Black Bear Harvest Research & Management in Montana

2011 Final Report

Richard D. Mace and Tonya Chilton-Radandt

Montana Fish, Wildlife & Parks

Wildlife Restoration

Black Bear Harvest Research and Management in Montana

Montana Fish, Wildlife and Parks
Wildlife Division
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Contributors

Dr. Richard D. Mace. Dr. Mace received his Ph.D. from the Swedish University of Agricultural Sciences and his Master's degree from the University of Montana. He is a Research Biologist for MFWP specializing in black bears and grizzly bears. He has worked in the Research and Technical Services Bureau for MFWP since 1984.

Tonya Chilton-Radandt. Tonya's work with bears first focused on black and grizzly bear conflict management, but changed to bear research in 2002. She obtained her Master's degree in Wildlife Biology from the University of Montana in 2006. Tonya has worked for MFWP since 1998.

Julie Beston. Julie is a Ph.D candidate at the University of Montana, Missoula. She has been working on meta-population analyses of black bear dynamics in the western United States and assisted in the estimation of harvest rates from the mandatory harvest data collected by MFWP in Montana.

Dr. Michael Proctor. Dr. Proctor is a Research Biologist who has specialized in the application of genetics to bear population viability and conservation. He is the Director of Birchdale Ecological Ltd. in Kaslo, British Columbia, Canada. Michael contributed the analyses of genetic distances among bear populations in Montana.

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FOREWARD

January 16, 2011

Montana offers world renowned, fair-chase black bear hunting, and black bears are a highly treasured big game animal in Montana. From the high density bear populations of the maritime, wet, forested northwest corner of the state to the dry, rugged country in southeastern Montana, black bear hunters and enthusiasts enjoy a variety of season types and viewing opportunities. Annually, more than 20,000 black bear licenses are sold, and roughly 10,000 people spend 90,000-100,000 days hunting to harvest approximately 1000 black bears in Montana.

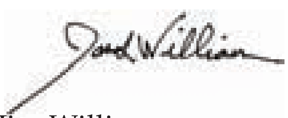
In the early 1990's, controversy over recreational harvest of black bears by the public reached a zenith. Public harvest of grizzly bears in Montana had recently been halted by a federal court that determined the state of Montana did not have adequate data to indicate that the recreational harvest was not impacting grizzly populations. Several public stakeholders and even some internal Montana Fish, Wildlife, and Parks (FWP) staff argued the same was true for black bears in Montana. At the same time, black bear harvest was (and is) an important part of the lives of many Montanans. As a result of this controversy, FWP initiated a public scoping and Environmental Impact Assessment process to update the black bear management program.

The Montana Black Bear Environmental Impact Statement (EIS) was finalized in January 1994. This effort included consideration of the available data regarding the harvest of black bears in Montana, as well as summaries of research findings from other states like Idaho. The EIS set the subsequent management direction for Montana, based on research-based standards at the time, and included spring and fall black bear hunting seasons. The EIS also established benchmarks necessary to continue implementing recreational public harvest. These benchmarks were aimed at ensuring that the harvest of adult female bears was conservative across the state, in order to maintain the reproductive portion of each population and ensure their conservation. However, the benchmarks were established based on the available data collected when black bears were harvested, which remains problematic to many. Basic questions, such as the public harvest rate of black bear populations in different areas, went unanswered. Thus the controversy surrounding public recreational harvest of black bears continued through the late 1990's.

This research project is the first of its kind and was designed to fill information gaps concerning the impact of harvest on black bear populations throughout Montana. It started in 2001 with intensive capture, marking, and DNA-based harvest rate sampling efforts in the Swan Valley. Eventually it expanded to encompass areas spread throughout central and western Montana, over 8000 square miles. This project is an outstanding example of how technology and scientific rigor can be used to inform wildlife management and conservation programs, such that decisions regarding the conservation of wildlife are adequately informed and reliable. Of course, technology and rigor alone cannot fulfill this need; data from the field are requisite to effective applied wildlife research and management programs.

This project represented a tremendous collaborative effort to gather the necessary field data, including help from more than 400 public citizens, landowners, university staff and students, staff from other state and federal agencies, and FWP staff, particularly wildlife biologists and managers, during an 8-year period. In each area where the project operated, it was run jointly by wildlife research and management staff, and volunteers from all stakeholder groups were involved. This gave everyone a stake in the project, and allowed everyone to learn together.

This project represents the best of applied wildlife research. The project was focused on clear information needs surrounding a high-profile, contentious issue important to Montanans. The investigators amassed a tremendous amount of hard-earned field data, and used technology and analysis to get the answers they needed from these data in an objective and repeatable way, by any state or province that manages black bears. And, the project was conducted in close collaboration with the people that most need the resulting information and inferences to help with the wildlife conservation decisions that they make, inform, or care deeply about. For these reasons, the results of this project are already being applied to black bear management and conservation in Montana, and this report will help to form the basis of the black bear management program in Montana for years to come.



Jim Williams
Montana Fish, Wildlife, and Parks
Northwest Montana Wildlife Program Manager
Kalispell, Montana

Justin Gude
Montana Fish, Wildlife, and Parks
Wildlife Research and Technical Services Section Manager
Helena, Montana

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Mark Anderson
Mark Anderson
Steve Anderson
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Val Asher
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Chris Benske
Katie Benzel
Dwight Bergeron
Keith Bledsoe
Bob Brannon
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Chris Crane
Julie Cunningham
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Regan Dean
Dave Deavours
Alee Delsack
Rich DeSimone
Kristie Dubois
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Vickie Edwards
Charlie Eustace
Tom Everett
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Kevin Frey
Mel Frost
Robert and Barbara Garcia
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Hailey Graf
Brandon and Toni Green
Chris Gunderson
Nyeema Harris
Mo Hartmann
Kevin Heinle
Bob Henderson

Jeff Herbert
Lorin Hicks
Tara Hodges
John Hoerning
Jason Hollis
Lori Homstol
Leonard Howke
Dave Hulslander
Amy Jacobs
Fred Jakubowski
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Lynn Johnson
Jamie Jonkel
Craig Jourdonnais
Wayne Kasworm
Coy Kline
Joe Knarr
Quentin Kujala
Vernon LaFontaine
Sarah Lamar
Steve Lamar
Jared Lampton
Tom Lemke
Adam Lieberg
Roger Lindahl
Tom Lipke
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Jennifer Lund
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Adam Nelson
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Ellen Sullivan
Graham Taylor
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Mike Thompson
Ron Uchytil
Ray Vinkey
John Vore
Kerry Wahl
Dean Waltee
Erik Wenum
Julie White
Harry Whitney
Tom Wittinger
Randy Wuertz
Rick Yates
Nate Yorgason
Ryan Zijac

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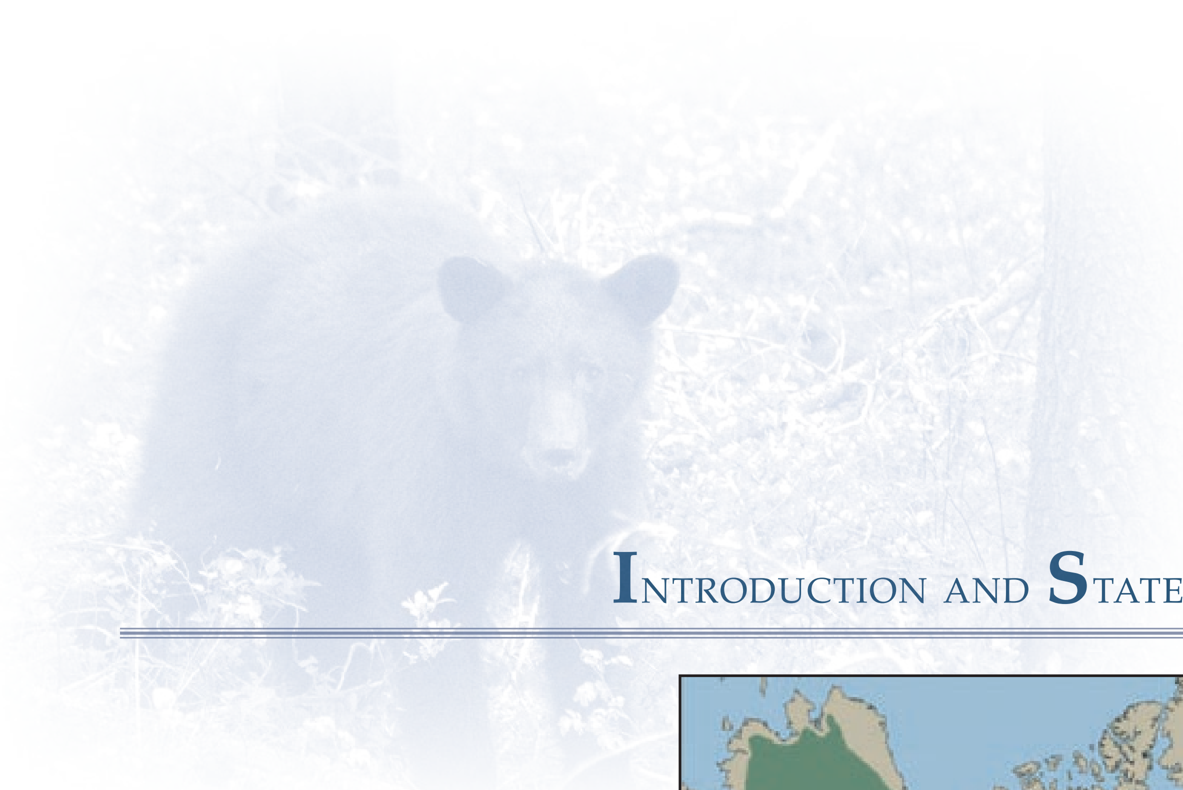
Executive Summary

- Since the mid-1990s, Montana's annual black bear harvest has averaged 4th in the nation behind Washington, Oregon, and Idaho in numbers of bears harvested. Use of dogs to hunt bears (of either species) was prohibited in Montana in 1921. Black bears were first classified as a predatory animal, but in 1923 they were designated as a big game animal. The harvesting of cubs, or females with cubs, was prohibited in 1947, followed by a prohibition of the use of baits in 1948. A mandatory check of all harvested black bears was instituted in 1985.
- On average, approximately 1,030 black bears were harvested in Montana annually between 1987 and 2006. Most (46%) bears were harvested in Region 1, and the fewest number of harvests occurred in Region 5 (6%). Forty-seven and 53% of the harvest occurred during the spring and fall hunting seasons, respectively.
- The harvest criteria of the percent of females in harvest, median female age, and median male age were variously met each year throughout regions of Montana. Statewide, all 3 criteria (harvest < 40% females, female median age >6 years, and median male >4 years) were met approximately 17% of the time.
- We approximated the current year-round distribution of black bears in Montana using regional MFWP wildlife biologists familiar with bear habits, movements, and historical harvest locations. The total extent of black bear habitat within the state is approximately 116,554 km^2, most of which is within Region 1.
- An average litter size of 2.08 cubs/litter and an average reproductive interval of 2.2 years were estimated from harvested female black bears. From these data, an average natality rate for female cubs was 0.473.
- DNA-based estimates of black bear harvest rates were conducted in 11 geographic areas of Montana from 2001 through 2008. These sample areas totaled 38,705 km^2, which was 33% of all bear habitat in Montana.
- All areas except BMU 411 (H_E = 0.67) and BMU 520 (H_E = 0.78) were $\geq$ 80% mean heterozygosity, suggesting relatively high genetic health.

- The number of shared loci for genetic differentiation scores varied from 2 to 6. Two shared loci were common to all study area combinations. In general, genetic differentiation, adjusted for spatial distance, was greatest for areas that were compared to the spatially-isolated BMU 411.
- Annual harvest rate estimates for female black bears in 9 study areas of Montana averaged 3.1%. Average harvest rate for females 1+ years old was estimated to be 4.2% and varied from 4.0% to 4.3%. The mean male harvest rate, over all study areas, was 8.1%.
- Using the Fraser et al. (1982) method to estimate harvest rate from the harvest data, the estimated annual harvest rates for male and female black were 10.0% and 4.0%, respectively.
- Population size and density were estimated from bear recapture frequency at hair-traps. Population density for all study areas combined and both sexes varied from 8.8 bears/100 km^2 (-90% CI) to 19.1 bears/100 km^2 (+90% CI). The mean density for all areas was 12.8 bears/100 km^2. Female densities, on average, were higher than those for males.
- We determined that bear density in our DNA study areas correlated with precipitation patterns. Using this relationship, we estimated bear population size and density throughout Montana. Our mean population estimate for the state was 13,307 black bears, and the mean density was 12.5 bears/100 km^2. Bear density generally decreased from north to south.
- Our simulations that explored relationships between female survival and fecundity showed, as expected, that population trend decreased as female mortality increased. We estimated that total mortality exceeding 15-17% would lead to population declines.
- Detailed nonhunting mortality data are not available for Montana. Based on the literature, credible nonharvest mortality levels may be within the range of 5-15%. Under a simple additive mortality scenario then, total female mortality rates may approach 10-15% in many areas of the state. Because of the uncertainty in nonhunting levels, there appears to be little decision space for population managers to increase black bear harvest above current levels anywhere in Montana.
- The harvest data, obtained from the mandatory check, were insufficient to gauge whether the bear population would be in decline on an annual basis. Based upon our analyses, it would take approximately 15 years for managers to be 78% sure that a decline in the population was occurring. Therefore, we see little practical value in the harvest records for estimating population trend in the wild population.
- It appears that, over time, black bear hunter numbers in various areas of Montana have struck a balance with inherent black bear densities. We have shown that bear density is greatest in the moist, coniferous habitats of northwestern Montana and generally declines with less moist habitats towards the south. Hunter numbers follow this same pattern.
- In our view, the value of the mandatory check is to maintain accurate records of the number and sex of bears harvested per BMU, which is valuable for ascertaining harvest trends. The collection of teeth for precise age determination of each harvested bear is not necessary. However, the decision to continue with tooth collection could be left up to individual regions, but we would caution that age data will be rather uninformative without data on hunter numbers and effort.



Introduction and Statement of Need

The historic range of black bears (*Ursus americanus*) included most of the forested habitats of North America, including northern Mexico (Hall 1981). Currently, black bears persist in forested habitats throughout Canada and in many eastern and western states (Fig. 1) where most populations are stable to increasing (Servheen 1990). Harvest levels and population data for most areas are also provided by Servheen (1990). The species has been extirpated from most of Kentucky, Alabama, Ohio, and Illinois (Pelton 1982).

Figure 1. Distribution of black bears in North America (green shading) (Vaughan and Pelton 1995).

The black bear occupies suitable forested areas in the western one-third of Montana, and bear hunting has a long tradition in the state. Black bears are hunted in 6 of 7 regions (Fig. 2) administered by Montana Fish, Wildlife & Parks (MFWP). These regions are further divided into Bear Management Units (BMUs) that are intended to provide a more precise accounting of black bear distribution and harvest levels (Fig. 3).

Beginning in the mid 1980s, wildlife biologists in the state recognized that several areas were experiencing increased interest in black bears by hunters, and that populations in those areas could become vulnerable to overharvest. From 1985 onward, all hunters were required to present their harvested black bear to MFWP personnel. This mandatory check was initiated to collect accurate information on the number of bears harvested in each BMU and the age and sex

Figure 2. Current MFWP administrative regions in Montana. Black bears are harvested in all but Region 6.

Figure 3. Black Bear Management Units (BMUs) in Montana.

composition of the harvest. To better address and evaluate options for black bear population management, MFWP wrote a Programmatic Environmental Impact Statement (MFWP 1994). Based on analyses of harvest data available at the time, authors of the impact statement cited the need for improved monitoring of populations and harvest levels.

In 2001, MFWP began a research study to better assess, at a statewide level, black bear harvest rates and population densities. The specific objectives of this study were to:

1. Summarize black bear harvest levels, hunter numbers, and harvest regulations;
2. Evaluate existing bear population management criteria;
3. Delineate black bear distribution in Montana;
4. Document black bear harvest rates in Montana using three methods:
    a. analysis of harvest data,
    b. genetic mark-recapture methods, and
    c. from a sample of radio-instrumented bears;
5. Develop estimates of black bear population size and density;
6. Estimate sustainable mortality levels for Montana black bears; and
7. Summarize the genetic structure of black bear populations.

History of Black Bear Management in Montana

Since the mid-1990s, Montana's annual black bear harvest has averaged 4th in the nation behind Washington, Oregon, and Idaho. Black bear hunting has a long history in the state. Hunting began with the Native Americans and the Lewis and Clark exploration. The meat, oil, hide, and claws were all used for nourishment, warmth, and to establish status. With the movement west by settlers, black bear harvest increased, and the need for conservation measures became apparent.

In 1889, the Montana Territory became a state. The philosophy of the early Montana conservation program was to allow recovery of game populations; laws were passed to restrict hunting, and people were hired to enforce the laws. The first game warden in Montana was hired in 1901. The codes of 1921 gave Montana's game commission the power to open and close seasons when residents showed that such action would be in the interest of fish, game, and/or people.

Use of dogs to hunt black bears or grizzly bears (*Ursus arctos horribilis*) was prohibited in Montana in 1921. Black bears were first classified as a predatory animal, but in 1923 were designated as a big game animal. The harvesting of cubs, or females with cubs, was prohibited in 1947, followed by a prohibition of the use of baits in 1948. With these regulations in place, black bear hunting became more of a fair chase sport in Montana. The original fair chase creed from the Boone and Crockett club is defined as "the ethical, sportsmanlike, and lawful pursuit and taking of any free-ranging, wild North American big game animal in a manner that does not give the hunter an improper advantage over such animal."

Use of dogs to hunt black bears or grizzly bears (Ursus arctos horribilis) was prohibited in Montana in 1921.

There is a long history of hunting black bears in Montana.

Annual black bear harvest numbers were officially recorded by MFWP beginning in 1985.

Changes have been made to MFWP's black bear regulations to maintain the concept of fair chase, especially as hunting equipment became more sophisticated. Regulations were implemented to restrict, for example, the use of two-way communication radios; motion-tracking devices, night vision equipment, recorded animal sounds, and automatic cameras.

Between 1959 and 1971, black bear hunting was open from mid-March through the end of November. In 1961, black bear hunting was made available to nonresident hunters. All hunters were initially allowed to harvest one of each species (black and grizzly bears), but in 1967 the harvest changed to one bear of either species per year.

Annual black bear harvest numbers were officially recorded by MFWP beginning in 1985, whereupon most black bear hunting was restricted to either a spring or a fall season (Table 1), and the summer harvest season was eliminated. Although the specific dates have varied

Table 1. Black bear season structure by year and BMU in Montana, 1985-2006.

BMU	Black bear harvest regulation by year[a]																					
	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06
100	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
102	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
103	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D
104	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
105	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
106	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D
107	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D
108	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
216	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
240	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
280	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
290	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
300	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
301	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
316	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
317	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
319	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
341	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
411	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
420	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
440	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
450	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
510	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
520	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
580	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
700	No Season																					C

[a] A – Spring and fall seasons
B – Year-round
C – Quota
D – Validation

by area and by year, the spring season generally occurred from 15 April to the end of May or into the middle of June. A typical fall season took place from early to mid September until the end of November.

All hunters were required to present their bear for inspection by an MFWP official beginning in 1985. Evidence of the bears' sex had to be naturally attached to the carcass. A premolar tooth was extracted for aging.

The cost of a resident black bear license has changed relatively little since 1985 (Table 2). Between 1985 and 2008, resident costs have risen from $8 to $19. Prior to 2002, a nonresident license could be purchased for $120. Since 2002, the nonresident fee has remained stable at $350.

Prior to 1984, with few exceptions, most hunting districts in Montana were open to black bear hunting between 1 April and 27 November, which constitutes the majority of the non-denning period for bears. Not coincidentally, conflict numbers between black bears and people (human-bear conflicts) were relatively low at that time; black bears involved in conflicts were often legally shot by landowners or hunters with a black bear license. After 1983, legal black bear hunting was constrained to a shorter period. Thereafter, many biologists began noticing an increase in the number of black bear conflict calls they received.

In response to this apparent rise in conflict numbers, MFWP created the first Bear Specialist position in 1985. By the mid-1990s, 3 more positions were filled in Regions 1, 2, and 3. In general, Bear Specialists respond to landowner complaints about bears and provide information on methods to reduce human-bear conflicts, as per MFWP protocol (MFWP Nuisance Black Bear Guidelines 2003, unpublished report). In 2001, to address concerns over wildlife disease and wildlife threats to public safety, the Montana legislature adopted a rule that prohibits the feeding of bears, mountain lions, and ungulates (Montana Code Annotated 87-3-130 2009).

Of particular importance to black bear management is that black bear hunters may, on occasion, mistakenly kill grizzly bears. According to mortality records, < 2 grizzly bears were known to be mistakenly killed by black bear hunters annually in each designated grizzly bear recovery area (Table 3).

In 2002, to reduce such mortality, MFWP developed a computerized black bear/grizzly bear identification test, available on the internet, that hunters were required to pass prior to obtaining their black bear hunting license.

To further reduce mistaken identity in northwest Montana, spring black bear hunting seasons were shortened in low-density grizzly bear areas, and the validation system was put into place in 2001. Originally, the purpose of the validation regulation was to reduce the relatively high number of unsuccessful hunters in the more western BMUs of

The cost of a resident black bear license has changed relatively little since 1985.

Of particular importance to black bear management is that black bear hunters may, on occasion, mistakenly kill grizzly bears.

Table 2. History of black bear hunting regulation units and resident and non-resident license cost in Montana, 1985-2008.

Years	Black bear hunting regulation unit	Resident license cost (dollars)	Non-resident license cost (dollars)
1985-1991	Same as deer, elk, and lion	8.00	120.00
1992-1993	Same as deer, elk, and lion	11.00	120.00
1994-2001	Bear Management Units	15.00	120.00
2002-2005	Bear Management Units	15.00	350.00
2006-2008	Bear Management Units	19.00	350.00

Table 3. Levels of grizzly bear mistaken identification in the federally-designated grizzly bear recovery zones of Montana.

Number of grizzly bears killed by mistaken identity by recovery zone (Montana portion only)			
Year	Northern Continental Divide	Cabinet/ Yaak	Greater Yellowstone
1999	0	1	0
2000	3	0	2
2001	0	0	1
2002	1	0	1
2003	1	0	1
2004	1	0	2
2005	1	1	1
2006	1	0	1
2007	1	0	1
2008	2	0	5
$\bar{X}$	1.1	0.2	1.5

Region 1 from shifting to the higher density grizzly bear areas of BMUs 103, 106, and 107 during the last few weeks of the spring season. This further minimized the risk of grizzly bears being mistakenly killed by black bear hunters. In 2010, the spring validation requirement was modified to include only the BMUs on the west side of Highway 93. A validation requirement in these particular BMUs would provide a mailing list of resident and nonresident black bear hunters to which MFWP's educational efforts could be directed. In addition, bear hunters could be identified as needed by MFWP enforcement using this list. Regulating hunter effort in these BMUs could help maintain grizzly numbers into the future and preserve MFWP's black bear harvest in areas with grizzly bears.

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The author examines a black bear harvested in western Montana.

Methods

Black bears are widely distributed in western Montana.

Black Bear Harvest Levels, Hunter Numbers, and Adherence to Harvest Criteria

Beginning in 1985, all hunters in Montana were required to present their harvested black bear to MFWP personnel to ensure that accurate information on the age and sex of harvested bears was collected. A premolar tooth was extracted for age determination (Stoneberg and Jonkel 1966). Adult bears were those >5 years old. We collated harvest data from 1987-2006 to summarize the annual harvest statistics for the state, each region, and each BMU. From 1996-2003, MFWP also collected hunter number and effort information from resident and nonresident black bear hunters using a telephone survey.

Harvest criteria were established in 1994 (MFWP 1994) to provide safeguards against overharvest. We evaluated the degree to which these criteria were met each year in each BMU. The criteria we assessed were:

a. no more than 40% of annual harvest be composed of females;

b. median age of harvested bears are > 6 years for females and > 4 for males; and

c. if harvest does not comply with a) and b) in any 3 consecutive years, all data for the management unit will be analyzed to determine what management changes are warranted.

Black Bear Distribution in Montana

We approximated the current distribution of black bears in Montana by soliciting information from MFWP wildlife biologists familiar with bear habits, movements, and historical distribution of harvest. Digital maps of conifer forest cover in each BMU (Fisher et al. 1998) were sent to these biologists who then drew bear distribution maps for the areas they manage. Two mapping criteria were established: 1) delineate only those areas considered to be year-round habitat, and 2) map areas in which resident black bear hunters would reasonably expect to see bears. Spatial analyses were conducted using the ArcGIS geographical information software (Environmental Systems Research Institute, ArcGIS: Release 9.3).

Reproductive Rates of Female Black Bears

Reproductive data were used for population analyses.

Aune and Anderson (2003) extracted and examined reproductive tracts of known-age female black bear carcasses collected across the state between 1990 and 1999. These black bears varied in age from 0.5 years to 32 years old. Ovaries were serially sectioned and scanned with a microscope to count corpora lutea. Additionally, 582 premolar tooth sections from female black bears killed between 1980 and 1999 were examined. Interbirth intervals for each individual were estimated by examination of the layering patterns of cementum (Coy and Garshelis 1992).

Field research by the co-author has aided MFWP in a better understanding of black bear populations.

The reproductive performance of female black bears was evaluated using the age of primiparity (first reproduction), litter size, and the interval between successive litters. The reproductive rate per female was defined as the number of female cubs/interbirth interval. The sex ratios of cubs were assumed to be 50:50.

Harvest Rate Estimation

Harvest Rates Determined From Genetic Analyses at DNA-monitoring Areas. —

We estimated the harvest rate of black bears in several hunting districts (HD) and BMUs. Our method using DNA-marked black bears was a variant of typical mark-recapture methods. Typically, a portion (sample) of a population under study is marked in the first time period, and the population is re-sampled later to look for the incidence of marked animals. As not all members of the population are captured, such study designs constitute a sample of the population. Conversely, our methods were a mixture of sample and census procedures. In the first session, a sample of the population was "captured" and genotyped at hair-traps. The fall and spring recapture sessions were from the subsequent 2 hunting seasons, where hunters were mandated by law to present the carcass to wildlife officials. These recapture sessions of harvested bears therefore constituted a census of bears legally harvested.

We marked a sample of black bears in each study area using the methods of Woods et al. (1999). Bears were attracted to barbed-wire hair-traps which were designed to gather hair on the wire when the bear entered the trap. Hair–traps were randomly selected on a 5 x 5 km grid. Hair-traps consisted of a single strand of barbed wire strung around trees to make a corral; at the center of which was placed a lure. Hair-traps were approximately 64 m^2, and we used double-strand, 14-gauge, 4-pronged barbed wire. As possible, the wire was strung at a continuous 46 cm from the ground. One liter of lure, consisting of one part livestock blood to one part decomposed fish, was placed in the center of the hair-trap. After approximately 14 days, the crews returned to sites to collect hair samples, which were uniquely numbered, and to dismantle the hair-traps. We then collected hair samples from bears harvested in each study area during the following fall and spring hunting seasons.

Our sampling protocol differed from above for 4 study areas. For most areas, MFWP personnel and volunteers conducted the field investigations. However, for BMUs 103 and 450, we used black bear hair samples previously collected for a grizzly bear population study (Kendall et al. 2009). For BMU 104, we used black bear hair samples collected in a grid during 2003 as a part of ongoing grizzly bear studies in the Cabinet/Yaak Ecosystem (W. Kasworm, U.S. Fish & Wildlife Service, pers. comm.). In BMU 520, hair-trap grids were established in each of 4 years by the local MFWP biologist.

Hair samples were genotyped by Wildlife Genetics International (W.G.I., PO Box 274, Nelson, B.C., Canada V1L 5P9). Three tests were performed on almost every sample following the protocol of Woods et al. (1999) and Paetkau (W.G.I., pers. comm.): species identification, individual identification, and sex analysis.

First, the differentiation of black bear hair samples from those of grizzly bear was necessary in areas where the 2 species overlapped. By extracting a short length of mitochondrial DNA (mtDNA) and amplifying it, lab technicians determined the species of each sample. The number of even or odd alleles at a specific locus on the mtDNA classified the sample as grizzly or black bear. After the species was determined, at least 5 unique microsatellite loci were selected and used to determine the individual genotype of each sample. Microsatellites were put through a Polymerase Chain Reaction (PCR), electrophoresis, and scoring. Single allele variance determined a sample's genotype, and any nonmatches were determined to be an individual genotype. The computer software GENOTYPER scored each genotype, which was then examined visually. Error-checking was complete and thorough, such that genotyping errors were equal to zero. Some samples were also analyzed to determine sex. Lab technicians performed a PCR on the sample in question. Following amplification, differences in gene sizes were used to qualify the sex of a sample.

A weakness in the genetic analysis of bear hair samples is that the age of the individual is unknown. Therefore, our samples collected from the wild population of bears came from a mixture of age classes, some of which are not legal to harvest. Of primary importance was determining whether dependent young were sampled at hair-traps. Most literature on this subject comes from studies of brown bears, and authors recognized that dependent young were captured at hair-traps (Mowat and Strobeck 2000, Boulanger et al. 2004, Kendall et al. 2009).

For our samples of black bear hair, we were most concerned about the incidence of cubs-of-the-year in DNA samples as this is the only age class of bear that is not legal to harvest. To explore this issue, we examined our genetic data to determine whether females and their attendant young were potentially detected at hair-traps. We first scrutinized each possible female/male or female/female dyad that was detected at the same hair-trap during the 2-week sampling period. We first examined the microsatellite data for each dyad and determined whether

Differentiation of black bear hair samples from those of grizzly bear was necessary in areas where the 2 species overlapped.

The age of a bear can not be determined from hair samples.

The premolar tooth is extracted to be analyzed for age.

to female cubs.

Harvest rates for male and female bears were calculated as the percentage of bears genotyped in the summer hair-trap sessions that were subsequently harvested in either the fall hunting or the following spring season. Harvest rates were estimated for all bears of each sex, and for those bears 1+ years old. Genotype matches between hair-trap samples and harvested bears were determined by WGI.

In some instances, the observed harvest in a study area was similar to the long-term average for that area, while in others it was not. We therefore calculated 2 estimates of harvest rate for each sex. The first was an estimate during the year of field study. The second was an "adjusted harvest rate" that incorporated information from the long-term harvest level for each area. We used the ratio of the harvest during the year of study to the long-term mean annual harvest to make adjustments that would represent harvest rates during an average year. The "adjusted harvest rate" was calculated as the harvest rate during the year of study divided by the ratio.

they shared > 1 allele per locus (zero-mismatch) for the 5-7 markers that we initially used to determine individuals. These then became candidates for parent-offspring pairs. We took a subsample of these dyads and extended the genetic analyses to 25 loci to ascertain likely parent-offspring pairs.

Because cubs cannot be legally harvested, it was necessary to estimate the proportion of this age class in the population and exclude them from harvest rate estimates. We estimated the plausible proportion of cubs in Montana's black bear population by examining the interbirth interval data derived from tooth cementum patterns (Coy and Garshelis 1992). We used the data of Aune and Anderson (2003) for which there were harvest samples for the years 1989-1992. For each year, we classified each female as a cub, a subadult, or an adult. Females were first considered to be adults in the year prior to their first litter. Using an average litter size of 2 cubs, we then estimated the proportion ($\overline{X}$ and 95% CI) of cubs that may have been detected at the hair-traps. We assumed a 50:50 ratio of male

Harvest rates were estimated for all bears of each sex, and for those bears 1+ years old.

Estimation of Harvest Rate from Harvest Data—Fraser et al. (1982) proposed a simple and straightforward method for estimating the harvest rate of a population based on the sex and age composition of the harvest. It is based on the fact that if one sex is more vulnerable to harvest than the other, the ratio of males to females in the harvest of a cohort will change as that cohort ages. Given an average harvest rate of k and a difference in vulnerability v, such that the harvest rate of males is $k+v$ and the harvest rate of females is $k-v$, then the ratio of males in the harvest, H_m, to females in the harvest, H_f, at age i can be written as,

$$\frac{H_{m,i}}{H_{f,i}} = \frac{M_1(1-(k+v))^{i-1} s_m^{i-1}(k+v)}{F_1(1-(k-v))^{i-1} s_f^{i-1}(k-v)}$$

where M_1 and F_1 are the numbers of males and females, respectively, in the cohort when it enters the harvestable population and s_m and s_f are the natural survival rates of males and females, respectively. If one assumes that the cohort begins with a sex ratio of 1:1 and that natural survival rates do not differ between sexes, one can estimate k as $1/y$, where y is the year in which the sex ratio of the harvest becomes 1. Fraser showed that this method is fairly robust for situations where v is much smaller than k or when k is close to 0.5.

While it is likely that the sex ratio of black bears is 1:1 when they enter the harvestable population as yearlings (Elowe and Dodge 1989, Miller 1994), several other assumptions are unlikely to hold for bears. It is also unclear whether the differential vulnerability, v, is much less than the average harvest rate, k, and it is certain that k does not approach 0.5 for black bears. Instead of using the simplifying assumption that v is much smaller than k, the information about the first harvest a cohort experiences was used to solve the original equation directly for k. In the first harvest,

$$\frac{H_{m,1}}{H_{f,1}} = \frac{M_1(k+v)}{F_1(k-v)}$$

We can therefore write v in terms of k,

$$v = k\,\frac{\left(\frac{H_{m,1}}{H_{f,1}} - \frac{M_1}{F_1}\right)}{\left(\frac{H_{m,1}}{H_{f,1}} + \frac{M_1}{F_1}\right)}$$

Letting

$$x = \frac{\left(\frac{H_{m,1}}{H_{f,1}} - \frac{M_1}{F_1}\right)}{\left(\frac{H_{m,1}}{H_{f,1}} + \frac{M_1}{F_1}\right)}$$

we can then replace v with $x \times k$,

Computer models are often used to understand black bear population dynamics.

$$\frac{H_{m,i}}{H_{f,i}} = \frac{M_1(1-(k+xk))^{i-1} s_m^{i-1}(k+xk)}{F_1(1-(k-xk))^{i-1} s_f^{i-1}(k-xk)}$$

At age *y*, the male and female harvests are equal, yielding

$$1 = \frac{M_1(1-(k+xk))^{y-1} s_m^{y-1}(k+xk)}{F_1(1-(k-xk))^{y-1} s_f^{y-1}(k-xk)}$$

To solve for *k*, define *b*:

$$b = \exp\left\{\frac{\log(M_1)-\log(F_1)}{1-y} - \log\left(s_m/s_f\right) + \frac{\log(1+x)-\log(1-x)}{1-y}\right\}$$

Then,

$$k = \frac{1-b}{1+x-b+x\cdot b}$$

Basing estimates on this equation allows one to manipulate the ratios of survival and initial cohort sexes and removes the requirement that v be much smaller than *k* or that *k* be close to 0.5.

It is unlikely that the natural survival rates are the same for both sexes. In reality, male black bears probably have lower survival than female black bears (Pelton 1982). To find *y*, the harvest in which the sex ratio is 1:1, each age group over the entire 20-year harvest dataset was summed. A regression was performed on the proportion of females in the harvest, at each age against age, to estimate *y*. To account for smaller sample sizes at older ages, the regression was weighted by total bears harvested at each age. The value *x* was calculated assuming that the sex ratio of living yearlings is 1:1. The *k* was calculated using these estimates of *y* and *x* while varying the ratio of male survival to female survival, s_m/s_f, from 0.9 to 1.

In reality, male black bears probably have lower survival than female black bears.

Variation in survival and harvest rates also has the possibility of affecting results. The harvest rate estimated in one year given the age structure of the harvest assumes that this snapshot represents the histories of each of the cohorts harvested. If there are no temporal trends in survival or harvest rates, combining several years of harvest information should ameliorate the annual variability and increase the precision of estimates. To assess how the length of harvest dataset affects the precision of estimates of harvest rate, we conducted stochastic simulations of harvested populations.

We simulated 2500 replicate populations for 20 years using a 60×60, sex- and age-based matrix model. The model was parameterized with survival rates and variances from the western half of North America. Harvest rate, fecundity, and their variances, as well as age at primiparity, were based on data from Montana (MFWP, unpublished data). Each year, a harvest rate was selected from a beta distribution, and bears were harvested by simulation. Then vital rates were selected from beta distributions for survival and a lognormal distribution for fecundity, and the population was multiplied by the matrix model. The harvest rate was estimated from the harvest age and sex structure beginning in year one. For each consecutive year, the harvest rate was estimated using the total of all bears harvested to date in each age and sex class.

Finally, the harvest rate for female black bears decreases at primiparity because mothers accompanied by cubs are illegal to harvest. Unfortunately, including this detail renders Fraser's equation algebraically intractable. To explore the potential bias, the same simulation procedure as described was used, but adult females were harvested in the model at half the rate of subadult females. We then compared estimated rates of harvest with the actual total female harvest rate and compared the pattern of the proportion of females in the harvest with the pattern observed in Montana.

Estimation of Harvest Rate from Radioed Black Bears.—Between 2000-2004, we radio-monitored a sample of black bears from the Swan River Valley of Region 1 (HD 130) to estimate male and female survival rates and to document sources of mortality. During June of each year, we utilized a systematic grid design and between one and four 2-person snaring teams. We placed approximately 58 Aldrich foot-snare sites within the study area most years, for a capture site density of approximately 1 site per 27 km^2.

Bears were immobilized using either Ketamine/Rompun or Telazol. Small, black ear tags were placed on each research bear. A sample of bears were fitted with VHF radio collars manufactured by Telonics (Mesa, Arizona, USA). To minimize the chance that bear hunters would be biased against shooting radioed individuals, black collars were placed on black-phase bears and brown collars on those bears with brown pelage. A premolar tooth was extracted from most bears for age determination (Stoneberg and Jonkel 1966). The age classes of the remaining bears were estimated by tooth wear. Bears were classified as either adult (> 5 years) or subadult based on age of first parturition.

We determined the location of radio-collared bears each week as possible using aerial telemetry and determined whether the bear was alive or not. Field crews investigated collars that were in the mortality mode as quickly as possible to determine if the bear had died or simply shed its radio collar.

Estimates of annual survival were made by investigating the number of cause-specific mortalities that occurred relative to the number of days that bears were monitored. Our estimates of survival were based on the entire year, which included winter months when bears were in dens. We used the program MICROMORT for analyses (Heisey and Fuller 1985).

Black bears were radio-collared in the Swan Valley.

Black Bear Population Size and Density in Montana

Black Bear Population Size and Density at DNA-monitoring Areas.—We used DNA recaptures at different hair-traps during the 2-week sampling period to estimate population size in study

Black bear hair was collected at barbed wire hair-traps to assess harvest rates.

Bear densities were estimated throughout Montana.

Sustainable mortality levels were estimated.

areas where sample sizes allowed. We used the general methods described by Caughley et al. (page 152, 1977) termed "frequency-of-capture models" and used Chao's estimator for these data (Chao 1988). Buffer strips surrounding sampling areas are often used to account for lack of geographic closure when estimating population density (Caughley 1977). We used a buffer around a minimum convex polygon (Mohr 1947) constructed from the hair-traps in each area. The size of the buffer strip was based on the "mean maximum distance moved" method of Wilson and Anderson (1985). Values for each distance were the averages of the maximum distance moved between hair-traps for bears that visited >1 trap. Sexes were pooled for this analysis. We were unable to estimate population size or density in HD 319-341 because of insufficient recaptures. For 2 areas, we used a modification of the buffer strip method. For BMU 411, which was an island mountain range surrounded by non-bear habitat, we did not construct a buffer. For BMU 450, black bear habitat did not extend on the east side of the unit, so the buffer did not include this area. We did not construct a buffer for BMU 411 because we sampled the entire extent of bear habitat in this BMU. Density estimates were calculated (bears/100 km^2) for the study areas and represented the density of all age and sex classes of black bears in a given area, including cubs-of-the-year.

Extrapolated Estimates of Black Bear Population Density throughout Montana. — We used the density estimates derived from our DNA study area to predict bear densities across Montana using several landscape variables. Using GIS, we ascertained metrics for road density, precipitation (cm), and the extent of roadless areas within each area. Data were obtained from the Montana Natural Information System website (http://nris.state.mt.us/). The statewide precipitation data represented estimates of the average annual precipitation for the period 1971 to 2000. The metadata for this layer can be found at http://nris.mt.gov/nsdi/nris/mesowest.html. We estimated the proportion of each area that was 'roadless.' The metadata for the roadless layer was found at http://nris.mt.gov/nsdi/nris/roadless_2004.html. Total road density (km roads/km^2) in each area was estimated from TIGER road files (U.S. Census Bureau 2000). These layers were evaluated separately using linear regression techniques. We used linear regression to evaluate each landscape variable relative to black bear density and constructed 90% confidence intervals around our estimates.

We estimated bear density for the BMUs under the jurisdiction of MFWP, and for several other jurisdictions. Aside from the BMUs, estimates were made for Glacier National Park, the Blackfeet Reservation, the Flathead Reservation, the Crow Reservation, the Bears Paw Mountains, and the Pryor and Bighorn Mountains of Region 7.

Estimating Sustainable Mortality

We first used our reproductive data (age of primiparity and reproductive rate) from the reproductive tracks of harvested black bears and applied it to the method of Bunnell and Tait (1980) to obtain an estimate of sustainable mortality for Montana populations. Secondly, to assess likely variability in sustainable levels, we used deterministic models of population growth (λ) with varying reproductive rates. We used the matrix tools within the Poptools add-on to Excel (G.M. Hood 2004; Poptools version 2.6.2 http://www.cse.csiro.au/poptools). We evaluated the effect of 3 reproductive rates on λ. Reproductive rates were estimated by using the mean and 95% confidence intervals of litter size (female cubs/mother/year). The 3 reproductive rate estimates we used were 0.409, 0.472, and 0.534.

Cub survival was held constant at 0.78 (Miller 1990) and age of primiparity was modeled at 6 years of age. We then varied independent female survival (1+ years old) from 0.99 to 0.75 in 1% survival increments. For each model, we recorded the observed change in λ.

Using Harvest Data to Estimate Population Trend

Using lambda (λ) and its variance for western North America, we simulated an unstructured population beginning with 30,000 bears (Beston, unpublished data). The simulated population was harvested for 50 years at 4% (SD = 0.4%). A linear regression was fit to the total number of bears harvested each year, initially starting with 3 years of harvests and adding consecutive years through the end of the dataset. Each year, we checked for a statistically significant decline in harvest numbers by assessing whether the coefficient of year was less than zero at $p = 0.05$. This represented a worst-case scenario because the spatial variation incorporated in probably overestimates the temporal variation in any one population (because management and habitat varied widely among populations). A simulation was performed with a deterministic population subjected to a stochastic harvest as a best-case scenario. Because the length of time to detection also depends on the rate of decline, the process was repeated with deterministic population growth and stochastic harvest and by varying the population growth rate. The length of time it would take to reach 90% power in detecting a decline in the harvest for values of between 0.95 and 1 was determined.

Genetic Structure of Black Bear Populations

Genetic Diversity.— Using the genotypes of black bears captured at hair-traps, we calculated the heterozygosity (H_E) of each study area.

A black bear investigates a hair-trap.

Heterozygosity is the most commonly used measure to compare the genetic variation within different populations, and is the expected proportion of heterozyotes if the population is mating at random.

Genetic Differentiation. — We also calculated the genetic differentiation (F_{ST})between DNA study areas. F_{ST} is the proportion of total genetic variation within a species that is due to differences among populations. F_{ST} varies between zero (no genetic differentiation) and one (complete differentiation). To calculate F_{ST}, study areas were grouped into pairs of interest (usually adjacent pairs), and GENEPOP (version 1.2, Raymond and Rousset 1995) software was used to analyze F_{ST} of the populations from each of our DNA study areas. At least five loci for genotyping were chosen from a suite of 16 markers to optimize the probability of identity for each study area. Because only 2 alleles were shared across all study areas, F_{ST} results reported here should be considered preliminary and were used to examine general patterns across the state. We offer this preliminary result only to provide a

We determined bear genetic diversity in Montana.

Little is known about how roads affect harvest vulnerability of black bears.

look at potentially interesting genetic relationships that might be worthy of further investigation. To obtain more conclusive results we recommend that genotypes in all study areas be run to a minimum of 8-9 common loci. Relationships were tested with more than 2 loci when possible, allowing us to examine whether patterns observed using only 2 shared loci held true with more loci.

Because genetic differentiation in bears is known to be influenced by geographic distance, the amount to which study areas were geographically distant from each other was accounted for by using an "adjusted F_{ST}." This value was calculated as: [(raw F_{ST} score/geographic distance between the geographic center study areas)*10,000].

Adult Male Vulnerability to Harvest Relative to Forest Roads in the Swan Valley

Little is known about how roads affect harvest vulnerability of black bears. MFWP worked with Tonya Chilton, as part of her Master's thesis through the University of Montana (Chilton 2006), to study the effects of roads on the harvest vulnerability of adult male black bears. Adult males are the most desirable age and sex class to many hunters, and this desirability, combined with putative effects of roads, has led to concerns about their overharvest.

A sample of radio-collared black bears from the Swan Valley were used to assess 2 attributes of bear behavior relative to roads when summer season was compared to hunting season: 1) bear locations relative to open road densities, and 2) the number and timing of open forest road crossings.

Fifteen adult male black bears were collared with Telonics (Mesa, Arizona, USA) Generation-3 model 3600 GPS collars that were programmed to obtain locations every 2 h and store these locations on-board the unit. The collars were programmed to fall off 5 October. Both 2-dimensional (2D) and 3-dimensional (3D) location fixes were used. Of 11 GPS collars that worked successfully, only 6 bears that used the roaded area in both summer and fall hunt seasons were used for this analysis.

The distribution of roads in the Swan Valley was used to approximate the study area ("roaded area"). Analyses were restricted to bear locations within a roaded area to help discriminate between the confounded factors of elevation and roads.

To delineate the roaded area, GIS layers of United States Forest Service wilderness areas and Plum Creek Timber Company road maps were used. In ArcView 3.3 (Environmental Systems Research Institute, Olympia, WA, USA), the outermost roads (roads nearest wilderness) were buffered by approximately 500 m, which roughly defined the end of most roads and the beginning of wilderness, or nonroaded, areas in the Swan Valley. Seasons were classified as "summer" and "fall hunt." Summer was defined

Black bear genetics provide information on black bear interchange amoung areas.

as 1 June to 31 August. Fall hunt season was defined by the state-regulated hunting season each year (September 1 – end of November).

Because the telemetry data included multiple observations per bear, and each bear could differ in habitat use, a mixed model ANCOVA was used. The effect of season, diel period, and factor interactions on both road metrics relative to bears' locations was evaluated. The mean and confidence intervals of associated road metrics were calculated, and compared within factors (e.g., comparing summer to fall hunt or day to night diel periods). An alpha-level of 0.15 was used because of small sample sizes. While the small sample sizes justify a greater alpha-level of 0.15 (Field et al. 2004), more conservative wildlife managers might select a smaller alpha-level.

A large field crew was needed to monitor barbed wire traps used to collect bear hair.

For the road density analyses, the density of open roads relative to each bear location was calculated, as a function of season and diel period, as well as interactions thereof. Six bears that had collars locations within the roaded area in both summer and fall hunt seasons were used. Within the roaded area, open road density proximate to these 6 bears was calculated by dividing length (km) of road by buffer area (km/km^2, Mace and Waller 1997). Each bear location was buffered with a circular buffer that had a diameter that equaled the average total movement length in a 2 h period, respective to each bear. Road densities of open roads were calculated within the movement buffer, for every bear location. As road density data were not normally distributed, they were ln-transformed prior to analysis.

The proportions of bear movements that crossed an open road between seasons, diel periods, and interactions thereof were compared. Six bears whose collars had locations within the roaded area in both summer and fall hunt seasons were used, and the proportion of movements that crossed an open road, per bear, as a function of season and diel period, was calculated. Using Animal Movement extension (SA v 2.04 beta, USGS-BRD, Alaska Science Center Biological Office, Glacier Bay Field Station, USA), bear locations were sequentially connected in the roaded area to form movement paths. Only 2 h successive points were used in this analysis; lone points and points at >2 h intervals were not included. Alternate Animal Movement Routes extension (Alternate Animal Movement Routes v. 2.1, Jeff Jenness, Jenness Enterprises, USA) was used to determine the proportion of movements in each season and diel period that crossed open roads. As these proportional data were not normally distributed, they were transformed using the arcsine-square root transformation prior to analysis.

Road density and road crossings were evaluated.

Black bears spend approximately half the year in winter dens, in this case a hollow cottonwood tree.

Results

Black Bear Harvest Levels, Hunter Numbers, and Adherence to Harvest Criteria

On average, approximately 1,030 black bears were harvested in Montana annually between 1987 and 2006, the period when records were complete for all regional BMUs. Based on mandatory check data, most (46%) bears were harvested in Region 1, while the fewest occurred in Region 5 (6%, Fig. 4). Fifteen percent, 20%, and 14% of the average annual harvest occurred in Regions 2, 3, and 4, respectively. Region 7 had < 5 black bears harvested annually since a season was initiated there in 2007. Forty-seven and 53% of the harvest occurred during the spring and fall hunting seasons. Hunter numbers varied among administrative BMUs (Fig. 5).

Summary harvest statistics for each BMU are given in Table 4.

There are 8 BMUs in Region 1, although a portion of BMU 108 is in Region 2. Harvest in this region averaged 471 bears ($\bar{X}$ = 180 females and 362 males). Median age was 4 years for both sexes during the period. On average, females represented 33% of the harvest. Most bears were harvested in BMU 106 ($\bar{X}$ = 107).

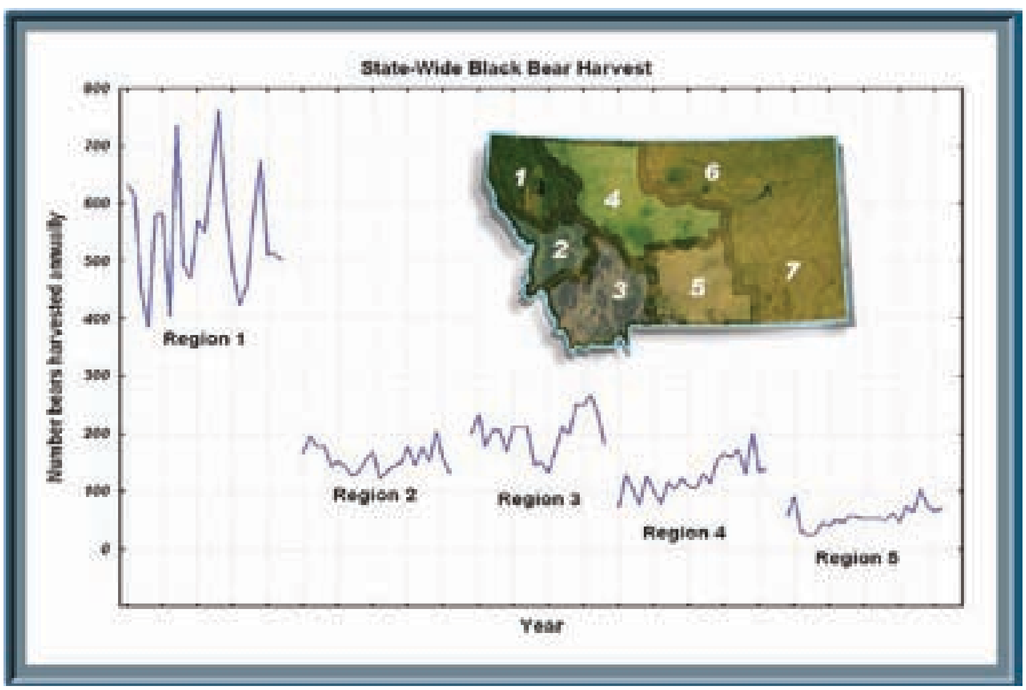

Figure 4. Annual harvest of black bears in Montana by region for the period 1987-2006, based on data from mandatory check of harvested bears.

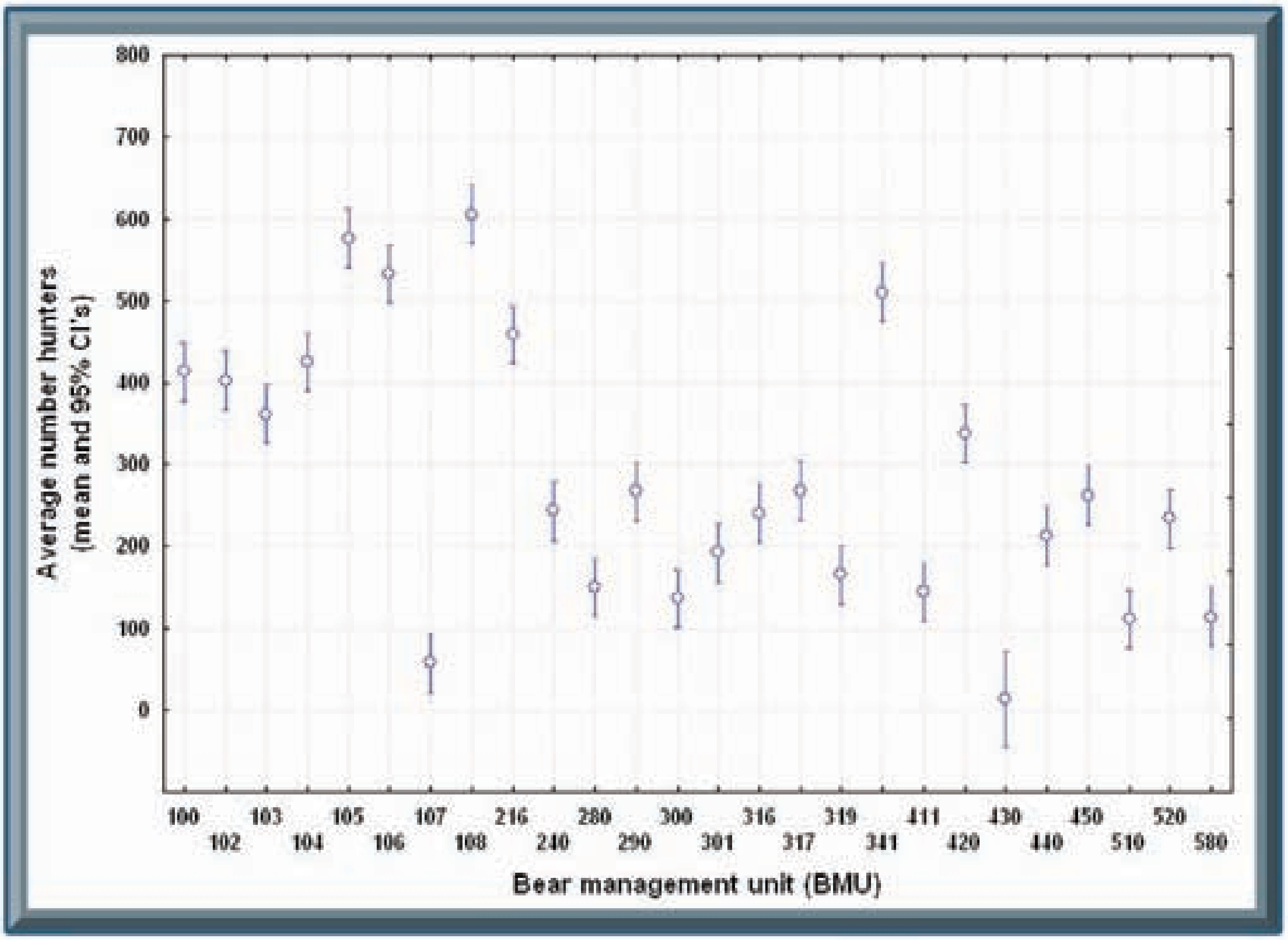

Figure 5. Number of black bear hunters by Bear Management Unit (BMU), 1996-2003.

There are 4 BMUs in Region 2. Bear harvest in this region averaged 154 bears ($\bar{X}$ = 55 females and 99 males). Total harvest has been declining in BMU 280 and increasing in BMU 290 (Table 4). Median age was 3 and 4 years for males and females, respectively.

There are 6 BMUs in Region 3. Harvest in this region averaged 202 bears ($\bar{X}$ = 74 females and 128 males). On average, females represented 37% of the harvest. Median age was 4 and 5 years for males and females, respectively. Most bears were harvested in BMU 341 ($\bar{X}$ = 80).

There are 4 BMUs in Region 4. Harvest in this region averaged 143 bears ($\bar{X}$ = 52 females and 91 males). On average, females represented 36% of the harvest. Median age was 4 years for both sexes. On average, most bears were harvested in BMU 440 ($\bar{X}$ = 44). Annual harvest has been increasing in most BMUs in this region (Table 4).

Region 5 has 3 BMUs. This is the only region in Montana with either a total harvest quota or a female subquota. Harvest in this region averaged 60 bears ($\bar{X}$ = 23 females and 37 males). On average, females represented 44% of the harvest. Median age was 4 and 5 years, for males and females, respectively. Annually, most bears were harvested in BMU 520 ($\bar{X}$ = 28). Harvest has been increasing in BMUs 520 and 580 (Table 4).

Over this time period, adult:subadult ratios in the harvest remained stable in most BMUs (Table 4). The average adult:subadult ratio in Montana was 35:65. The proportion of females in

Table 4. Annual harvest statistics for each BMU in Montana, 1987-2006

BMU	Avg. female harvest	Avg. male harvest	Avg. total harvest	Avg. % male	Avg. % female	Median age male	Median age female	Adult subadult ratio
100	21	48	69	0.69	0.31	3	4	34:66
102	19	34	53	0.64	0.36	3	4	32:68
103	21	41	62	0.66	0.34 (D)	4	4	39:61
104	28	58	87	0.67	0.33	4	5	42:58
105	30	55	85 (I)[a]	0.64	0.36	3	4	30:70
106	35	73	107	0.68	0.32	4	5	40:60
107	3	5	9 (D)	0.62	0.38	5	8	54:46
108	24	49	72	0.66	0.34 (D)	3	4	31:69
Region 1 Summary	180	362	471	0.67	0.33	4	4	35:65
216	22	37	59	0.63	0.37	3	5	35:65 (I)
240	9	20	29	0.70	0.30	4	4	35:65
280	7	15	21 (D)	0.67	0.33	3	4	35:65 (I)
290	18	26	45 (I)	0.59	0.41	3	3	31:69 (D)
Region 2 Summary	55	99	154	0.64	0.36	3	4	34:66
300	9	15	23	0.64	0.36	4	6	26:7
301	9	13	22	0.62	0.39	5	7	35:65
316	8	17	25 (I)	0.71	0.29	5	7	43:57
317	11	19	30 (I)	0.62	0.38 (D)	5	7	35:65
319	9	13	21	0.60	0.40 (D)	4	5	27:73
341	29	51	80	0.65	0.35 (D)	6	7	43:57
Region 3 Summary	74	128	202	0.63	0.37	4	5	63:37
411	7	15	21 (I)	0.65	0.35 (D)	3	4	32:68
420	15	27	42 (I)	0.64	0.36	3	5	34:66 (I)
440	19	26	44 (I)	0.58	0.42	3	4	33:67
450	11	25	36	0.68	0.32 (D)	4	4	36:64
Region 4 Summary	52	91	143	0.64	0.36	4	4	32:68
510	3	6	9	0.64	0.36	4	4	35:65
520	10	19	28 (I)	0.64	0.36	4	7	44:56
580	10	13	23 (I)	0.45	0.55 (D)	4	5	40:60
Region 5 Summary	23	37	60	0.56	0.44	4	5	41:59

D = declining trend, I = increasing trend.

the harvest averaged 35%, and showed a decline in 8 BMUs, most notably in Region 3.

The harvest criteria of the percent of females in harvest, median female age, and median male age were variously met each year throughout regions of Montana. Statewide, all 3 criteria were met approximately 17% of the time (Table 5). The criterion of $< 40\%$ females in the annual harvest was met most often ($\bar{X} = 71.03\%$). The female median age criterion of > 6 years, was met most infrequently ($\bar{X} = 36.97\%$). In just over

Table 5. Adherence to established harvest criteria for each BMU regarding percent of females in the harvest, and median female and male ages.

BMU	% of years harvest criteria met			
	% Female in harvest < 40%	Median female age > 6	Median male age >4	All 3 criteria
100	86.96	17.39	47.83	13.04
102	73.91	21.74	26.09	8.70
103	82.61	43.48	60.87	26.09
104	91.30	47.83	65.22	26.09
105	82.61	8.70	26.09	0.00
106	91.30	26.09	78.26	8.70
107	69.57	86.96	78.26	43.48
108	81.82	27.27	31.82	9.09
$\bar{X}$	82.50	34.93	51.80	16.89
SD	7.71	24.64	22.02	13.99
216	68.18	31.82	31.82	9.09
240	95.45	45.45	54.55	27.27
280	81.82	22.73	40.91	9.09
290	54.55	4.55	31.82	0.00
$\bar{X}$	75.00	26.13	39.77	11.36
SD	17.60	17.15	10.74	11.43
300	65.00	35.00	20.00	0.00
301	60.00	35.00	45.00	10.00
316	80.00	45.00	80.00	30.00
317	50.00	45.00	60.00	25.00
319	45.00	20.00	30.00	5.00
341	70.00	45.00	95.00	25.00
$\bar{X}$	61.66	37.50	55.00	15.83
SD	12.90	9.87	28.98	12.41
411	63.64	40.91	31.82	13.64
420	63.64	45.45	36.36	22.73
440	31.82	36.36	13.64	4.55
450	95.45	31.82	72.73	27.27
$\bar{X}$	63.63	38.63	38.63	17.04
SD	25.97	5.86	24.75	10.07
510	78.26	39.13	65.22	21.74
520	65.22	73.91	82.61	43.48
580	47.83	47.83	78.26	13.04
$\bar{X}$	63.76	53.62	75.36	26.08
SD	15.26	18.10	9.05	15.67
Statewide				
$\bar{X}$	71.03	36.97	51.36	16.88
SD	16.69	17.94	23.22	12.43

one half of the years, the median male criterion of >4 years was achieved.

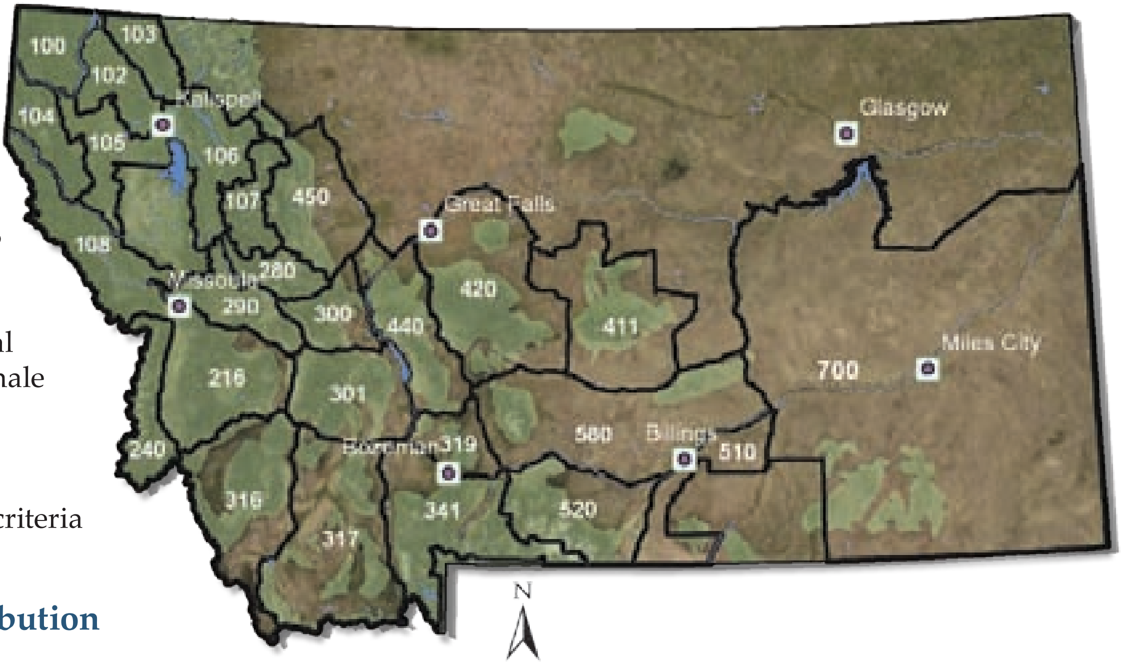

Figure 6. Year-round distribution (green shading) of black bears in Montana relative to BMUs.

All 3 harvest criteria were most often met each year in Region 5 (26.08% of the years). Units within this region had either total harvest quotas or female subquotas. Region 2, on average, exhibited the poorest annual achievement of all 3 criteria ($\bar{x} = 11.36\%$).

Black Bear Distribution in Montana

Black bears occur in all administrative regions of Montana (Fig. 6). Distribution is closely associated with coniferous forest habitats within the various mountain ranges in the state. Black bears are most widely distributed in Regions 1 and 2. Black bears may occasionally occur in the intermountain valleys of the more southern portions of the state. These valleys are used to travel to preferred habitats, and at times bears may be attracted to both natural and unnatural food sources on private lands in these low elevation areas. There are approximately 104,831 km^2 of black bear habitat within Montana BMUs (Table 6). Outside of BMUs, black bears also reside in Glacier and Yellowstone National Parks, and 3 Native American reservations. Black bears are restricted to the Bears Paw and Little Rocky Mountain Ranges of Region 6, and in the Pryor and Bighorn Mountains of Region 7. The total extent of black bear habitat within the state is approximately 116,554 km^2, most of which is within Region 1. Grizzly bears, listed as a "threatened species" under the Endangered Species Act, are sympatric with black bears in Montana (Fig. 7).

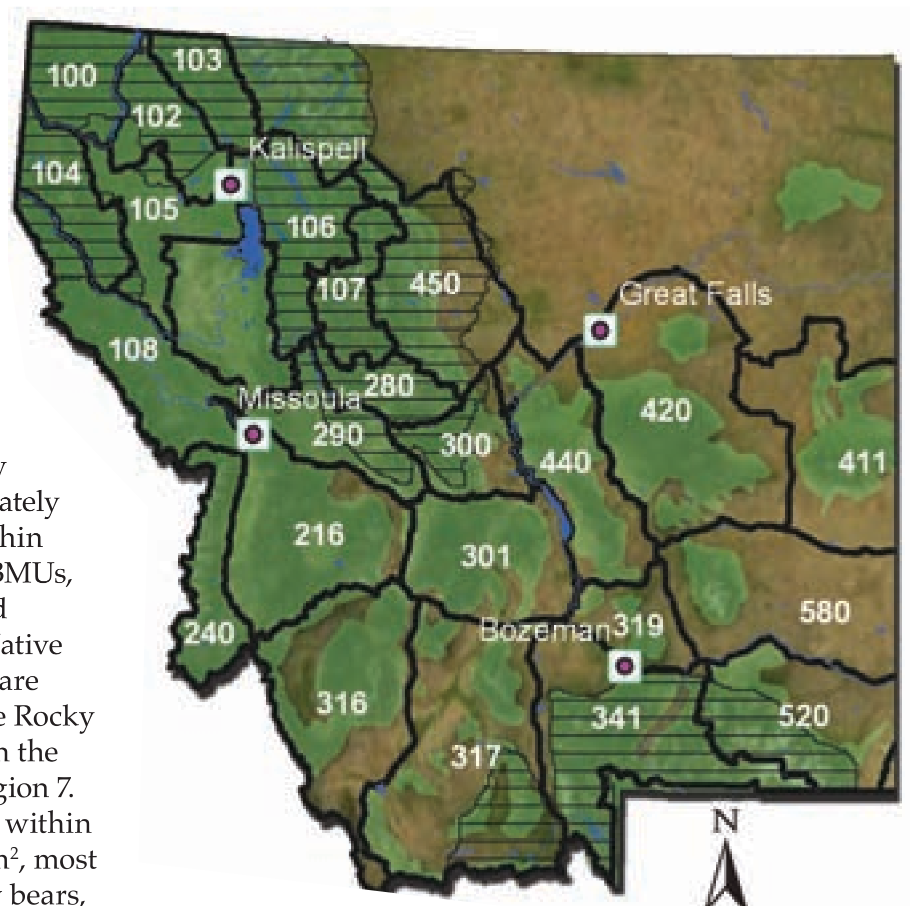

Figure 7. Distribution of grizzly bears (cross-hashed lines) and black bears (green) relative to black bear BMUs in Montana.

Table 6. The extent (km²) of black bear habitat in each BMU in Montana.

Region	BMU	BMU size (km²)	km² bear habitat within BMU
1	100	3665	3665
1	102	3710	3710
1	103	2761	2761
1	104	3615	3615
1	105	4523	4507
1	106	5545	5529
1	107	3055	3055
1	108	7012	6887
Region 1 Total			33729
2	216	9188	8317
2	240	3838	3716
2	280	2532	4377
2	290	4119	2071
Region 2 Total			18481
3	300	3636	2474
3	301	7202	5124
3	316	10173	862
3	317	14128	4567
3	319	3030	940
3	341	10465	7415
Region 3 Total			21382
4	411	11537	2531
4	420	13963	6352
4	440	7207	4074
4	450	7729	4050
	510	4879	5014
Region 4 Total			22021
5	510	4879	360
5	520	7993	4000
5	580	16354	2864
Region 5 Total			7224
Region 6 Total	none	n/a	1494
Region 7 Total	700	79087	500

Reproductive Rates of Female Black Bears

Reproductive tracts of cub, yearling, and 2-year-old black bears appeared immature and did not demonstrate evidence of pregnancy. Five of 10 samples from 3-year-old bears exhibited corpora lutea, suggesting that the minimum age of first reproduction was 3 years. Aune and Anderson examined 37 tracts of bears > 2 years old having corpora lutea and found that the number of corpora lutea averaged 2.08 (95% CI = 1.82-2.35, SE = 0.13) and varied between 1 and 5 (Table 7). There was no difference in litter size, based on corpora

Table 7. The number of corpora lutea found in female black bear (> 2 years old) reproductive tracts, Montana.

n corpra lutea	%
1	16.22
2	67.57
3	10.81
4	2.70
5	2.70

lutea, among administrative regions in Montana (P = 0.09, Fig. 8).

Reproductive interval (*n* = 1228, total number intervals found in *n* = 582 premolar teeth) varied from 2 to 7 years (Table 8) and averaged 2.2 years (95% CI = 2.18-2.25, SE = 0.01, Fig. 9). No difference was observed among regions (*P* = 0.49). Over 80% of the intervals were 2 years in duration (Table 8). The mean age of primiparity, demonstrated from tooth sections, was 6.1 years (95% CI = 6.01-6.21, SE = 0.05) and varied from 2 to 10 years (Table 9). There was a significant difference (*P* = 0.02) among regions (Fig. 10). The oldest bear with corpora lutea present was 22 and the

Table 8. The distribution of inter-birth intervals for female black bears harvested between 1980 and 1999 in Montana.tracts, Montana.

Inter-birth interval (years)	*n*	% of total
2	1017	82.81
3	171	13.92
4	31	2.52
5	5	0.40
6	3	0.24
7	1	0.08

Table 9. Age of primiparity of female black bears as determined from analysis of tooth samples from bears harvested between 1980 and 1999 in Montana.

Age of primiparity	*n*	%
2	1	0.16
3	11	1.75
4	91	14.47
5	218	34.66
6	169	26.87
7	100	15.90
8	26	4.13
9	11	1.75
10	2	0.32

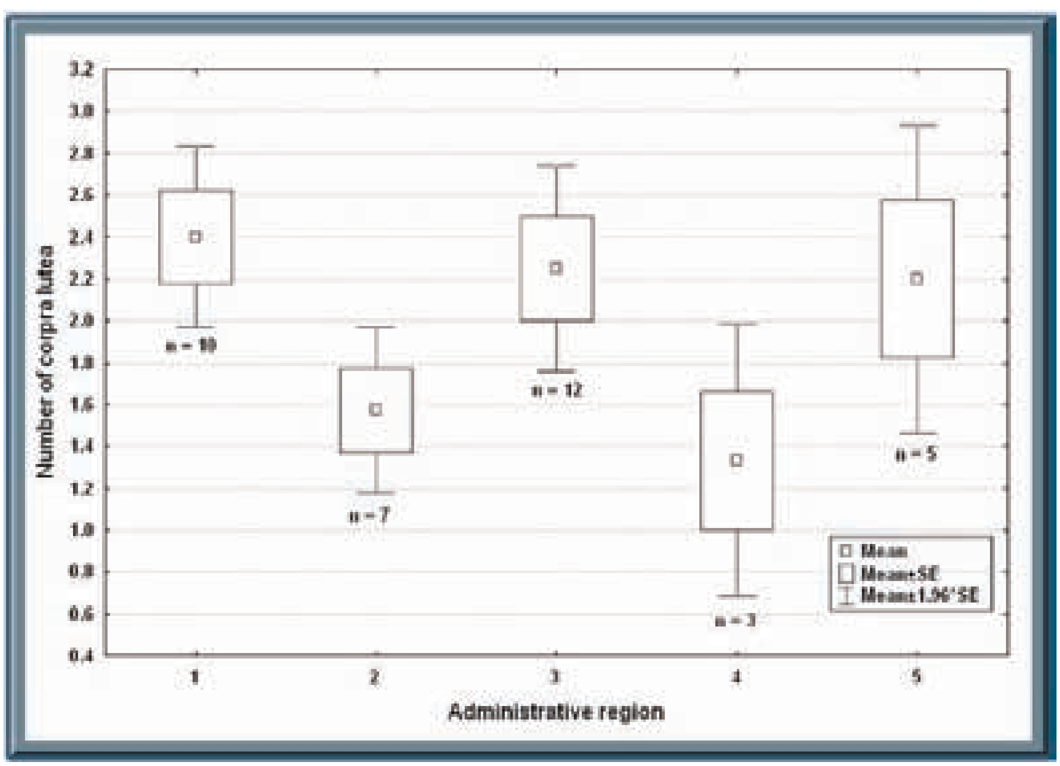

Figure 8. Average number of corpora lutea found in the reproductive tracts of female black bears collected 1990–1999, across 5 administrative regions of Montana.

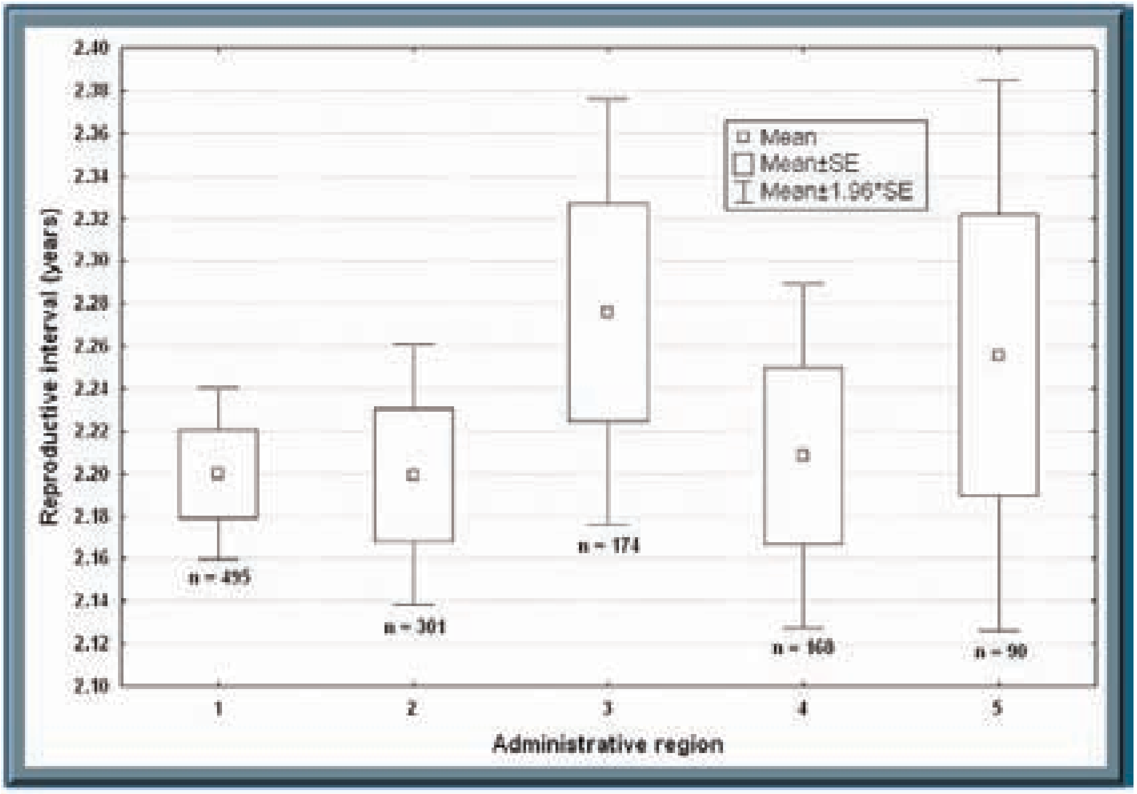

Figure 9. Estimates of average inter-birth interval for female black bears collected 1990–1999, across 5 administrative regions of Montana.

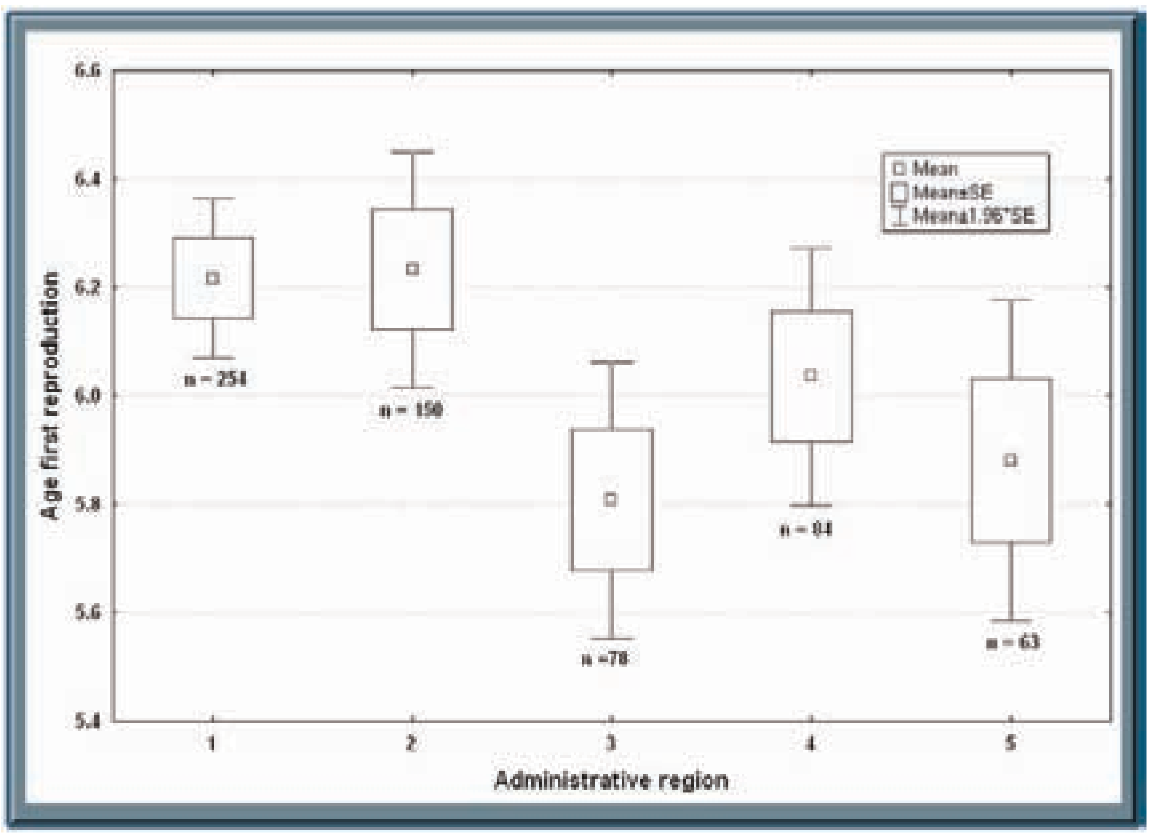

Figure 10. Estimates for the average age of primiparity of female black bears harvested between 1980 and 1999, across 5 administrative regions of Montana.

oldest age of a bear showing evidence of reproduction was 26 years old.

An average reproductive rate for black bears in Montana was generated from the above data. Dividing an average litter size of 2.08 by an average reproductive interval of 2.2 years produced an average natality rate of 0.945 for both sexes of cubs. Assuming a 50:50 male to female cub ratio, the reproductive rate for female cubs was 0.473.

Geographic Extent of DNA Studies for Estimating Harvest Rate and Density

DNA-based estimates of black bear harvest rates were conducted in 11 geographic areas of Montana from 2001 through 2008 (Fig. 11). Depending on the area sampled, estimates were made at either the hunting district or BMU landscape scale. These sample areas totaled 38,705 km^2, which were approximately 33% of all bear habitat in Montana (Table 10).

Estimated Composition of Population at Hair-traps

Our analyses of tooth cementum layering to ascertain composition of the female black bears in the population suggested that, on average, 25% of the female segment (95% CI = 20-29%) would be attended by cubs-of-the-year, and by harvest regulation could not be hunted (Table 11). On average, 73% of the female population (95% CI = 70-76%) were estimated to be 1+ years old. These estimates from Montana bears

Table 11. Composition of the female segment of black bear populations in Montana as determined by evaluation of tooth cementum layering.

	% of female population		
Female age class	$\bar{X}$	-90% CI	+90% CI
% cubs-of-year	25	20	29
% females 1 + years old	73	70	76

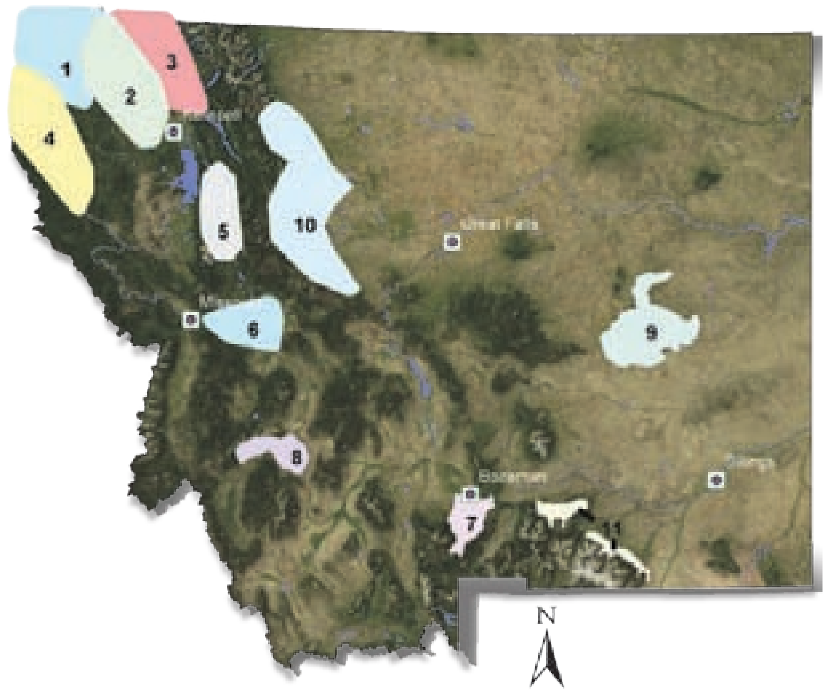

Figure 11. Distribution of black bear sampling areas in Montana for estimation of population size and harvest rate. Study area names are given as reference numbers in Table 10.

Table 10. Hunting districts and BMUs where black bear DNA studies were conducted to estimate harvest rates and population densities in Montana.

DNA study area	Map reference number	Size (km^2)[a]	Period studied[b]
BMU 100	1	4999	2002-03
HD 101-102	2	6423	2008-09
BMU 103	3	4162	2004-05
BMU 104	4	5240	2003-04
HD 130	5	2195	2001-02
HD 292	6	2071	2004-05
HD 301	7	1219	2005-06
HD 319-341	8	1606	2006-07
BMU 411	9	3407	2002-03
BMU 450	10	6452	2004-05
BMU 520	11	931	1999-2002
Total area studied		38705	

[a] Study area size included, where appropriate, a buffer zone surrounding the minimum convex polygon derived from hair-traps.

[b] The date studied includes the summer sampling grid, the fall harvest of that year, and the following year's spring hunting season. BMU 520 was the exception where bears were sampled in each of 4 years.

correlated well with proportions found in the literature (Table 12). From our genotyping of bears in each study area, we documented that on average, 58% and 42% of the population were female and male bears, respectively (Table 13). The greatest proportion of females was observed in HD 292.

Table 12. Composition of female black bear population in representative black bear populations in North America. Composition of age classes are given from samples of radioed bears, and as calculated from vital rates.

		% of each age class				
Publication	Area	Cub	Yearling	Subadult	Adult	Family
FEMALE						
Estimated From Radioed Bears						
Beecham 1980-1	Idaho (heavily harvested)			35	65	
Beecham 1980-2	Idaho (lightly harvested)				80	
Cunningham and Ballard 2001	Arizona			17	83	
Czetwertynski et al. 2007	Alberta		10.5	44.7	44.7	
Kasworm and Thier 1994	Montana	10.5	27	63	33.2	
Reynolds and Beecham 1980	Idaho					31
$\bar{X}$				31.0	67.1	32.1
Calculated From Vital Rates With Stable Age Distribution (families = cub survival/birth interval)						
Costello et al. 2001-1	New Mexico	21.3	11.1	18.9	48.7	28.1
Costello et al. 2001-2	New Mexico			28	72	32.3
Jonkel and Cowan 1971	Montana	15.9	16.8	15.2	52.1	28.8
Schwartz and Franzmann 1991	Alaska	21	19	22.8	37.1	44.0
$\bar{X}$	19.4	15.6	21.2	52.5	33.3	
MALE						
Beecham 1980-1	Idaho (heavily harvested)			58	42	
Beecham 1980-2	Idaho (lightly harvested)			36	64	
Czetwertynski et al. 2007	Alberta			75	25	
Cunningham and Ballard 2001	Arizona			20	80	
$\bar{X}$				47.2	52.8	

Table 13. The proportion of female and male black bears detected in DNA hair-traps.

Area	% Female	% Male
BMU 100	52	48
HD 101-102	64	36
BMU 103	59	41
BMU 104	50	50
HD 130	63	37
HD 292	69	31
HD 301	59	41
HD 319-341	59	41
BMU 411	51	49
BMU 450	58	42
$\bar{X}$	58	42
95% CI	54-63	37-46

To ascertain whether we were detecting cubs at hair-traps, we extended the genotypes of 24 zero-mismatch female/male or female/female dyads to 25 markers that were detected at the same hair-trap. Twelve of 24 (50%) were determined to be parent/offspring pairs, 37.5% were deemed siblings, and the relationship between 3 dyads (12.5%) could not be resolved. These results suggest, but do not unequivocally confirm, that cub black bears left hair at our hair-traps.

Although our extended genetic analyses determined that parent-offspring pairs were detected at the same hair-trap, we could not determine if they were mothers with dependent young because the age of individuals cannot be determined from genetic analyses. It is feasible, for example, that a 20-year-old mother could visit the same hair-trap as her 10-year-old daughter.

Harvest Rate Estimation

Harvest Rates Determined from Genetic Analyses at DNA-monitoring Areas.— We estimated harvest rates for each sex. Annual harvest rate estimates for female black bears of all ages in 9 study areas of Montana averaged 3.1% (Table 14). The average harvest rate for females 1+ years old was estimated to be 4.2% and varied from 4.0% to 4.3%. The highest female harvest rate (5.4%) was observed for the Snowy Mountains (BMU 411). The lowest observed harvest rate for females of all ages was 1.1% and occurred in both BMU 100 and HD 130.

When harvest rates were adjusted to more accurately reflect the "average" year, mean female harvest rate for all females changed from 3.1% to 3.2% for all females (Table 15). The mean adjusted harvest rate for females 1+ years old was 4.4%, and varied from 4.2% to 4.5%.

Table 14. Estimates of female black bear harvest rates in DNA study areas of Montana for the year of DNA sampling.

Area	*n* Females detected in hair-traps	*n* Estimated females 1 + years old	*n* Harvested	Harvest rate All females	Harvest rate Females 1+ years old
BMU 100	94	66-69-71	1	1.1	1.5-1.4-1.4
HD 101-102	84	59-61-64	3	3.6	5.1-4.9-4.7
BMU 103	122	85-89-93	3	2.5	3.5-3.4-3.2
BMU 104	68	48-50-52	3	4.4	6.3-6.0-5.8
HD 130	87	61-64-66	1	1.1	1.6-1.6-1.5
HD 292	41	29-30-31	1	2.4	3.4-3.3-3.2
HD 301	36	25-26-27	1	2.8	4.0-3.8-3.7
HD 319-341	26		0		
BMU 411	37	26-27-28	2	5.4	7.7-7.4-7.1
BMU 450	96	67-70-73	4	4.2	6.0-5.7-5.5
$\bar{X}$				3.1	4.3-4.2-4.0

Table 15. Estimates of female black bear harvest rates in 9 study areas of Montana, adjusted to the long-term average harvest.

Area	Female harvest rate	
	All females	Females 1+ years old
BMU 100	1.6	2.2-2.1-2.1
HD 101-102	3.8	5.4-5.2-4.9
BMU 103	2.0	2.8-2.7-2.5
BMU 104	3.7	5.3-5.0-4.8
HD 130	4.4	6.4-6.4-6.0
HD 292	1.8	2.6-2.5-2.4
HD 301	4.2	6.0-5.8-5.6
BMU 411	4.2	6.0-5.9-5.6
BMU 450	2.9	4.1-3.9-3.8
$\bar{X}$	3.2	4.5-4.4-4.2

Table 17. Estimates of male black bear harvest rates in DNA study areas of Montana, adjusted to the long-term average harvest.

Area	Male harvest rate	
	All males	Males 1+ years old
BMU 100	11.3	16.1-15.1-14.2
HD 101-102	14.1	20.3-19.1-17.6
BMU 103	3.9	5.5-5.1-4.9
BMU 104	4.4	6.6-5.8-5.4
HD 130	1.8	2.6-2.5-2.3
HD 292	11.1	15.4-14.3-14.3
HD 301	3.2	6.4-6.0-5.7
BMU 411	6.2	8.7-8.4-7.7
BMU 450	10.4	14.8-13.7-13.0
BMU 520	19.0-9.1-4.0	
$\bar{X}$	7.6	10.7-10.0-9.5

Male harvest rates were higher than those of females (Table 16). The mean male harvest rate, for bears of all ages, was 8.1%; for males 1+ years old, the mean harvest was 10.6%. The male harvest rate for BMU 450 was highest of all areas studied (17.4%). The adjusted male harvest rates for bears of all ages, and those > 1 year old, were 7.6% and 10.0%, respectively (Table 17).

Estimation of Harvest Rate from Harvest Data.—The R2 of the regression of the proportion females in Montana's harvest from 1985 to 2005 against age was 0.94, and the estimated value of y was 14.2 (Fig. 12). The estimated annual harvest rates for male and female black bears in Montana were 10.6% and 4.3%, respectively, given a starting sex ratio of 1 and equal natural mortality rates for both sexes. Using Fraser's simplified k = 1/y, the harvest rate estimates were 10.0% for males and 4.0% for females. As the ratio of male survival to female survival decreased, the estimate of harvest rate also decreased (Fig. 13). An estimate assuming the ratio was 1 overestimated harvest rate. The bias was greater for male harvest rates than female harvest rates. If the natural survival was dramatically biased

Table 16. Estimates of male black bear harvest rates in DNA study areas of Montana.

Area	*n* Males detected in hair-traps	*n* Estimated males 1 + years old	*n* Harvested	Harvest rate	
				All males	Males 1+ years old
BMU 100	86	61-65-69	10	11.6	16.4-15.4-14.5
HD 101-102	47	33-35-38	5	10.6	15.2-14.3-13.2
BMU 103	85	60-64-68	4	4.7	6.7-6.3-5.9
BMU 104	67	48-50-54	3	4.5	6.2-6.0-5.6
HD 130	52	37-39-42	1	1.9	2.7-2.6-2.4
HD 292	18	13-14-14	2	11.1	15.4-14.3-14.3
HD 301	25	18-19-20	1	4.0	5.6-5.3-5.0
HD 319-341	18	13-14-14	0		
BMU 411	35	25-26-28	2	5.7	8.0-7.7-7.1
BMU 450	69	49-52-55	12	17.4	24.8-23.1-21.8
BMU 520				4.0-9.1-19.0	
$\bar{X}$				8.1	11.2- 10.6-10.0

towards females, the estimated harvest rate became negative to compensate for the changing sex ratio. This put a lower limit on the possible survival ratios.

An increase in the number of years incorporated in the estimation of *y* yielded more precise estimates of the harvest rate. Given the levels of variance seen in black bear vital rates across the western half of their range, much improvement was gained in the first 5 years of data gathering (Fig. 14). The variance in the harvest rate estimate leveled out after about 15 years. Populations experiencing lower levels of variance will require fewer years to gain similar precision in harvest rate estimates.

Estimation of Harvest Rate from Radioed Black Bears.—We followed the fate of 54 male and 36 female black bears wearing radio collars in the Swan River Valley (HD 130). Twenty of 36 females were adults, and 12 were subadults. Four females transitioned between age classes. We sampled more adult males ($n = 40$) than subadult males ($n = 12$). Two males transitioned between subadult and adult classes.

We obtained approximately 104 bear-years of telemetry data on male and female black bears in the Swan Valley. Mean annual survival, when sexes were pooled, was 0.86 (95% CI = 0.79 and 0.93, respectively) for the 90 individuals monitored (Table 18). Thirteen deaths (7 hunting, 6 nonhunting) were recorded during the study period. When sexes were pooled, hunting mortality ($\bar{X} = 0.07$) and nonhunting mortality ($\bar{X} = 0.06$) rates were similar. Nonhunting mortalities included vehicle collisions, management removals, and one illegal killing.

Female survival averaged 0.89 (95% CI = 0.79-1.00) (Table 18). For females, both hunting and nonhunting mortality rates averaged 0.06. Subadult female survival was lower than that for adults ($\bar{X} = 0.87$). Male survival averaged 0.85 (95% CI = 0.76-0.94) (Table 18). Our estimate of male hunting mortality for this area was 0.09 (95% CI = 0.01-0.16).

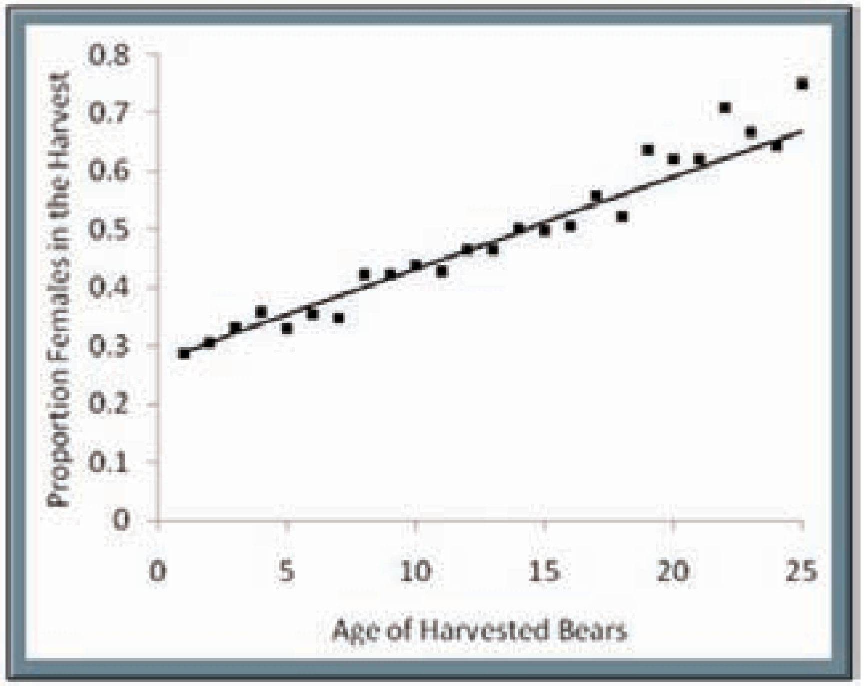

Figure 12. As Montana black bear cohorts are repeatedly subjected to male-biased harvesting, the proportion of females in the harvest increases. Analysis based harvest data 1985-2005.

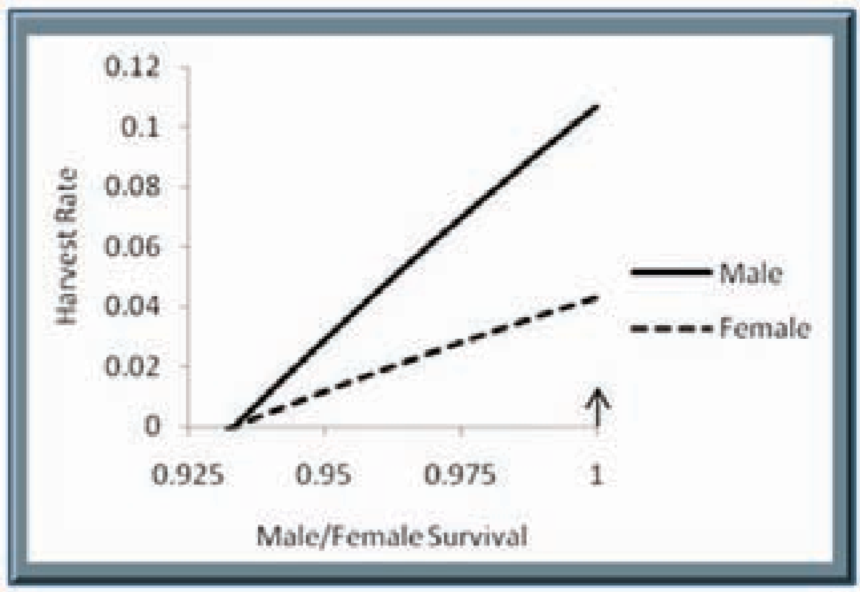

Figure 13. As the ratio of male to female survival decreases, the estimate of black bear harvest rate using the Fraser (1984) sex ratio analysis method decreases for both males and females.

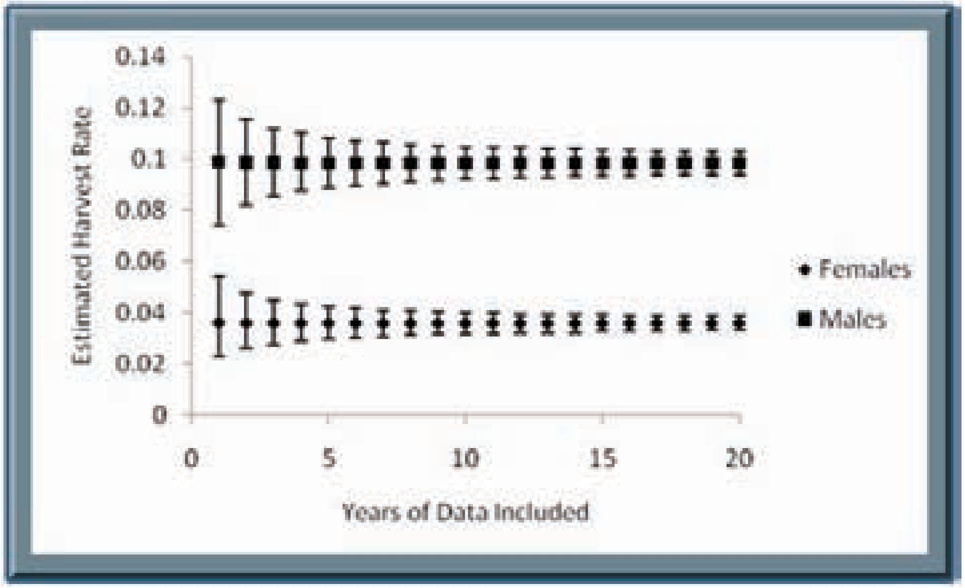

Figure 14. The precision of the estimate of harvest rate relative to the number of years of data.

Table 18. Annual survival rate estimates for black bears in the Swan Valley of Montana, 2000-2004.

Cohort	Radio days (*n* individuals)	- 95% CI	$\bar{X}$	+ 95% CI	*n* Radioed deaths
Survival: both sexes	31528 (90)	0.79	0.86	0.93	13
Hunt mortality (both)		0.02	0.07	0.13	7
Other mortality (both)		0.01	0.06	0.11	6
All male survival	19555 (54)	0.76	0.85	0.94	9
Hunt mortality		0.01	0.09	0.16	5
Other mortality		0.00	0.07	0.13	2 vehicles, 2 mgmt removals
All female survival	11973 (36)	0.79	0.89	1.00	4
Hunt mortality		0.00	0.06	0.13	2
Other mortality		0.00	0.06	0.13	2
Adult female survival	9420 (24)	0.78	0.89	1.00	
Hunt mortality		0.00	0.07	0.17	2
Other mortality		0.00	0.04	0.11	1 unknown
Subadult female survival	2553 (16)	0.65	0.87	1.00	1 illegal

Black Bear Population Size and Density in Montana

Black Bear Population Size and Density at DNA-Monitoring Areas.—The "mean maximum distance moved" between hair-traps was used to construct buffers around the MCP in each study area for more precise density estimates. The mean maximum distance moved across all sampling areas was 5503 m (95% CI = 4546-6460 m) (Table 19). BMU 450 exhibited the greatest mean distance moved ($\bar{X}$ = 8043 m), while bears in HD 319-341 moved the least distance between hair-traps ($\bar{X}$ = 3562 m).

The population density for all study areas combined and both sexes varied from 8.8 bears/100 km^2 (-90% CI) to 19.1 bears/100 km^2 (+90% CI) (Table 20). The mean density for all areas was 12.8 bears/100 km^2. Except for BMU 450, densities for females were higher than for males. Mean male and female densities, when study areas were pooled, were 5.1 and 7.9 bears/100 km^2, respectively. Black bear density in HD 130 (Swan River Valley) was higher than all other sampled areas ($\bar{X}$ = 22.7 bears/100 km^2). Hunting Districts 319-341 exhibited the lowest mean density ($\bar{X}$ = 6.1 bears/100 km^2), and varied from 4.3 bears/100 km^2 to 10.0 bears/100 km^2.

Extrapolated Black Bear Population Size and Density throughout Montana. We found no relationship between black bear densities at DNA study areas and either road density (P = 0.61) or the proportion of the area classified as roadless

Table 19. The mean maximum distance moved between hair-traps during a 2-week period by black bears.

Area	Mean maximum distance between DNA hair-traps (m) n	$\bar{X}$
BMU 100	30	6053
HD 101-102	10	6867
BMU 103[a]	10	5578
BMU 104	9	5834
HD 130	53	4502
HD 292	14	3754
HD 301	12	7904
HD 319-341	8	3562
BMU 411	16	6134
BMU 450[a]	8	8043
-95% CI - $\bar{X}$ - +95% CI		4546-5503-6460

[a] Four 2-week sessions were used in these areas. Distances represent movement within the same session only.

(P = 0.38). Conversely, a significant relationship was found between bear density and mean annual precipitation ($F(1,5) = 18.359$, $P < 0.008$). Bear density increased with mean precipitation (R^2 = 0.79, Fig. 15). The highest average mean precipitation (137 cm) was observed for Glacier National Park/Blackfeet Reservation area, and the estimated black bear density in this area was 25 bears/100 km^2 (Table 21). Bear habitat in Region 7 exhibited the lowest mean precipitation (43 cm). Bear density in this area was the lowest, estimated at 5 bears/100 km^2.

Our mean population estimate for the state of Montana was 13,307 (-90% CI= 9,868, +90% CI= 16,758) black bears. The mean density was 12.5 bears/100 km^2 (-90% CI= 9.0 bears/100 km^2, +90% CI= 16.0 bears/100 km^2). The point estimate of black bears in those areas (BMUs) open to hunting was 12,072 individuals.

Table 20. Population size (+90% CI's) and density (bears/100 km^2) estimates for DNA study areas of Montana based on recapture frequencies in DNA hair-traps.

Study area	Size (km^2)	Male population size (density)	Female population size (density)	Population size (density) both sexes
BMU 100	4999	208-308-491 (4.2-6.2-9.8)	296-477-818 5.9-9.5-16.4)	552-759-1082 (11.0-15.2-21.6)
HD 101-102	6423	103-239-375 (1.6-3.7-5.8)	169-488-807 (2.6-7.6-12.6)	399-744-1150 (6.2-11.6-17.9)
BMU 103	4162	199-295-470 (4.8-7.1-11.3)	327-467-670 (7.9-11.2-16.1)	578-760-1031 (13.9-18.3-24.8)
HD 130	2195	113-184-337 (5.2-8.2-15.4)	212-315-503 (9.7-14.4-23.0)	361-499-721 (16.5-22.7-32.9)
HD 292	2071	34-74-215 (1.6-3.6-10.4)	70-105-183 (3.4-5.1-8.8)	114-169-280 (5.5-8.2-13.5)
301	1219	na	25-91-158 (2.1-7.5-13.0)	na
HD 319-341	1606	22-30-55 (1.4-1.9-3.4)	46-81-178 (2.9-5.0-11.1)	69-98-161 (4.3-6.1-10.0)
BMU 411	3407	64-105-202 (1.9-3.1-5.9)	99-207-509 (2.9-6.1-14.9)	217-345-591 (6.4-10.1-17.4)
BMU 450	6452	247-466-952 (3.8-7.2-14.8)	205-285-426 (3.2-4.4-6.6)	484-669-961 (7.35-10.4-14.9)
$\bar{X}$ density		3.1-5.1-9.6	4.5-7.9-13.6	8.8-12.8-19.1

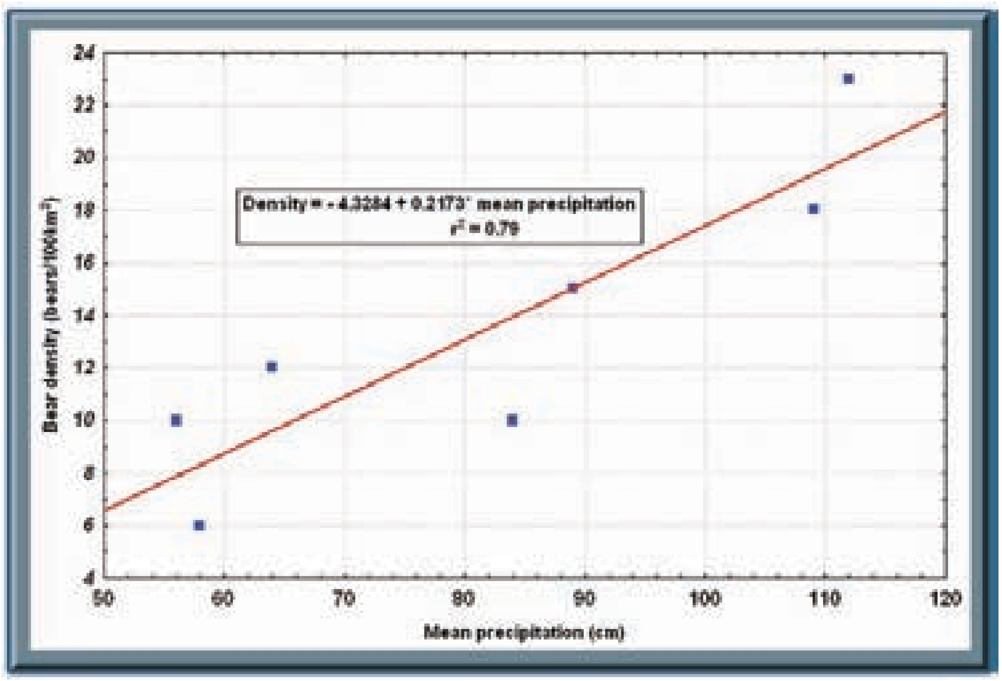

Figure 15. Linear regression of black bear density (both sexes) at DNA study areas and mean annual precipitation.

Table 21. Black bear population size and density estimates for areas in Montana (-90% CI-mean-+90% CI).

Area	Density bears/100km²	Population size	Area	Density (Bears/100km²)	Population size
BMU 100	13-15-17	650-750-850	BMU 317	6-9-12	204-337-489
BMU 102	7-10-12	329-450-564	BMU 319	13-15-18	122-145-169
BMU 103	16-19-23	442-534-635	BMU 341	5-8-12	373-617-894
BMU 104	17-21-25	615-763-904	BMU 411	4-8-11	129-253-356
BMU 105	5-8-12	225-373-541	BMU 420	5-8-12	318-526-762
BMU 106	16-20-24	615-769-923	BMU 440	5-8-12	204-337-489
BMU 107	18-23-27	550-691-825	BMU 450	12-14-16	486-564-648
BMU 108	1-15-18	895-1064-1240	BMU 510	3-7-11	11-24-40
BMU 216	7-10-12	582-797-998	BMU 520	9-12-14	360-470-560
BMU 240	13-15-18	483-574-669	BMU 580	5-8-12	143-237-344
BMU 280	11-14-16	481-600-700	Bears Paw Mtns[a]	3-7-11	15-34-55
BMU 290	16-20-24	331-414-497	Crow Reservation[a]	1-8-10	2-19-35
BMU 300	4-7-11	99-178-272	Flathead Reservation[a]	5-8-11	101-180-259
BMU 301	4-7-11	180-368-538	Glacier Park/ Blackfeet Reservation[a]	19-25-32	790-1037-1284
BMU 316	7-10-13	60-86-112	Region 7	1-5-10	2-25-48

[a] Areas where black bear hunting is not allowed or regulated by MFWP.

Bear density generally decreased from north to south (Fig. 16).

Estimating Sustainable Black Bear Mortality in Montana

Bunnell and Tait (1980) used deterministic modeling techniques to estimate the absolute upper level of total mortality that bear populations may experience and remain stable over time. Sustainable rates for any given population are a function of the natality rate and the average age of first reproduction for females. They defined natality rate as the average litter size divided by the average interval between litters. Bunnell and Tait (1980) provided a figure of maximum sustainable mortality isoclines given these 2 reproductive parameters (Fig. 17). These isoclines represent annual total mortality (hunting + nonhunting). It should be noted that these isoclines were based on the assumption that mortality is equal for all age- and sex-classes. Using our estimate of a reproductive rate of 0.945 (both sexes of cubs), and a mean age of primiparity of 6 years, returned a sustainable mortality rate of approximately 16%.

Our simulations exploring relationships between female survival and fecundity showed, as expected, that λ decreased as female mortality

Figure 16. *Black bear population size estimates (white numbers) for various areas of Montana. Bear Management Unit (BMU) numbers and boundaries are given in black.*

increased (Fig. 18).With reproductive rate fixed at 0.409, the female population reached γ = 1 (stable) at 15.0% total mortality. When reproductive rate was set at 0.472, populations would decline when female survival exceeded 16%. With a high reproductive rate of 0.534, the critical level of female mortality, before population decline, was approximately 17%.

Using Harvest Data to Estimate Population Trend

Given the estimated harvest rate and variation in Montana and the population growth rate and variance for western North America, managers can only be 78% sure that a decline in the population will be observed in the harvest after 15 years of harvest data collection (Fig. 19). Under ideal conditions, with no stochasticity in population growth itself, the decline would be identified within 15 years 99% of the time.

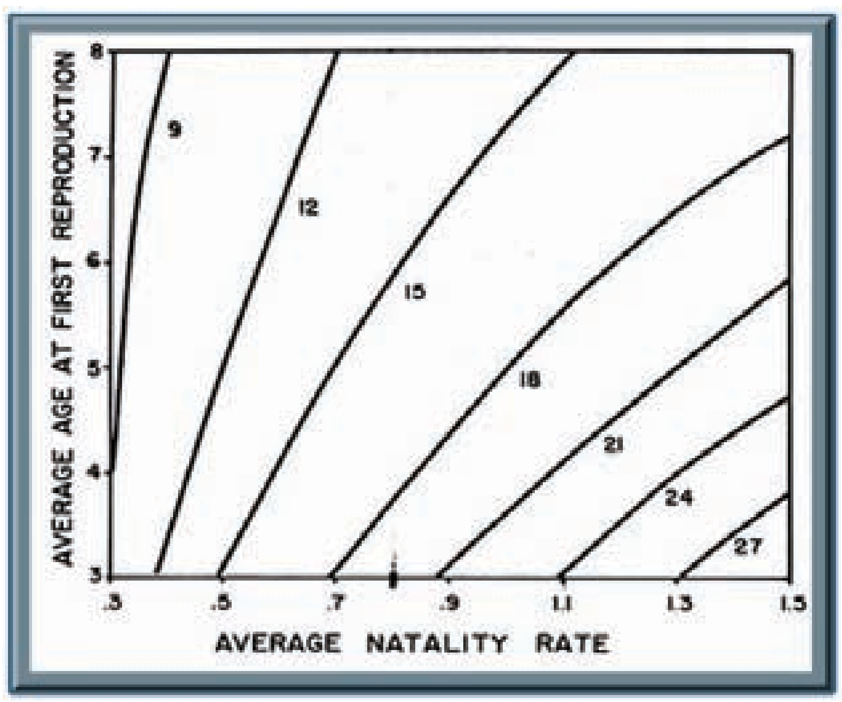

Figure 17. *Total maximum sustainable mortality isoclines for bear species from Bunnell and Tait (1980). The maximum sustainable mortality for a particular bear population can be estimated from 2 reproductive parameters: average natality rate, and average age of primiparity.*

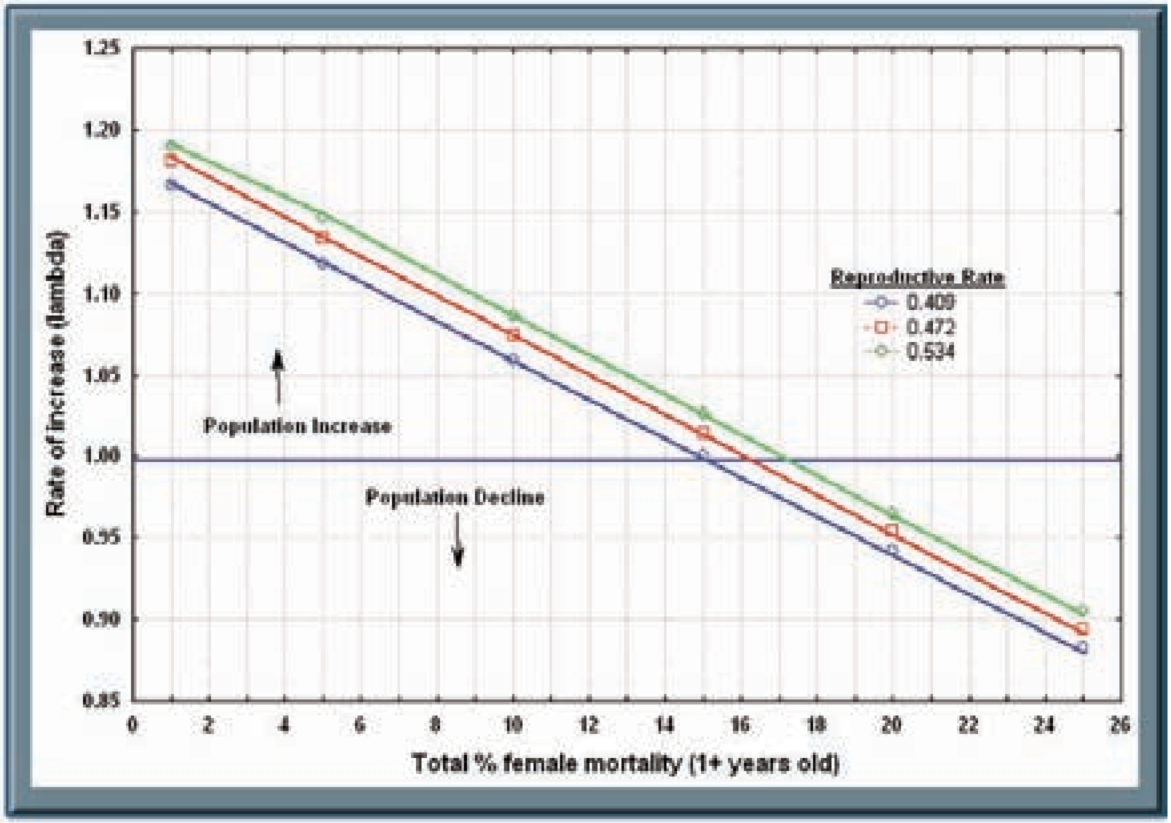

Figure 18. Relationship between female black bear mortality (1+ years' old) and rate of increase under 3 reproductive rate scenerios.

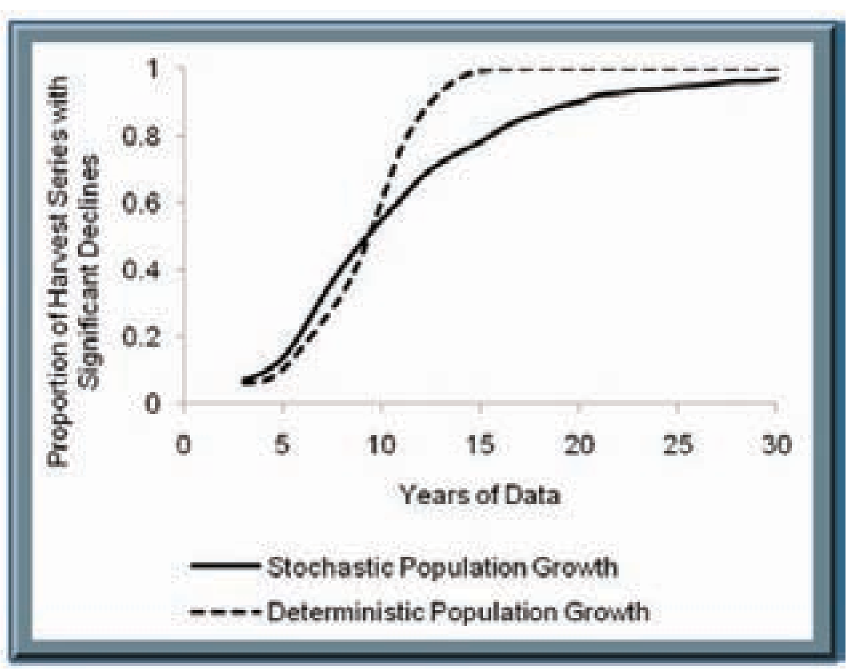

Figure 19. The proportion of simulated populations in which a statistically significant negative trend was identified in the harvest data increases rapidly with the years of data for deterministic populations but more slowly for stochastic populations.

As the population growth rate approaches 1, the number of years required to reach 90% power in detecting declines using only the harvest numbers increases dramatically (Fig. 20). Populations decreasing at 1-5% a year are reliably identified within 10-20 years of harvest data; annual decreases of less than 1% a year may take dramatically longer to detect. After 5 years, only 20% of the most rapidly declining populations, $\lambda = 0.95$, had statistically significant declines in the harvest numbers.

Genetic Structure of Black Bear Populations

Genetic Diversity.—All areas except BMU 411 ($H_E = 0.67$) and BMU 520 ($H_E = 0.78$) were ≥ 80% mean heterozogosity (Table 22). Relatively higher genetic diversity was found in both the HD 130 and HD 319-341 ($H_E = 0.85$) study areas. The lower HE value for BMU 411 was not surprising as this is an area of isolated mountain ranges encompassing the Big Snowy Mountains, the Little Snowy Mountains, and the Judith Mountains. Interestingly, the greatest number of alleles (*n*= 19) found anywhere came from the G10H maker used in BMU 104.

Genetic Differentiation.—The number of shared loci used for genetic differentiation scores between areas varied from 2 to 6 (Table 23). Using 2 shared loci, raw genetic differentiation scores were lowest between the adjacent BMU 450 and HD 130 (F_{ST} = 0.002, (Table 23) and highest between the most spatially separated areas, the BMU 411 and BMU 100 (F_{ST} = 0.224).

In study areas sharing more loci, F_{ST} analyses were run again using the greater number of loci. The F_{ST} between the BMU 450 and HD 130 remained low using 3 shared loci (Table 23). Using 4 shared loci, relationships were generally consistent for the following study area combinations: BMU 104→HD 130, HD 130→HD 101/102, HD 101/102→BMU 103, BMU 103→BMU 450, HD 319/341 → HD 301, HD 301→BMU 520, BMU 411→BMU 520, BMU 411→HD 319/341, and for the BMU 411→HD 301 (Table 23).

Six loci were also shared between BMU 104→BMU 100, BMU 100→HD 101/102, and HD 101/102→BMU 103. F_{ST} values were consistently low for the BMU 104→BMU 100 and HD 101/102→BMU 103 with additional loci, but the adjusted F_{ST} for BMU 100→HD 101/102 decreased with the additional loci. Using 2 loci, the adjusted F_{ST} was 6.2, but decreased to 3.6 with a 4 loci test and decreased further to 2.7 using 6 loci (Table 23).

The strongest pattern apparent with 2 loci, which preliminarily held up with 4 loci, was the elevated adjusted F_{ST} values associated with BMU 411 and all adjacent areas (Fig. 21, Table 23) relative to all other adjusted F_{ST} values of adjacent areas across our study region. The other 2-locus pattern of interest are the paired adjacent adjusted F_{ST} values

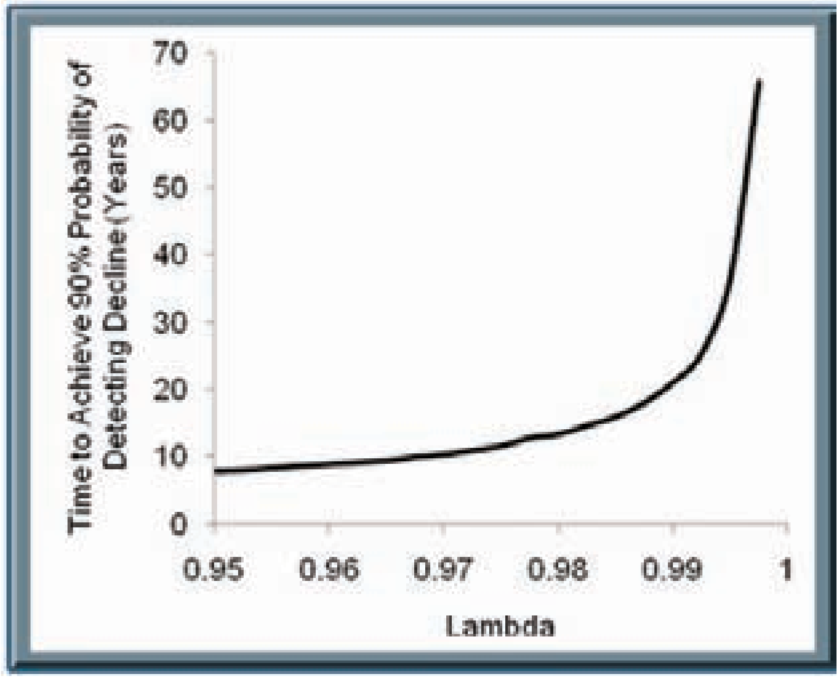

Figure 20. The number of years of harvest data required to identify statistically significant declines in 90% of simulated populations given the deterministic population growth rate.

of all the areas south of the HD 292 (HD 319/341, HD 301, and BMU 520) that are elevated relative to the areas north of HD 292. This pattern begins with the elevated F_{ST} values associated with the HD 130 and HD 292 areas, and that pair was tested only with a marginally-better 3 locus test.

Adult Male Vulnerability to Harvest Relative to Forest Roads in the Swan Valley

Eight adult male black bears were captured in 2003 and 7 bears in 2004 (Table 24). These 15 adult male black bears were monitored during a total of 3 seasons in each of 2 years. The mean age of the bears was 9 years. One of the 15 total captured bears was a recapture from 2003; 2 black bears were recaptures from the MFWP black bear vital rates study in the Swan Valley.

Eleven of the 15 total GPS collars contained data that could be successfully retrieved; 3 of the 4 remaining bears' collars malfunctioned and one disappeared. Among this

Table 22. Summary of number of alleles (A) and heterozygosity (H_E) for black bear DNA study areas in Montana.

Marker	HD 100		HD 101-102		BMU 103		BMU 104		HD 130		HD 292		HD 301		HD 319-341		BMU 411		BMU 450		BMU 520	
	A[a]	Hg[b]	A[a]	Hg[b]	A	Hg	A	Hg	A	Hg	A	Hg	A	Hg	A	Hg	A	Hg	A	Hg	A	Hg
G10X	12	.85					13	.85	12	.84	12	.88		12	.87	4	.66					
G10J	11	.84	12	.86	12	.86	12	.86	9	.85	10	.86	8	.84	10	.87	4	.58	12	.87	8	.79
G10L	15	.84	15	.85			16	.82					11	.82	12	.79	6	.71	16	.79	9	.80
G10U	12	.82					12	.85								7	.75					
MU59	10	.80	11	.81	14	.81	10	.83	8	.83	7	.82	7	.71	9	.85			8	.80	7	.74
G10H			16	.89	8	.79	19	.85	16	.89	17	.82	10	.81	14	.87	4	.63	18	.87	6	.78
G10M											6	.67		7	.74	5	.72					
G10P					18	.88					7	.73	8	.83			6	.61			6	.77
MU23			10	.76	10	.85												10	.78			
G1D													6	.80	8	.77					6	.77
G10P														8	.83							
G10B			7	.79														9	.77			
Mean A	12		11		12		14		11		10		8		6		5		12		7	
Mean Hg		.83		.83		.84		.84		.85		.80	.80		.85		.67		.81		.78	

[a] number of alleles
[b] expected heterozygosity

Table 23. F_{ST} values for adjacent black bear study areas in westesrn Montana. ***See Fig. 21 for a map of spatial arrangement.***

Adjacent areas		Geographic distance (km)	2 Locus raw F_{ST}	2 Locus adjusted F_{ST}/GD	3 Locus adjusted F_{ST}/GD	4 Locus adjusted F_{ST}/GD	6 Locus adjusted F_{ST}/GD
BMU 104	BMU 100	64	0.007	1.1		1.1	1.5
BMU 100	HD 101-102	62	0.039	6.2		3.6	2.7
HD 101-102	BMU 103	36	0.006	1.7		2.2	2.2
BMU 104	HD 130	151	0.016	1.0			
BMU 100	HD 130	184	0.033	1.8			
HD 101-102	HD 130	130	0.007	0.5			
BMU 103	HD 130	133	0.005	0.4			
BMU 103	BMU 450	184	0.006	0.3		0.6	
HD 130	BMU 450	97	0.002	0.2	0.4		
HD 130	HD 292	92	0.021	2.3	2.2		
BMU 450	HD 292	110	0.022	2.0	1.9		
HD 292	HD 319-341	88	0.034	3.9			
HD 319-341	HD 301	163	0.039	2.4		2.5	
HD 301	BMU 520	116	0.033	2.9		1.7 / 2.3	
BMU 411	BMU 520	171	0.099	5.8		5.1	
BMU 411	HD 319-341	321	0.177	5.5		5.3	
BMU 411	HD 301	216	0.129	6.0		5.4	
BMU 411	HD 292	314	0.209	6.7			
BMU 411	BMU 450	265	0.170	6.4			

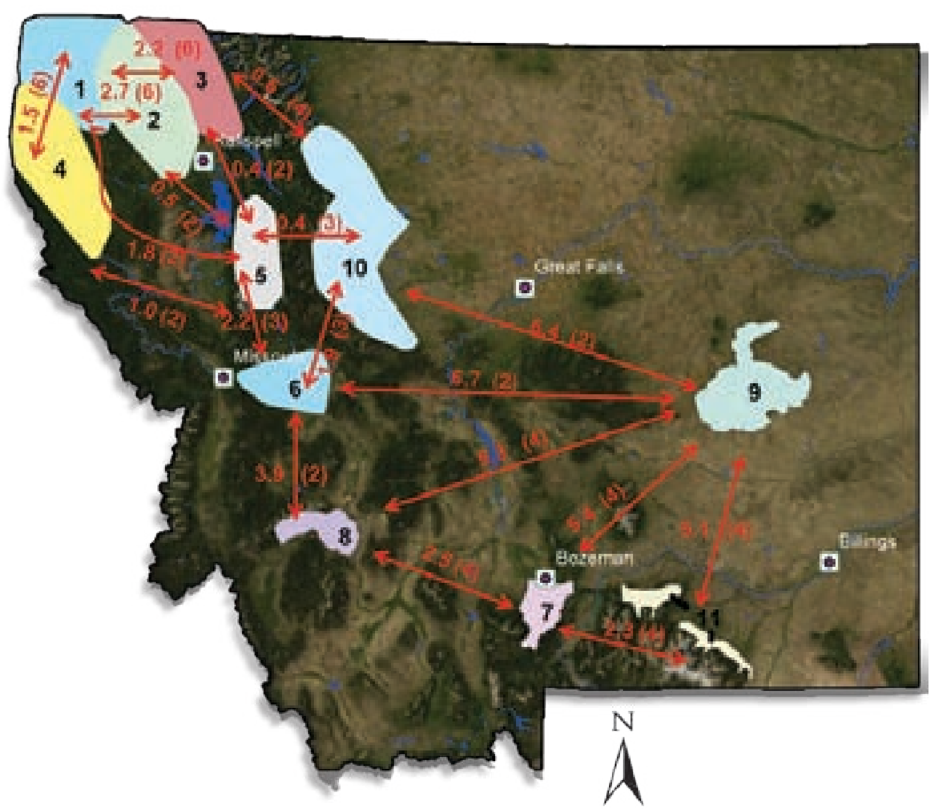

Figure 21. Genetic distance among DNA study areas in Montana. Codes for various areas are given in Table 10.

Table 24. Adult male black bear (n = 15) capture, age, and telemetry information. Swan Valley of Montana, 2003-04.

Black bear number	Capture date	Age (years)	Radio days	Total No. successful fixes attempted	Total No. number successful fixes	Fix success (%)
104	5/18/03	14	140	1683	1285	76
105[a]	5/19/03	14	139	1671	1179	73
109	6/4/03	10[b]	123	1480	997	67
113[a]	6/6/03	10	121	1453	1034	71
117	6/8/03	8	120	1433	1054	74
119	6/12/03	5	115	1382	907	66
120[a]	6/13/03	7	115	1380	1016	74
299	6/7/03	5	55	651	377	58
5[a]	4/28/04	9	160	1923	1476	77
28	4/23/04	10[b]	C[c]	C	C	C
32[a]	5/18/04	12	143	1678	630	38
117	5/18/04	10	C	C	C	C
182	5/15/04	6	C	C	C	C
185	5/13/04	5[b]	C	C	C	C
192[a]	5/27/04	9	1984	1984	1569	79
Mean	---	9	127	1520	1048	69
SD	---	5	29	355	350	11

[a] Individuals used for ANCOVAs.
[b] Estimated age. Tooth not collected, or, if tooth collected, lab was unable to process for age.
[c] Collar malfunctioned or is missing.

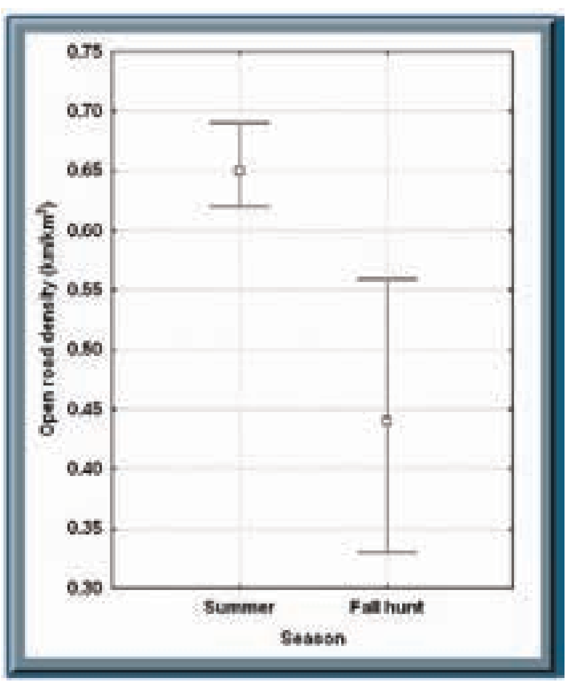

Figure 22. Average open road density (km/km²) and 95% confidence intervals proximate to bear locations between summer and fall hunt seasons (n = 6 bears). Swan Valley of Montana, 2003-04.

sample of GPS collared bears, fix success for combined 2-D and 3-D fix types averaged 69% (Table 24).

Average open road density around bear locations was 0.65 km/km² (95% CI = 0.62, 0.69) during summer and decreased to 0.44 km/km2 (95% CI = 0.33, 0.56) during fall hunt (Fig. 22). After accounting for the relationship between road density and elevation, adult male black bears (n = 6) were in areas with higher open road density during summer than during the fall hunt (P = 0.11). Elevation explained more of the variation (Table 25). Open road densities proximate to bear locations did not differ significantly among diel periods (P = 0.51, Table 25).

For 6 bears during 2 seasons, the average proportion of movements that crossed an open road was 0.08 (95% CI = 0.07, 0.09) during summer, and decreased to 0.03 (95% CI = 0.01, 0.07) during the fall hunt (Fig. 23). After the effects of elevation were removed, the proportion of movements that crossed open roads differed among seasons (alpha level = 0.15, P = 0.07, Table 26), but not among diel periods (P = 0.42). Elevation explained most of the variation (Table 26).

Table 25. Open road density as a function of season, diel period ("Diel"), individual bear ("Bear number"), and interactions, with elevation as a covariate. Error terms were calculated from SPSS default as described in footnotes. Swan Valley of Montana, 2003-04.

			OPEN ROADS				
Effect	SS	df	Hypothesis MS	Error MS	Error df	F	p
Bear number	11.8	5	2.3	1.0[a]	4.0	2.3	0.22
Season	3.0	1	3.0	0.8[b]	6.1	3.5	0.11
Elevation	21.2	1	21.2	0.3[c]	4470.0	70.2	<0.01
Diel	0.5	2	0.2	0.3[d]	16.0	0.7	0.51
Bear*season	5.4	5	1.1	0.4[e]	12.2	2.3	0.10
Bear*diel	4.2	10	0.4	0.5[f]	10.0	0.8	0.60
Season*diel	0.2	2	0.1	0.4[g]	15.1	0.2	0.76
Bear*season*diel	4.9	10	0.5	0.3[c]	4470.0	1.6	0.09

[a] 0.978 MS (Season * Bear number) + 0.834 MS (Diel * Bear number) – 0.834 MS (Season * Diel * Bear number + 0.022 MS (Error)

[b] 0.719 MS (Season * Bear number) + 0.281 MS (Error)

[c] MS (Error)

[d] 0.727 MS (Diel * Bear number) + 0.273 MS (Error)

[e] 0.852 MS (Season * Diel * Bear number) + 0.148 MS (Error)

[f] 1.000 MS (Season * Diel * Bear number) – 0.000 MS (Error)

[g] 0.727 MS (Season * Diel * Bear number) + 0.273 MS (Error)

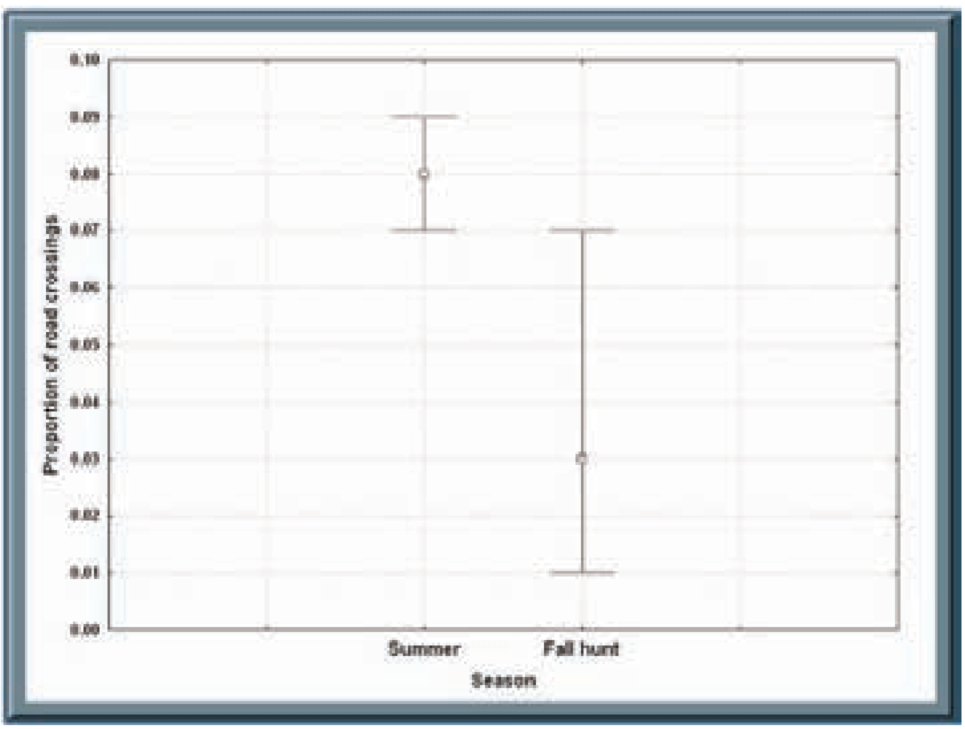

Figure. 23 Averages and 95% confidence intervals for the proportion of movements by bears that crossed open roads between summer and fall hunt seasons (n = 6). Swan Valley of Montana, 2003-04.

Table 26. Proportion of movements that crossed open roads as a function of season, diel period ("Diel"), individual bear ("Bear number"), and interactions, with elevation as a covariate. Error terms were calculated from SPSS default as described in footnotes. Swan Valley of Montana, 2003-04.

OPEN ROADS							
Effect	SS	df	Hypothesis MS	Error MS	Error df	F	p
Bear number	6004.8	5	3200.9	839.0[a]	4.5	3.8	0.10
Season	3027.0	1	3027.0	742.5[b]	12.8	4.0	0.07
Elevation	3303.6	1	3303.6	588.7[c]	3277.0	5.6	0.02
Diel	668.1	2	334.0	387.0[d]	160.8	0.8	0.42
Bear*season	4404.5	5	880.9	274.3[e]	18.2	3.2	0.03
Bear*diel	1887.4	10	188.7	231.1[f]	10.0	0.8	0.62
Season*diel	296.1	2	148.0	408.3[g]	120.3	0.3	0.70
Bear*season*diel	2312.2	10	231.2	588.77[c]	3277.0	0.3	0.95

[a] 0.982 MS (Season * Bear number) + 0.863 MS (Diel * Bear number) – 0.863 MS (Season * Diel * Bear number) + 0.018 MS (Error)
[b] 0.527 MS (Season * Bear number) + 0.473 MS (Error)
[c] MS (Error)
[d] 0.504 MS (Diel * Bear number) + 0.496 MS (Error)
[e] 0.897 MS (Season * Diel * Bear number) + 0.121 MS (Error)
[f] 1.000 MS (Season * Diel * Bear number) – 0.000 MS (Error)
[g] 0.505 MS (Season * Diel * Bear number) + 0.495 MS (Error)

Discussion and Recommendations

Harvest Levels and Adherence to Criteria

Approximately 1,000 black bears are harvested annually in Montana during the spring and fall hunting seasons. This is accomplished without the use of baits or hounds. Most black bears are harvested in the northern and western portions of Montana (Regions 1 and 2), with fewer bears being harvested in central, southern, and eastern Montana. In most areas, male bears accounted for over 60% of the harvest, and the median age of males was typically between 3 and 4 years old. Through a radioed sample of adult males, we documented that they may avoid areas of high road density, where many hunters seek bears, and may be under-represented in the harvest sample relative to their occurrence in the population.

Approximately 1,000 black bears are harvested annally in Montana.

The harvest criteria of age and sex ratio, established to guard against over-harvest and to promote long-term stability of populations were poorly met in most BMUs. Statewide, the criteria of were met in only 17% of the years. Further, analysis of annual hunting regulations revealed that no substantial changes were made to season structures in an attempt to comply with the criteria. We therefore have no empirical data to judge the usefulness of the criteria in altering the structure of the harvest. However, noncompliance with criteria does not mean that bear populations were necessarily over-harvested. The stable trends in harvest over time in most BMUs, coupled with relatively low female harvest rates, may well indicate that the criteria are insensitive to actual changes in harvest levels. We therefore conclude that use of these harvest criteria be discontinued.

The use of these harvest criteria could be discontinued

Bear Distribution

Research and Technical Services staff, working with FWP wildlife biologists, were able to accurately map the distribution of black bears in Montana. This updated mapping effort was needed to more accurately estimate population size and density, and was especially valuable for those BMUs that did not contain contiguous black bear habitat. In addition to the BMUs where bears were legally hunted, our mapping product provided a mechanism to estimate population size and density in areas not open to hunting that could be considered population reserves. Periodic updating of the map would help managers evaluate black bear range contraction or expansion. Further, because black and grizzly bears are sympatric in many areas of Montana, joint mapping of both species would provide hunters with a better understanding of areas where they may encounter grizzly bears while hunting black bears.

Black Bear Population Size and Density

There are about 13,000 black bears in Montana.

We estimated black bear densities (both sexes) of between approximately 9 and 19 bears/100 km^2 in our DNA monitoring areas, including a buffer strip. Based on our regression of bear density at DNA monitoring areas and precipitation patterns, the highest density in Montana was in the Glacier National Park/Blackfeet Reservation area (25 bears/100 km^2) and the lowest was in Region 7 (5 bears/100 km^2). Comparisons to other studies were complicated by differences in analytical methods, habitat, harvest rates, and bear behavior (Beecham and Rohlman 1994). Using extrapolation techniques, we estimated the population size and density of black bears throughout Montana. Our point estimate for the state was approximately 13,000 black bears, 12,000 of which live in areas where hunting occurs. Although the confidence intervals were wide, we believe the point estimate was reasonable, as it tracked well with our observed harvest rates.

Table 27. Population density estimates from representative eastern and western black bear populations.

Study	Area	Avg. Density (bears/100km^2)
This study	Montana	8-18
Miller et al. 1997	Alaska	9-28
McLean and Pelton 1994	West Virginia	9-35
Yodzis and Kolenosky 1986	Ontario	20-60
Rogers 1987	Minnesota	2
Jonkel and Cowan 1971	Montana	23-48
LeCount 1982	Arizona	33
Beck 1991	Colorado	14
Beecham 1980	Idaho	48
Wadell and Brown 1984	Arizona	28
Kellyhouse 1980	California	60
Garshelis and Visser 1997	Upper Penn. Michigan	16
Garshelis and Visser 1997	Minnesota	19

Few estimates of black bear density have been made for Montana. Jonkel and Cowen (1971) reported densities of between 23-48 bears/ km^2 in the North Fork Flathead River, which were based on movements of tagged bears. Kasworm and Thier (1991) provided a density estimate for an area roughly encompassing BMU 100. Their estimates in 1990 and 1991 were 13.5 bears/100 km^2 and 10 bears/100 km^2, respectively. Our current estimate for this BMU varied between 13 and 17 bears/100 km^2. This increase in density is consistent with observations by regional wildlife staff, and may be a consequence of a more restrictive spring hunting season and improved security due to forest road closures. However, it is probable that densities of black bears in Montana are lower than those in Idaho (31-58 bears/km^2, Beecham and Rohlman 1994) and several other North American populations (Table 27).

Genetic Structure

The genetic diversity of black bears in Montana was relatively high, compared to values reported for other black bear populations, suggesting movement of individuals across wide geographic areas. BMU 411 exhibited the lowest heterozygosity of all DNA areas studied

(67.0%), which was reasonable as this area encompasses the Big and Little Snowy Mountains, an isolated mountain range. Heterozygosity in other black bear populations across the U.S. was generally lower than those in Montana. The heterozygosity of a Utah population was 52.9% (Sinclair et al. 2003), varied from 32.7% to 70.5% in several Florida black bear populations (Dixon 2004), between 35-84% across 2 populations in New Mexico (Costello et al. 2008), and between 62.2 and 78.5% in an Idaho population (McCall 2009).

Radio-collared bears have helped researchers document causes of death.

In general, higher F_{ST} values may be associated with increasing anthropogenic or natural barriers to gene flow (Proctor et al. 2005). However, lower F_{ST} values do not necessarily mean that barriers to gene flow do not exist. It can also be difficult to observe genetic variation in populations with high numbers of individuals such as those in our study areas, especially if fragmentation is recent, as some level of genetic drift is needed to observe genetic variation, and genetic drift that becomes apparent from fragmentation may take time to develop.

The difference in loci used for each of our study areas made it difficult to derive estimates of genetic differentiation between many study areas. We offer this preliminary result only to provide a look at interesting genetic relationships that might be worthy of further analysis; for more conclusive results, we recommend that genotypes in all study areas be analyzed to a minimum of 8-9 loci. For example, the results for the 2-locus F_{ST} test between BMU100 (the Yaak) and HDs 102-102 (the Salish Mountain Range) relative to other adjacent areas nearby suggested genetic fragmentation between these 2 study areas, however this relationship was considerably muted with additional loci. Other relationships remained consistent with the addition of more loci.

Our results suggest possible fragmentation between the HD 292 (Garnet Mountain Range) and study areas to the north, although the 3-loci test only marginally improved our resolution. We suggest additional sampling is warranted between this and other areas for more conclusive results.

The elevated F_{ST} values associated with the BMU 411 (the Snowy Mountain area) were consistent, even after adjusting for geographic distance and adding more loci. This relationship held for the 4-locus test with 3 of the 5 adjacent areas, supporting a hypothesis of fragmentation (anthropogenic or natural) between the BMU 411 and our other study areas.

In general, our F_{st} results are very preliminary, because of the paucity of shared loci among areas, but suggest that there may be variation in the genetic relationships between

Heterozygosity in other black bear populations across the U.S. was generally lower than those in Montana.

Harvest data for black bears can be difficult to interpret.

adjacent areas across our study region. Verification and the development of more conclusive results as to causes of any fragmentation (natural or anthropogenic) would require additional loci coupled with a landscape ecology analysis.

Use of DNA to Assess Harvest Rate and Population Size

Interpretation of harvest data are difficult.

To our knowledge, this is the first study to use genetic "tagging" of black bears to estimate harvest rates. Between 2001 and 2008, we sampled bear populations across approximately 38,705 km^2 of habitat in Montana. During our 2-week marking program at hair-traps, we obtained genotypes from 691 female and 502 male black bears that could later be cross-referenced with the harvested sample. We believe that our use of a 5 x 5 km grid-density was sufficient in most areas, but would recommend a sampling regime of somewhat higher intensity in the lower-density habitats of southwestern Montana. We would also recommend that the sampling period be extended beyond 2 weeks to increase the number of bear visits within and between hair-traps. An increased sample size would improve estimates of harvest rate and population size. We also believe that DNA sampling be replicated over several years to gain more confidence in harvest rate estimates. Because of sample size constraints, we would not recommend using this technique to estimate harvest rates in areas where fewer than 20 bears are harvested annually. Our methodology of estimating harvest rate using DNA extracted from hair samples appears to be a reasonable, yet generalized, method to track harvest rates in areas that may be of management concern.

Value of Mandatory Check

Montana instituted a mandatory check of black bears in 1985 with the intent of using these data to assess harvest levels and composition. Although harvest data are commonly used to reconstruct population structure, interpretations of such data are difficult (Kohlmann et al. 1999) and often return contradictory signals regarding impact of harvest (Garshelis 1991). Further, for some types of analyses, accurate data on hunter numbers and effort on a finer scale are necessary. In Montana, MFWP did not routinely collect long-term hunter effort data at the scale of the BMU, which stymied our evaluations.

Sex ratios of harvest are commonly used to manage black bear populations in the western states (Garshelis 1991), where an increasing proportion of females in the harvest may be interpreted as an indication of overharvest. For example, Harris (1984) reported that bear populations that are becoming overharvested follow 3 patterns: 1) the harvest sex ratio shifts to females, 2) males get younger, and 3) females get slightly older. Conversely, there are several instances in which no relationship was found between sex ratio and hunting pressure (LeCount 1982, Young and Ruff 1982, Kolenosky

1986, Miller 1990, Schwartz and Franzmann 1991, and Kasworm and Thier 1994). Waller and Mace (1997) cited several authors who cautioned against using sex ratio data to determine wildlife population status (Caughley 1974, Downing 1981, and Garshelis 1991). Garshelis (1991) cited several examples with healthy bear populations, including Maine, Minnesota, and Pennsylvania, where > 40% of the annual harvest was female. In Montana, female harvest averaged less than 40% of total harvest, and there was no indication of major increases in female harvest in any BMUs.

Age structure of the harvest is also used to monitor bear populations. Most biologists interpret a shift to younger bears in the harvest as an indication of overexploitation. Again, Garshelis (1991) showed that this was not necessarily the case, and cautioned against using unpredictable age data. There has been no notable broad-scale shift to subadult bears in the Montana bear harvest.

Statistical evaluations suggest that harvest data were insufficient to gauge, on an annual basis, whether populations would be in decline. We determined that it would take approximately 15 years for managers to be 78% sure that a decline in the population was occurring.

For the reasons discussed above, we do not recommend maintaining the mandatory harvest check for use in population reconstruction or for estimating population trend. Rather, the value of the check is to maintain accurate records of the total number and the sex of black bears harvested per BMU to ascertain long-term trends in harvest levels. The annual mandatory check is still useful to tag bear hides for enforcement purposes and to inspect females for evidence of recent lactation. The extraction and collection of black bear teeth for precise age determination is not necessary. Rather, similar to mountain lions (*Puma concolor*), we suggest that harvested bears be classified by ocular inspection as either subadults or adults based on tooth wear, body size, or reproductive status at the time of inspection. Because some hunters may want to know the age of a bear, and some biologists may have special population management circumstances, the decision to continue with tooth collection should be determined by individual regions; but we would again caution that age data are rather uninformative. We recommend that the regions utilize a consistent statewide database such as Mandatory Reporting Response Entry (MRRE) to track nonhunting related mortality, especially in those BMUs where total annual black bear harvest rates are approaching 15%. MRRE should be adequate in providing biologists and managers a tool to evaluate annual nonhunting-related mortality by BMU.

We do not recommend maintaining mandatory harvest check for use in population reconstruction.

Harvest Management

We used three techniques to estimate harvest rate of black bears in Montana. In the first technique, we used a variant of the mark-recapture procedure to examine the proportion of bears DNA-marked (genotyped) that we subsequently harvested. The second method applied a statistical method (Fraser et al. 1982) to the historical bear harvest records to estimate harvest rates. The third method employed a sample of radio-instrumented bears in HD 130, the Swan River Valley. The first and second methods gave the same result: average annual harvest was approximately 10% for males and 4% for females. Our mean harvest rate estimate from radioed black bears in HD 130 was 9% and 6% for all males and females, respectively. Using DNA estimates of harvest rates for the same area, we calculated an adjusted mean harvest rate of 1.8% and 4.4% for males and females, respectively.

We recommend that the regions utilize a consistent statewide database.

White et al. (www.cnr.colostate.edu/~gwhite/bgmodel/BearModel.html) conducted simulation modeling for black bears in Colorado, using the long-term data from Beck (1991). These authors concluded that, without density-dependent compensation in the population, approximately 15% of a black bear population > 2 years old could be removed annually without a population decline. This rate applied to total mortality of both sexes.

Female black bear harvest rates are generally lower than for males.

Female harvest levels were well within the sustainable levels.

Vaughan and Pelton (1995) presented a summary of black bear management in North America and the stated that "Many wildlife agencies accept that black bear populations can sustain 20-25% annual harvest mortality, with the understanding that some areas are more sensitive to overharvest than others." (internet article; http://biology.usgs.gov/status_trends/static_content/documents/olrdocs/Mammals.pdf). Freedman et al. (2003) conducted extensive simulations of black bear populations with the goal of determining which vital rates most affected population trend. The authors determined that, by varying reproductive and survival rates, survival of adult females was the most important variable affecting population trend.

Miller (1990) also reviewed sustainable mortality levels for bears. Again using reproductive rates for females, and a cub mortality rate of 22%, a maximum sustainable annual hunting mortality rate for black bears (both sexes) was calculated to be 14.2%. Using generous estimates of reproductive rates, and low levels of natural mortality, the maximum sustainable mortality level for black bears >1 year old was estimated to be approximately 15.9% (Miller 1990, p. 366).

Kasworm and Thier (1994) studied the survival and reproductive rates of male and female black bears in the Cabinet Mountains and Yaak River areas of Montana. Survival rates for adult males and females were estimated to be 0.73 and 0.79, respectively. They further reported a reproductive rate of 0.51 and an age of first reproduction of 6 years. Using the technique of Bunnell and Tait (1980), the authors calculated a sustainable mortality rate from all causes of 12%. However, the sustainable rate using Bunnell and Tait is for bears of all ages, not just adults, as in the Kasworm and Thier study. Hebblewhite et al. (2003) calculated adult and subadult survival rates of 0.84 and 0.77 for bears of both sexes in the Bow Valley, Alberta. Given these survival rates and estimates of reproduction, the bear population in this area was determined to be declining.

Female harvest levels, as determined by DNA alone, were well within the sustainable levels for both adult females and all females 1+ years old. However, there are other sources of nonhunting mortality (e.g., management removals, road kills, natural mortality, wounding loss, etc.) that need to be factored into population management. Nonhunting mortality estimates vary by method of study and area literature (Table 28), but are plausibly between 1% and 15%.

Table 28. Review of literature regarding non-hunting mortality levels for black bears.

Study	Data type	% Non-harvest mortality rate Male	Female	Combined	Notes
Swan[b]	Radio-days	0.0-0.07-0.13	0.0-0.06-0.13	0.01-0.06-0.11	
Obbard and Howe, 2008[b]	Radio-days		0.026-0.06-0.093		Only adult female black bears in sample
Mace and Waller, 1997[b]	Radio-days	0.127	0.102		For grizzly bears
Wakkinen and Kasworm, 2004[b]	Radio-days	0.094	.071		For grizzly bears. Includes bears >2 years old
Hebblewhite et al., 2003[b]	Radio-days			0.217	Includes bears >2 years old & nuisance bears inside Banff Ntl Park
HD292[a]	DNA			0.024	1 of 41 dna marks
Kolenosky, 1986[a]	Ear-marked and radioed bear	< 3 years 0.18 -0.38. Adult 0.10-0.22	< 3 years 0.17 -0.21, Adult 0.11-0.12		Observed for a hunted population
Klenzendorf, 2002[a]	Marked and radioed bears			0.012	Observed for hunted population
Koehler and Peirce, 2005[a]	Marked and radioed bears			0.191	Observed for hunted population, ONLY for black bears <8 years old
Maryland DNR website, 2009[a]	DNA-marked bears			0.12-0.17 (excluding cubs + 8% hunting mortality)	Observed for hunted population & sustainable. Population has only been hunted since 2004
Kasworm and Thier, 1994[a]	Marked and radioed bears	0.0	0.15		Observed for hunted population

[a] Proportion of non-hunting mortalities divided by number of total marks
[b] Non-hunting mortality rate based upon radio-days

Kasworm and Thier (1994) provided a nonhunting mortality estimate of 15% for black bears in northwestern Montana during the period between 1983-1992.

Credible nonharvest mortality in Montana may well exceed 10% per sex. Our mean estimate of nonhunting mortality from radioed bears in HD 130 was 6%. Under a simple additive mortality scenario then, total female mortality rates may approach 15% in many areas of the state. Based upon our modeling, given that the mean age of primiparity in Montana was 6 years, and an average litter size of 2.08, populations could be expected to decline if subjected to > 16.0 % mortality of females over time. Therefore, with the uncertainty in levels of nonhunting mortality that exists, there appears to be little decision space for population managers to increase black bear harvest above current levels anywhere in Montana. Although harvest numbers are relatively low in southwestern Montana (e.g., BMU 319), the more fractured nature of bear habitat there warrants a more conservative approach to harvest management. We strongly recommend that game managers in each region track the extent of nonhunting mortality in each BMU for a period of at least 5 years to gain a better understanding on how these sources of mortality may affect harvest management.

We strongly recommend that game managers in each region track the extent of nonhunting mortality in each BMU.

It appears that over time, Montana black bear hunter numbers and harvest levels have struck a balance with inherent black bear densities. We have shown that bear density is greatest in the moist coniferous habitats of northwestern Montana and generally declines with less moist habitats towards the south, and hunter numbers follow this same pattern. Like other low-density species, management of black bears in Montana will continue to be most successful, and populations will remain most healthy, if conservative harvest management programs, that utilize several sources of information, are implemented and periodically evaluated.

Black bears are harvested during spring and autumn seasons.

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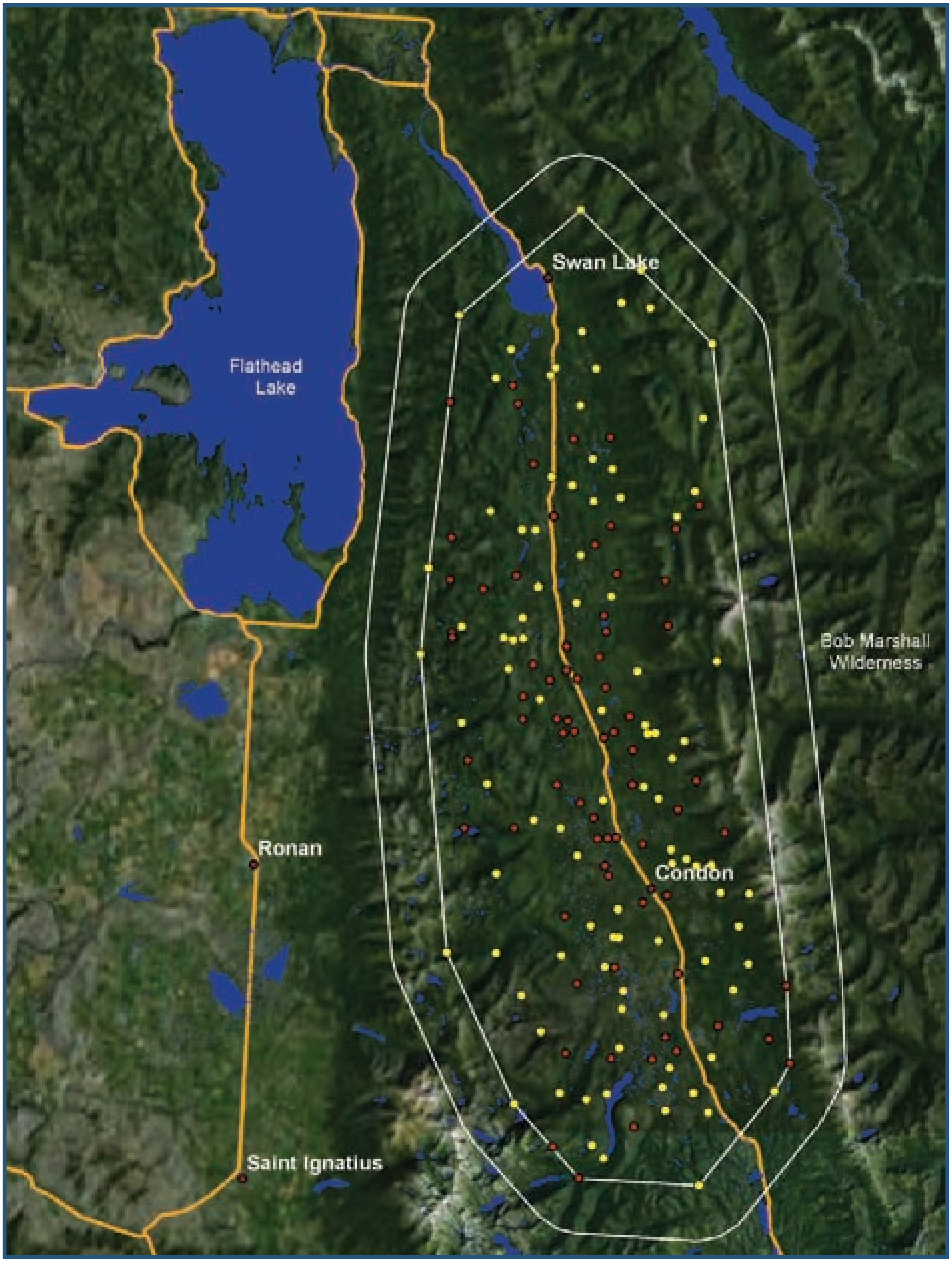
Black Bears in Montana will continue to be most successful, and populations will remain most healthy, if conservative harvest management programs, that utilize several sources of information, are implemented and periodically evaluated.

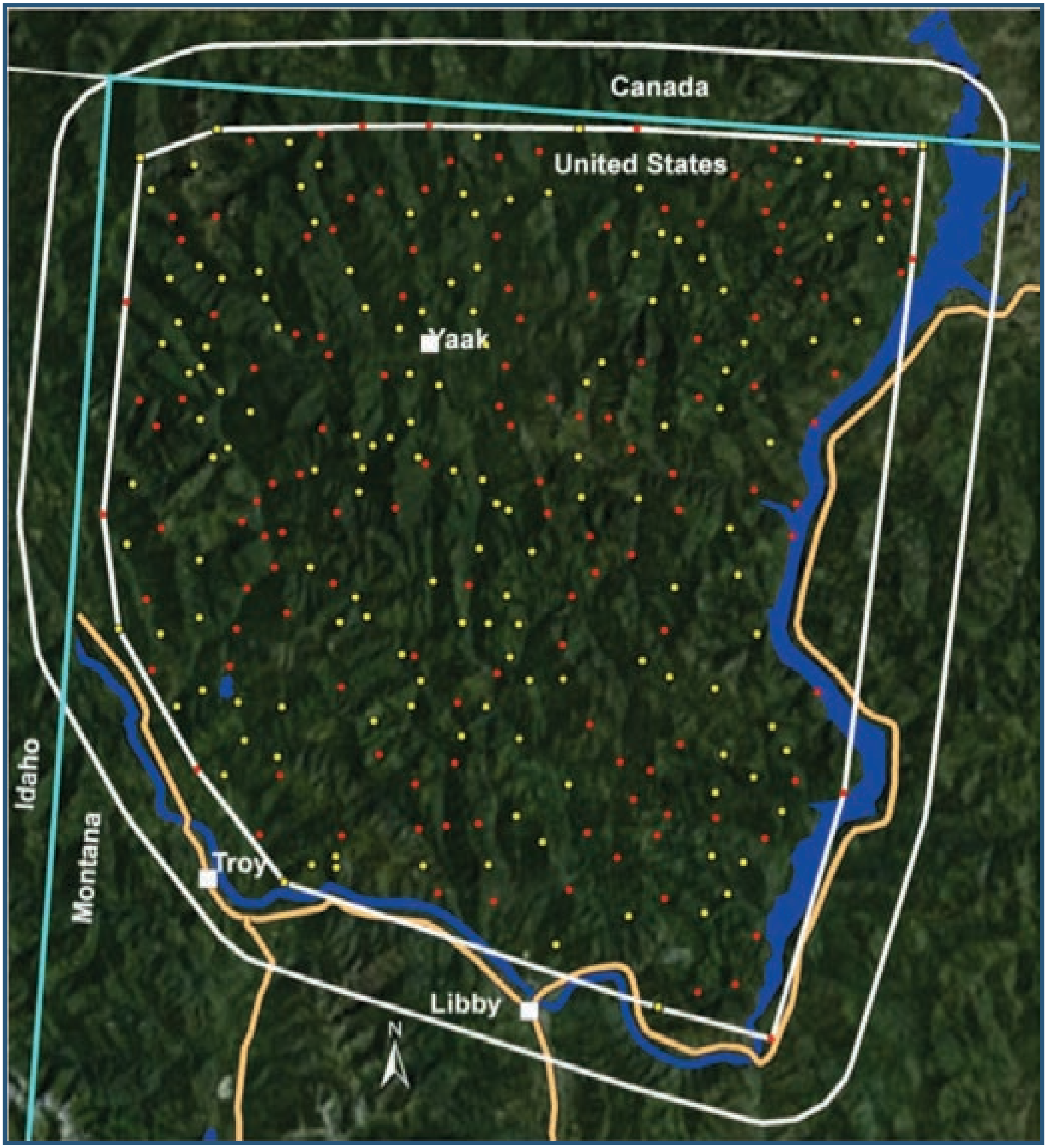
Appendix 1

Locations of DNA hair-traps in each study area of Montana

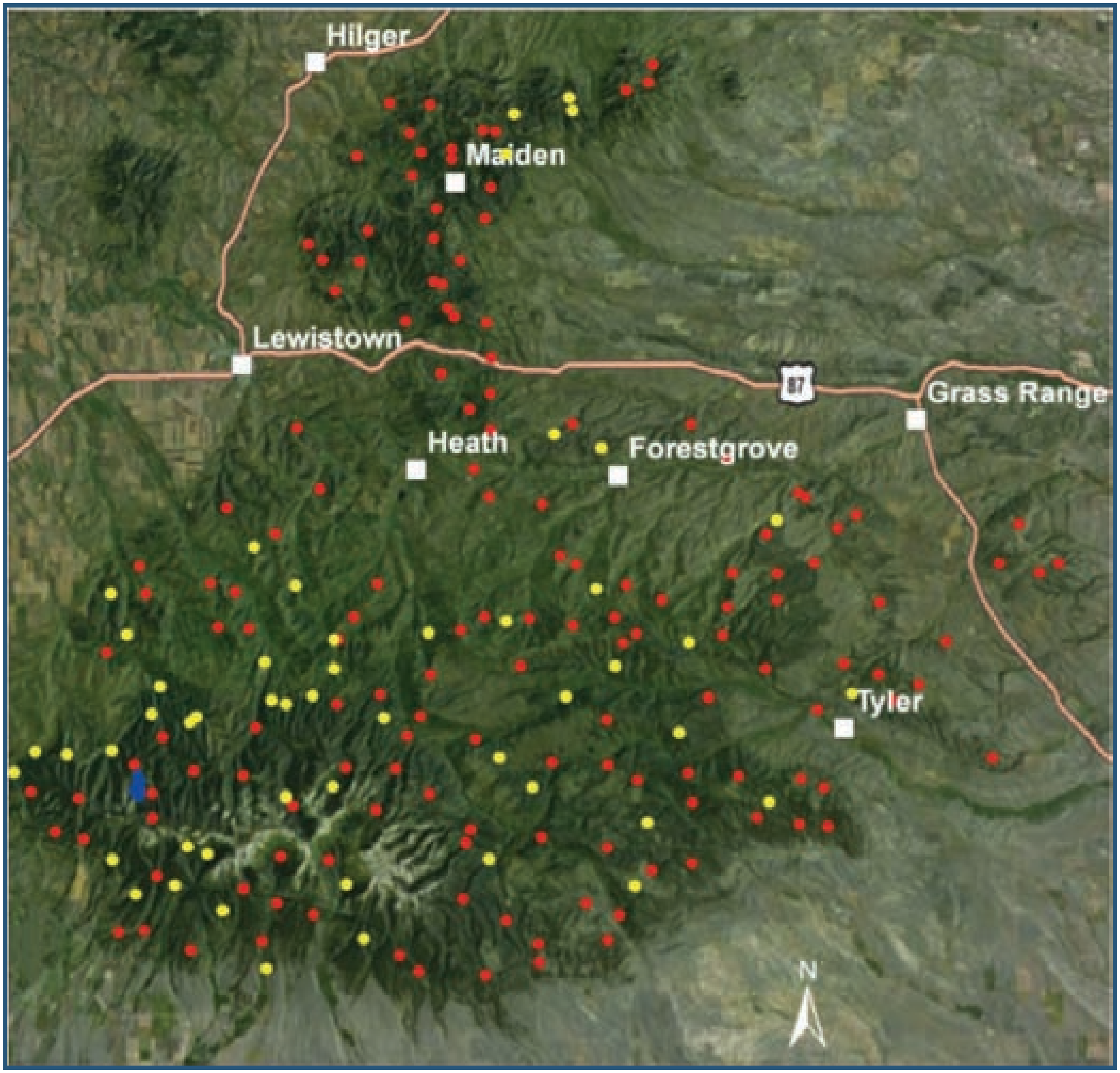
Appendix 1A. Location of DNA sampling in Hunting District 130 (Swan Valley) during 2001-2, with buffer. Yellow points represent hair-traps visited by bears and red points were traps not visited.



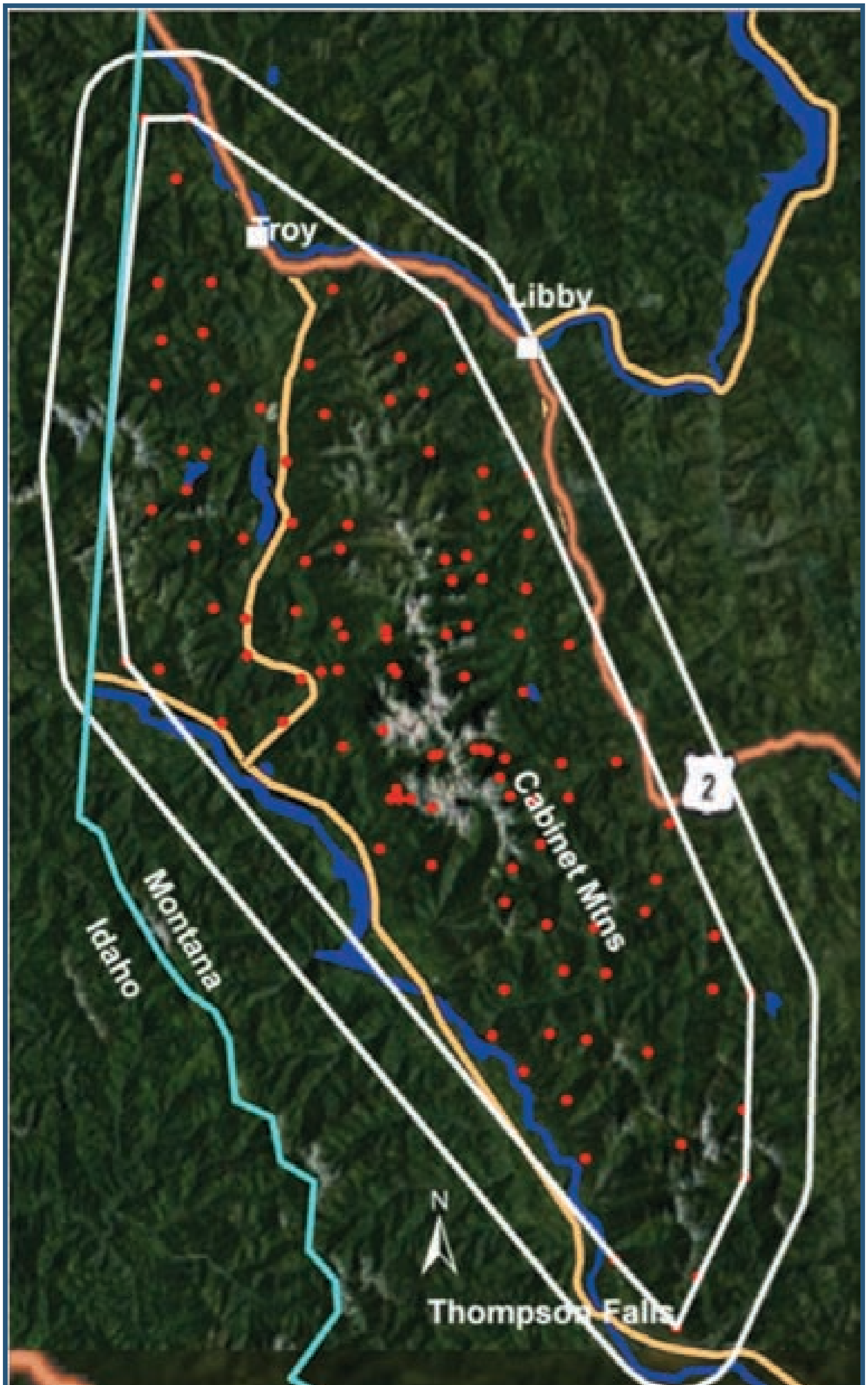
Appendix 1B. Location of DNA sampling in BMU 100 (the Yaak) during 2002-3, with buffer. Yellow points represent hair-traps visited by bears and red points were traps not visited.



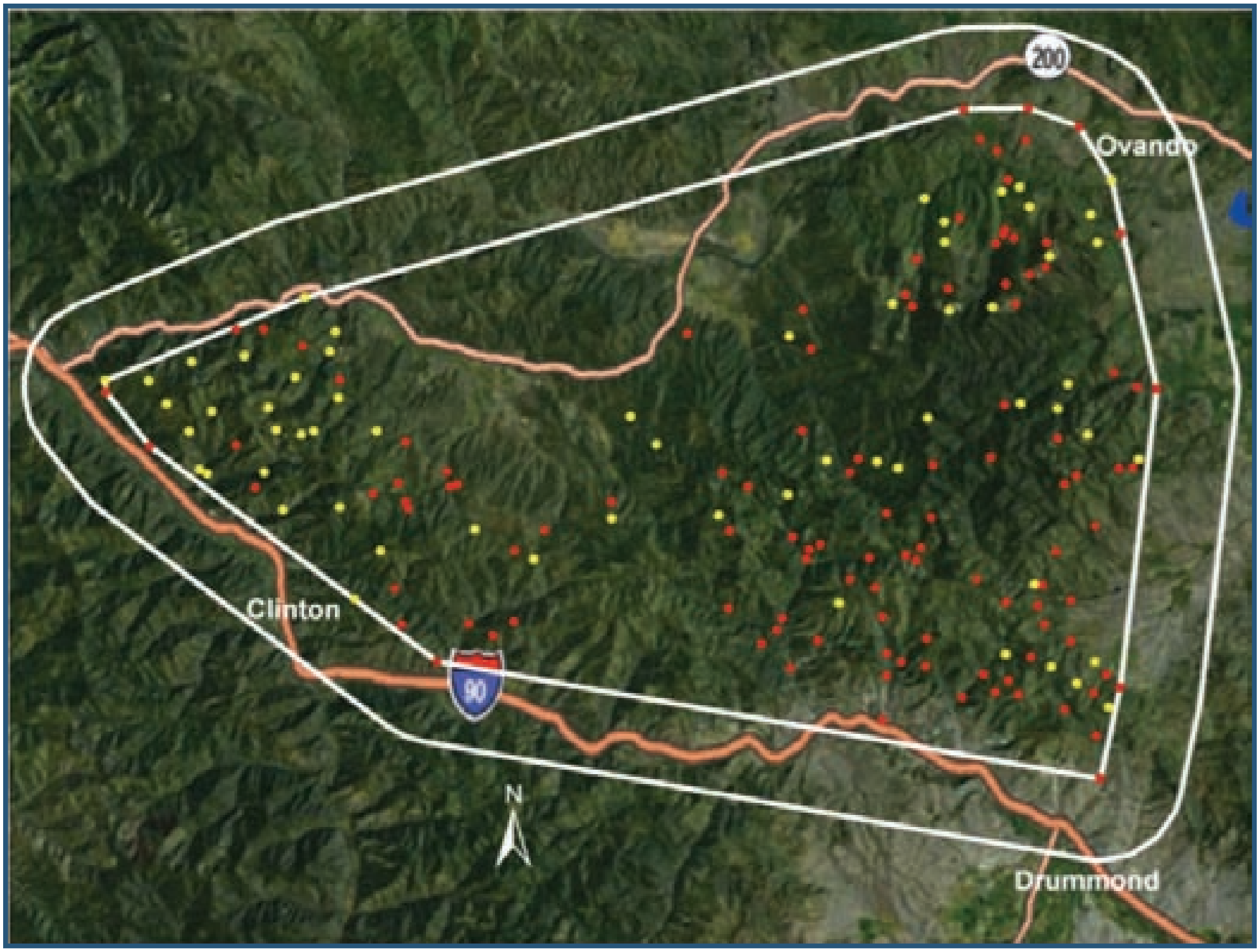
Appendix 1C. Location of DNA sampling in BMU 411 (the Snowy Mountains) during 2002-3. Yellow points represent hair-traps visited by bears and red points were traps not visited. A buffer strip was not used for this area, as bears do not inhabit the prairie habitats beyond the mountains.



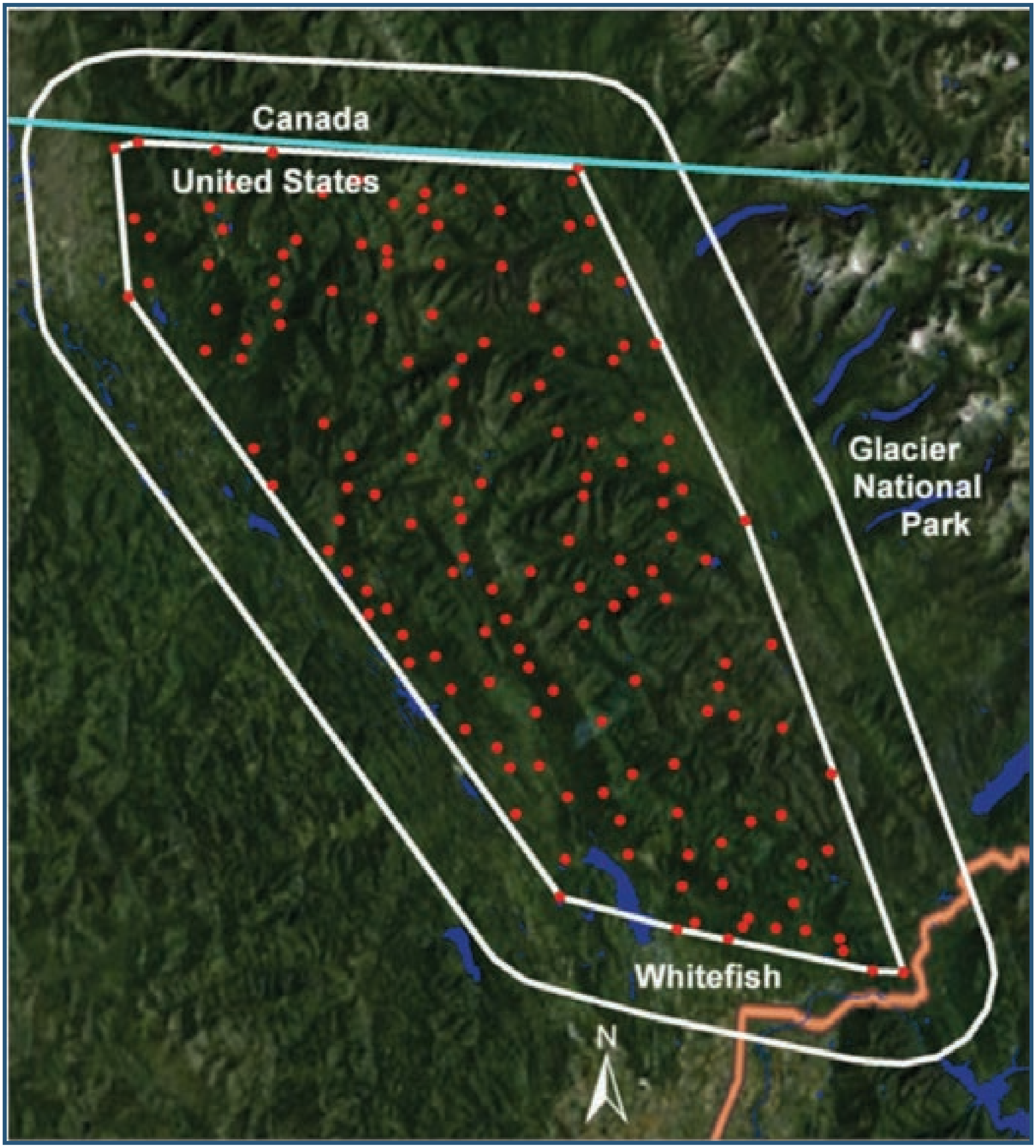
Appendix 1D. Location of DNA sampling for black bears in BMU 104 (the Cabinet Mountains area) during 2003-4, with buffer.



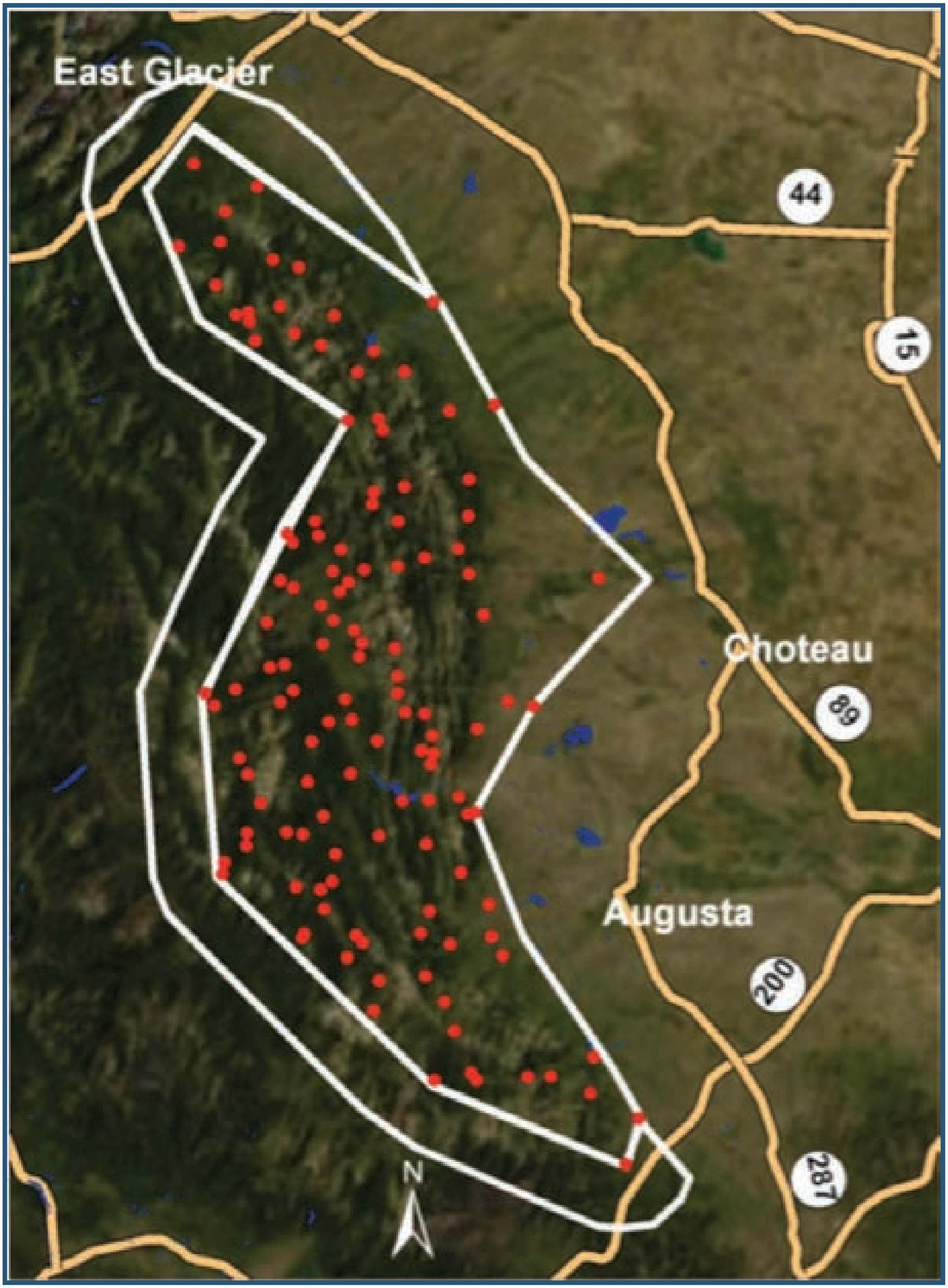
Appendix 1E. Location of DNA sampling HD 292 (the Garnet Mountains) during 2004-5, with buffer. Yellow points represent hair-traps visited by bears and red points were traps not visited.



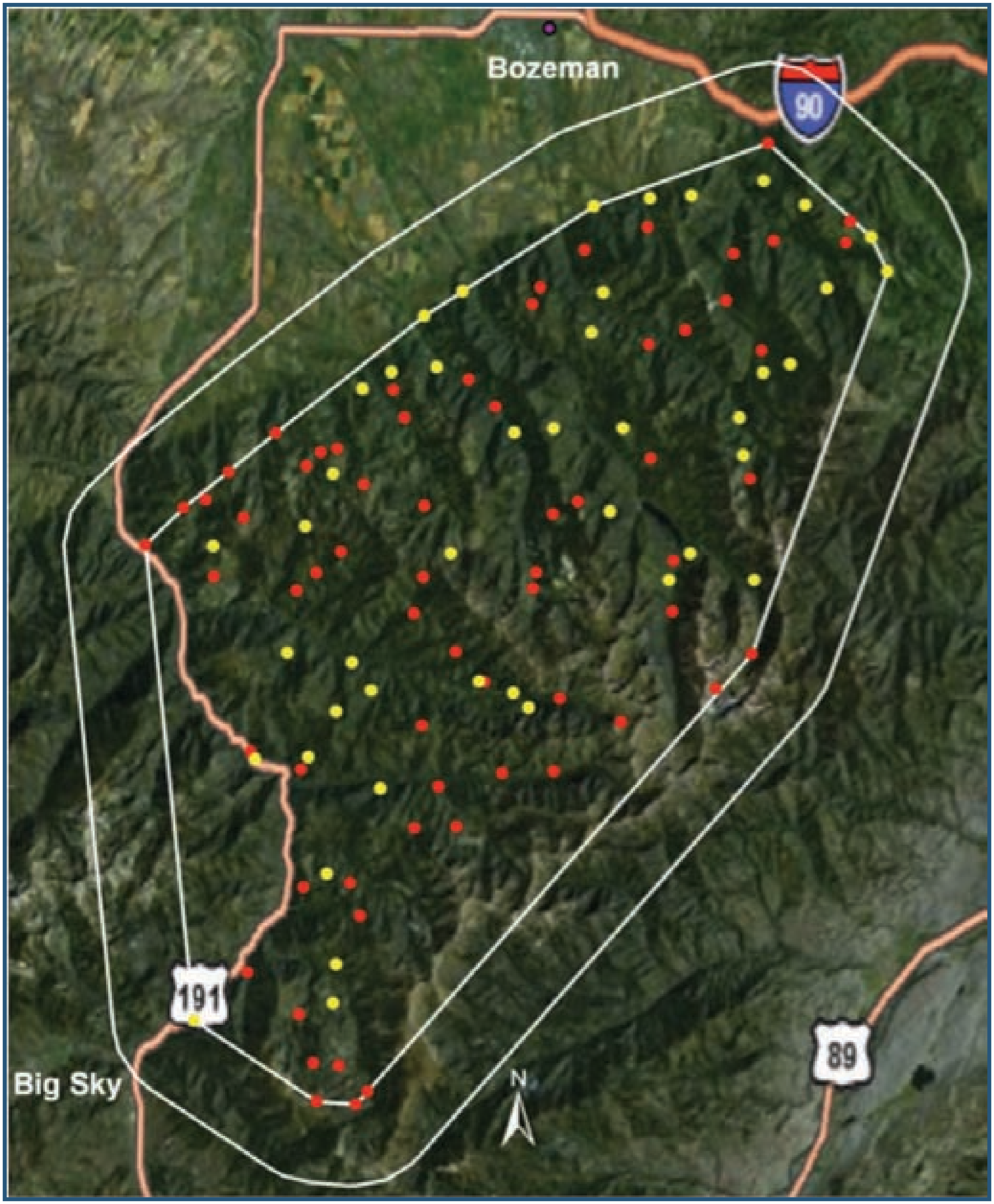
Appendix 1F. Location of DNA black bears in BMU 103 (the Whitefish Mountain Range) during 2004-5, with buffer.



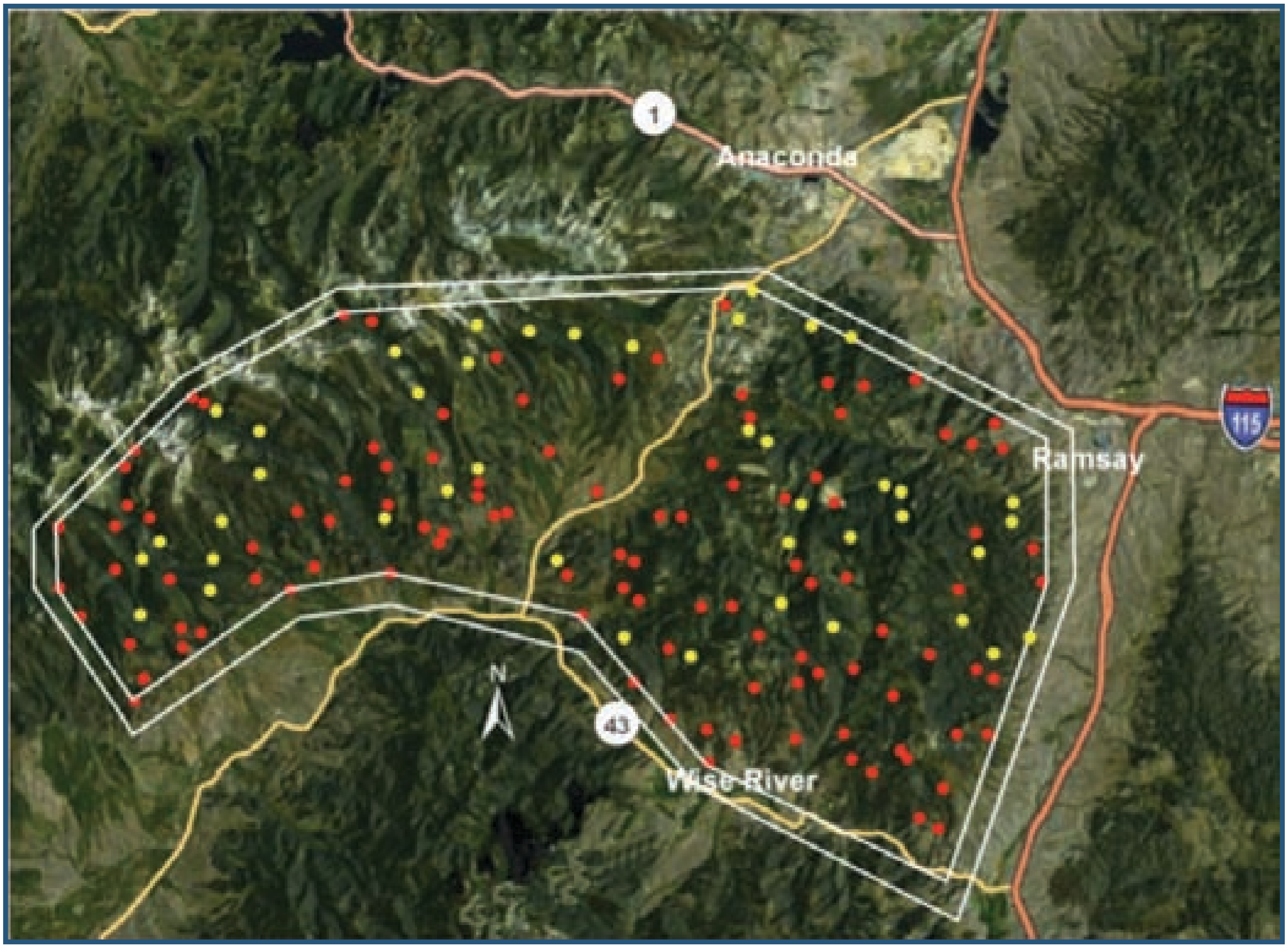
Appendix 1G. Location of DNA sampling for black bears in BMU 450 (the East Front area) during 2004-5, with buffer. We did not extend the buffer stip to the eastern side of the sampling area as black bears rarely inhabit this non-forested prairie habitat.



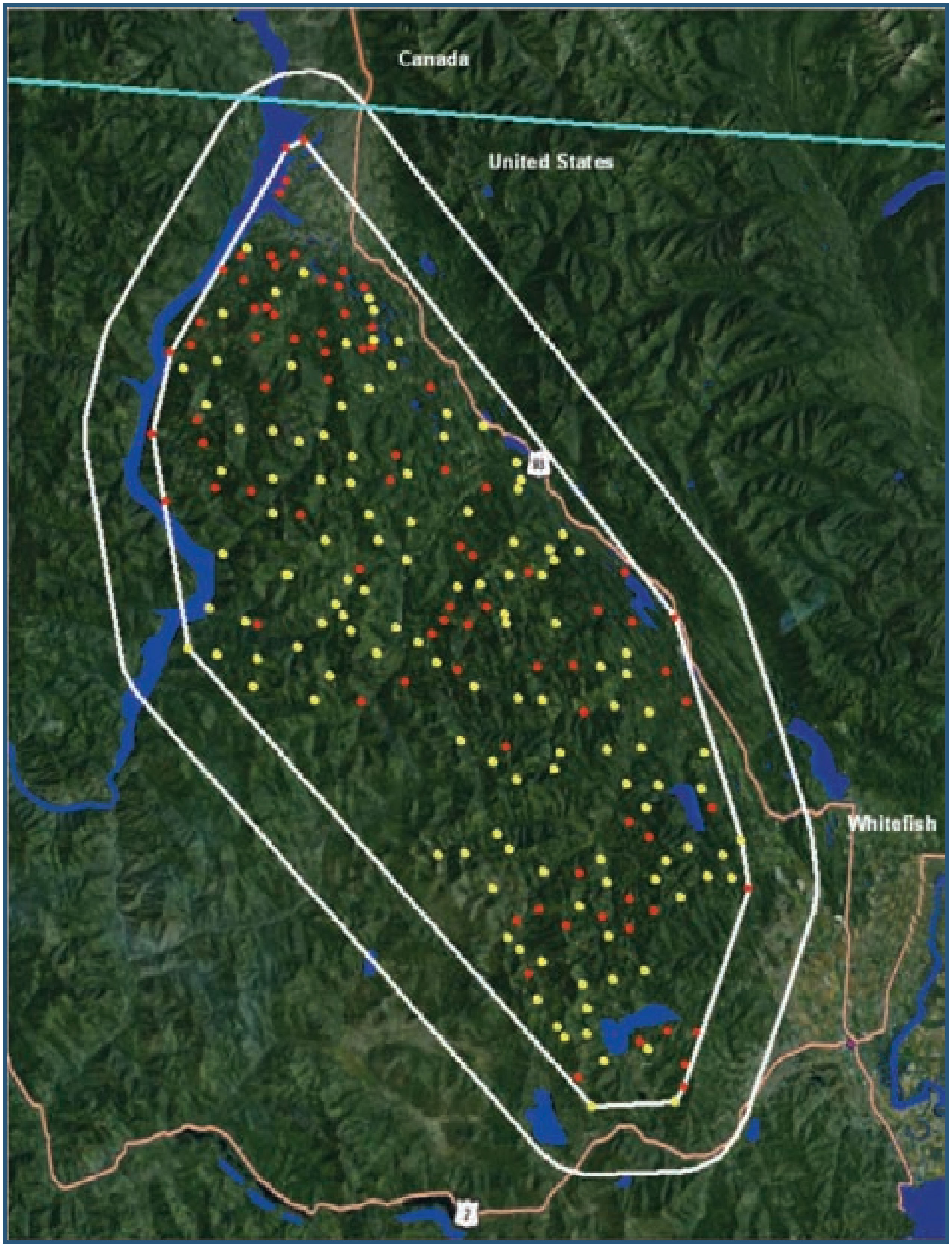
Appendix 1H. Location of DNA sampling for black bears in HD 311 (the Gallatin Mountains area) during 2005-06, with buffer. Yellow points represent hair-traps visited by bears and red points were traps not visited.



Appendix 1I. Location of DNA sampling for black bears in HD 319-341 during 2006-7 with buffer. Yellow points represent hair-traps visited by bears and red points were traps not visited.



Appendix 1J. Location of DNA sampling for black bears in HD 101-102 during 2008, with buffer. Yellow points represent hair-traps visited by bears and red points were traps not visited.



Appendix 1K. Location of DNA sampling for black bears in HDs 520 and 560, 1999-2002.