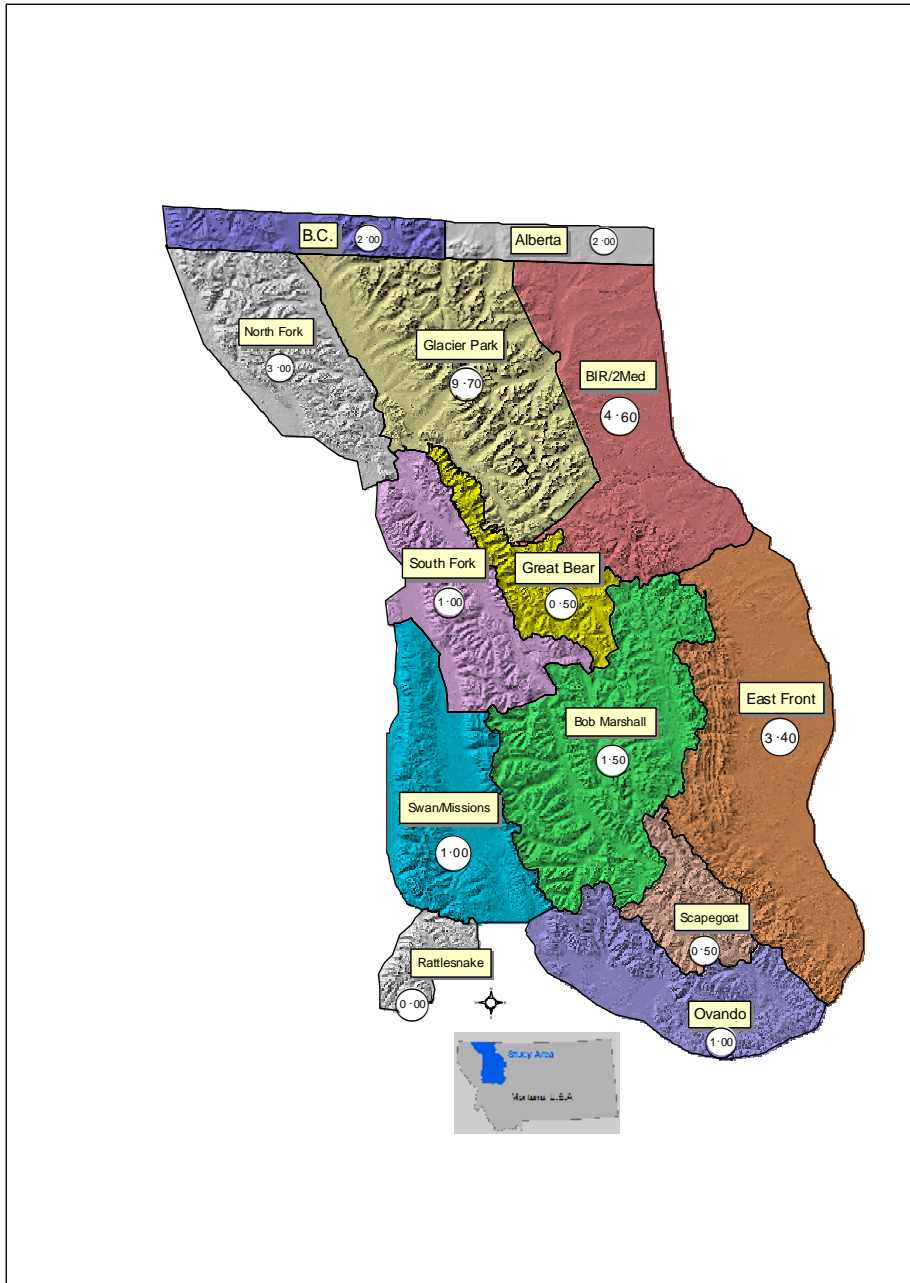
**Figure 2. Locations (black stars) of 191 known grizzly bear mortalities in the NCDE; 1994-2004. Mortalities for which there are not coordinates are not shown.**



**Figure 3. The relationship between the number of radio-years obtained on female grizzly bears and the confidence (risk) in the estimate of survival. Each line represents the lower 95% confidence interval for one of 5 example survival rates (89, 91, 93, 95 and 97%). The lower interval is especially important for population management.**



**Figure 4. Preliminary distribution of radioed female grizzly bears in the NCDE and Canada. The number of females to monitor in each monitoring zone was based on population density estimates from the first (June) of 4 DNA surveys conducted in the NCDE in 2004.**



**Appendix A**  
**List of Participants in a Meeting to Review Study Design**  
**February 2005**

Sterling Miller, PhD. bear research biologist, Alaska Fish and Game, Montana Wildlife Federation

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Tim Manley, B.S. grizzly bear management specialist, Montana Fish, Wildlife and Parks

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Mike Madel, B.S. bear management specialist, Montana Fish, Wildlife and Parks

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