

# ESTIMATING POPULATION SIZE OF A LOW-DENSITY BLACK BEAR POPULATION USING CAPTURE–RESIGHT

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**Abstract:** We estimated black bear (*Ursus americanus*) density and population size in the Snowy Range of southeast Wyoming, an area suspected of supporting few bears. We captured 26 bears in 3 study areas during intensive trapping efforts (1,161 trap nights) in 1994–95. Using infrared-activated camera systems to identify marked and unmarked bears visiting bait stations, we estimated population size of the 3 areas with program NOREMARK then calculated density. The estimated population size in 1995 was 70 bears; density estimates ranged from 1.75–3.73 bears/100 km<sup>2</sup> for the 3 areas, with a mean of 2.54 bears/100 km<sup>2</sup> (95% CI = 2.11–2.97). Black bear density in the Snowy Range was considerably lower than density estimates previously reported for populations in the mountains of western North America.

*Ursus* 11:117–122

**Key words:** black bear, capture–resight, density estimation, population estimation, *Ursus americanus*, Wyoming

The low reproductive rate of black bears (Bunnell and Tait 1981) makes them particularly vulnerable to management errors such as overharvest (Gill and Beck 1990, Garshelis 1993). This is especially true for low-density populations. Managers often use density estimates from the literature to assist them in managing black bear populations (Bunnell and Tait 1980); however, most of these estimates come from moderate to high-density populations (Jonkel and Cowan 1971; Beecham 1980; Beck 1994, 1995). Because research projects usually have other objectives such as identifying birth and survival rates or habitat use, researchers typically select high-density bear populations where large samples are attainable. Thus, applying even the lowest density reported in the literature may result in overestimation of low-density populations.

Most black bear population or density estimates in the mountains of western North America are based on capture–recapture methods (Jonkel and Cowan 1971; Beecham 1980, 1983; LeCount 1982; Young and Ruff 1982; Goodrich 1990). Capture–resight, a variant of capture–recapture which incorporates radiotelemetry and remote photography, has been developed in recent years. Recently, capture–resight techniques have been used to estimate both grizzly (Mace et al. 1994; Miller et al. 1997) and black bear populations (Beck 1994, 1996, 1997; Miller et al. 1997). A major advantage of capture–resight over traditional capture–recapture techniques is that animals need only be handled once; resights are gained by photography, telemetry, or direct observation (Mace et al. 1994, Miller et al. 1997).

Most capture–resight studies involve >1 year of data collection (Mace et al. 1994; Beck 1994, 1996; Miller et al. 1997). Monetary savings, and the likelihood of meeting the assumption of population closure, may be in-

creased if trapping and resighting were accomplished in the same year.

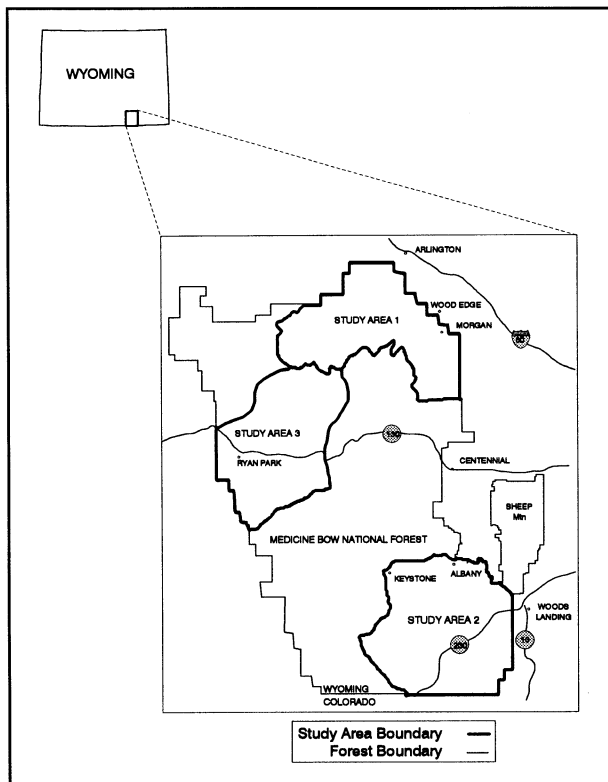
No density or population estimates were available for Wyoming black bear populations outside Yellowstone National Park. Estimated densities in adjacent states ranged from 8 bears/100 km<sup>2</sup> in north-central Colorado (Beck 1997), where neither soft or hard mast species were common, to 80 bears/100 km<sup>2</sup> in west-central Idaho (Beecham 1980), where soft mast species were abundant. Because southeast Wyoming has little soft mast and no hard mast, black bear densities in the Snowy Range were suspected to be lower (Wyoming Game and Fish Department 1994). Managers could benefit from accurate estimates of low-density populations when managing bears in similar habitats to those found in the Snowy Range.

Our goal was to estimate density and population size of a suspected low-density black bear population in the Snowy Range of southeast Wyoming. We also evaluated whether capture and resight efforts could be completed in a single year.

## STUDY AREA

We sampled 3 study areas chosen to represent the habitats found in the Snowy Range portion of the Medicine Bow National Forest (MBNF) of southeast Wyoming (Fig. 1). Although vegetative composition of the 3 study areas differed, when combined they were similar to the composition of the entire MBNF (Table 1). The Snowy Range (Medicine Bow Mountains) extends 56 km north of the Wyoming–Colorado border in southeastern Wyoming and is about 3,000 km<sup>2</sup> in area. The Range is bordered on the east by the Laramie Basin and on the west by the North Platte Valley. Major land uses included logging, cattle grazing, and recreation. Elevations ranged

from 1,830 m to 3,658 m. Mean annual precipitation varied from about 38 cm at lower elevations (1,830 m) to  $\geq 64$  cm at high elevations (3,050 m). Most precipitation fell as rain from April through September at lower elevations and as snow at higher elevations ( $>2,440$  m) from October through May. Mean annual temperatures ranged from 7°C at lower elevations to  $<2^\circ\text{C}$  above 2,440 m (Western Regional Climate Center 1996).



**Fig. 1.** Location of the 3 Snowy Range study areas and adjacent boundaries of the Medicine Bow National Forest in southeast Wyoming.

**Table 1.** Vegetation types and composition (%) of the Snowy Range portion of the Medicine Bow National Forest (MBNF) and study areas in southeast Wyoming.

Vegetation type	Scientific name	Composition (%)				
		Study areas				MBNF
		1	2	3	1,2,3	
Forblands		0.2	0.3	0.1	0.2	0.3
Grasslands		2.9	2.0	5.1	3.2	5.9
Nonvegetated		0.1	0.6	0.8	0.5	2.0
Shrublands		3.0	16.7	4.3	8.2	10.2
Aspen	<i>Populus tremuloides</i>	1.4	4.2	3.2	2.9	3.5
Douglas-fir	<i>Pseudotsuga menziesii</i>	0.4	1.0	0.4	0.6	1.3
Limber pine	<i>Pinus flexilis</i>	0.6	0.1	0.0	0.2	0.2
Lodgepole pine	<i>Pinus contorta</i>	58.6	71.6	47.6	60.3	52.2
Spruce-fir	<i>Picea engelmannii</i> – <i>Abies lasiocarpa</i>	29.5	3.3	36.1	21.9	21.5
Ponderosa pine	<i>Pinus ponderosa</i>	0.0	0.0	0.0	<0.1	0.5
Water		0.3	0.2	0.1	0.2	0.4
Unclassified		3.0	0.0	2.1	1.7	1.7

### Study Area 1

Study area 1 comprised 375 km<sup>2</sup> of the MBNF. Lodgepole pine and Engelmann spruce (*Picea engelmannii*)–subalpine fir (*Abies lasiocarpa*) dominated, but stands of aspen and limber pine were scattered throughout (Table 1). Understory dominants in the lodgepole and spruce–fir stands included bear foods such as grouse wortleberry (*Vaccinium scoparium*), common juniper (*Juniperus communis*), buffaloberry (*Shepherdia canadensis*), and sedges (*Carex* spp.) (Irwin and Hammond 1985, Beck 1991). This area had been logged less extensively than areas 2 and 3.

### Study Area 2

Study area 2 was 353 km<sup>2</sup> and dominated by lodgepole pine but it supported scattered stands of aspen and spruce–fir. Shrubland habitat was common, and understory dominants included grouse whortleberry, buffaloberry, and sedges. Topography was mountainous and intersected with tributaries of the Laramie River.

### Study Area 3

Study area 3 was 264 km<sup>2</sup>. Lodgepole pine dominated, but this area had the highest proportion of spruce–fir habitat of the 3 areas. It also contained scattered stands of aspen and ponderosa pine. Understory dominants included grouse whortleberry, sedges, serviceberry (*Amelanchier alnifolia*), and snowberry (*Symphoricarpos* spp.). Several tributaries of the North Platte River crossed the area. Clearcut logging was common.

## METHODS

### Capture and Handling

We captured bears with foot snares and culvert traps and immobilized them with Telazol<sup>TM</sup> (Elkins-Sinn, Inc.,

Cherry Hill, New Jersey, USA) at a dose of 5 mg/kg estimated body weight (Gibeau and Paquet 1991). Bears >1 year of age received radiocollars (Advanced Telemetry Systems Incorporated, Isanti, Minnesota, USA) attached with cotton spacers to assure the collar would be dropped 2–3 years after attachment (Strathearn et al. 1984). We obtained a minimum of 1 relocation/week (ground or aerial) for each instrumented bear from time of capture to den entrance in 1994 and from den emergence or time of capture to den entrance in 1995 (Grogan 1997).

We attached an ear tag in 1 ear of each bear  $\geq 1$  year of age. Each ear tag was color-coded, numbered, and had 2 colored polyvinyl chloride (PVC) cloth streamers (25 mm x 127 mm) attached. Unique combinations of streamer and ear tag colors allowed identification of individual bears from photographs.

We extracted a vestigial premolar from each bear >1 year to estimate age (Willey 1974). Bears  $\geq 4$  years old were classified as adults, bears 1–3 years as subadults, and bears <1 as cubs-of-the-year. Cubs-of-the-year were not included in population or density analyses.

### Resighting Technique

We used infrared-activated game monitoring systems (TrailMaster, Lenexa, Kansas, USA) to resight (photograph) marked and unmarked bears. The resight system consisted of an automatic 35-mm camera, which recorded date and time of each photograph, controlled by an active infrared monitor and receiver. We used 36-exposure color print film (ASA 100). We hung 5–8 kg of meat scraps in a burlap bag at each site 3–4 m from the camera and above the ground in a position that a bear investigating the bait would break the infrared beam and trigger the camera.

We established camera sites in each study area at a density of 1 camera site/12–16 km<sup>2</sup>. We initially overlaid study areas with a 12-km<sup>2</sup> grid and chose a camera site in each block within forested habitat  $\geq 500$  m from any previous trap site and  $\geq 2$  km from any other camera site. We based camera site density on minimum home range size (32 km<sup>2</sup>) and movements of female black bears captured and monitored in the Snowy Range during 1994 (Grogan 1997). We felt this density would ensure that each bear using the study areas was exposed to  $\geq 1$  camera site during resight sessions. We checked camera sites weekly to replace film or bait as necessary; we did not move camera sites after establishment.

We conducted 2-week resight sessions in study areas 1, 2, and 3 from May to September 1995 and in area 3 in 1996. We separated resight sessions into 2-week intervals to better meet the assumption of population closure and to facilitate calculation of a mean population esti-

mate for each study area based on multiple resight sessions (Mace et al. 1994). Because we were limited to 50 camera systems, we sampled only 2 areas simultaneously in 1995.

We examined print photographs with an 8-power eye lens to determine if bears were marked or unmarked and to identify those with marks. If we could not determine whether a bear was marked or unmarked, the photograph was not included in analyses. Marked bears that could not be identified were classified as unidentified-marked sightings. We considered a marked bear available for resight during a 2-week session if it was relocated by telemetry at least once within the study area boundary during the resight session or if it was photographed during the resight session. To avoid counting multiple photographs of the same bear as separate sightings, consecutive photographs of the same bear (marked or unmarked) at the same site within a 24-hour period were treated as a single sighting. Because of the large variety of color phases and the low number of bears in the Snowy Range, we were confident we could identify individual unmarked bears revisiting the same site within a 24-hour period.

### Population and Density Estimation

We calculated population estimates with 95% confidence intervals for each 2-week resight session in each of the 3 study areas using program NOREMARK with Bowden's estimator (White 1996) from photographic records of marked and unmarked bears. Model parameters included: (1) number of marked animals available for resight, (2) number of marked animals sighted and number of sightings for each, (3) number of unidentified-marked animal sightings, and (4) total number of unmarked animal sightings (not to be confused with number of unmarked individuals; no attempt was made to count individual unmarked bears). Model assumptions included: (1) population closure, (2) marks were not lost between sampling periods or overlooked by the observer, and (3) marked individuals were representative of the population. To accommodate the closure assumption we used 2-week sampling periods and included only marked animals known to be in the study area during the sampling period in calculation of the population estimates. However, realizing the assumption of geographic closure would be difficult to meet, we calculated the proportion of telemetry relocations inside the study area boundary for each marked bear during resight sessions and used them to adjust density estimates (Woods and McLellan 1997). We checked ear tag retention during den visits each winter and replaced tags if necessary. We also radiocollared all marked bears, further minimizing the

probability of mis-identifying or not detecting marked bears. We intensively and evenly trapped each study area to obtain a representative sample of bears.

We estimated density with associated confidence intervals ( $\alpha = 0.05$ ) for each 2-week resight session in each of the 3 study areas using the population estimate and area of the respective study area. We compared density estimates from the 3 areas to each other with a 2-sample *t*-test ( $\alpha = 0.05$ ; MINITAB Inc. 1996). We computed a weighted mean density estimate (Sokal and Rohlf 1981:41) for each study area, weighted on the variance of each 2-week resight session's density estimate. We weighted the estimates with less variance heavier than those with higher variance, assuming that estimates with less variance were more accurate. We adjusted the weighted mean density estimate for each study area to compensate for violation of the closure assumption by multiplying the weighted mean density estimate by the average amount of time marked bears occupied the study area during resight sessions. We then calculated an average density estimate for the 3 study areas combined, weighted on the variance of each area's mean density estimate.

To evaluate the feasibility of trapping bears and gathering resight information in the same year, we conducted resight sessions the same year we trapped (not simultaneously) in study area 3 (1995) and re-sampled the area with 6 resight sessions in 1996 using the same camera

**Table 2. Black bear density estimates, weighted means, and adjusted means with 95% confidence intervals for resight sessions in the Snowy Range of southeast Wyoming, 1995.**

Study area	Resight session	Date	Density estimate (bears/100 km <sup>2</sup> )
1	1 and 2 <sup>a</sup>	6/30–7/27	7.20 (2.40–20.0)
1	3	7/28–8/10	4.27 (2.40–7.73)
1	4	8/11–8/24	4.80 (3.20–7.47)
1	5	8/25–9/7	3.73 (2.13–6.67)
1	6	9/8–9/22	3.73 (2.40–5.87)
1	1–6	Wt mean <sup>b</sup>	4.24 (3.46–5.02)
1	1–6	Adj mean <sup>c</sup>	3.73 (3.04–4.42)
2	1	6/22–7/5	2.83 (1.13–8.50)
2	2	7/6–7/19	2.27 (0.57–7.65)
2	3	7/20–8/2	1.70 (0.28–6.23)
2	1–3	Wt mean <sup>b</sup>	2.01 (1.38–2.46)
2	1–3	Adj mean <sup>c</sup>	1.75 (1.20–2.14)
3	1 and 2 <sup>a</sup>	8/6–9/3	3.03 (1.89–5.30)
3	3 and 4 <sup>a</sup>	9/4–9/17	2.65 (1.52–4.17)
3	4	Wt mean <sup>b</sup>	2.80 (2.00–3.60)
3	4	Adj mean <sup>c</sup>	2.63 (1.88–3.38)

<sup>a</sup> Resight sessions were combined as 1 resight session did not provide sufficient data to calculate a density estimate.

<sup>b</sup> Mean is weighted on the variance of the density estimate for each resight session.

<sup>c</sup> Weighted mean is adjusted by proportion of locations for marked bears within the study area boundary.

sites. We used a 2-sample *t*-test ( $\alpha = 0.05$ ) to compare 1995 and 1996 density estimates.

We estimated size of the Snowy Range black bear population in 1995 by extrapolating the weighted mean density estimate of the 3 study areas over the entire Snowy Range portion of the Medicine Bow National Forest and a 2-km buffer zone outside the National Forest. The buffer zone was included to encompass contiguous timbered habitat outside the Forest border as shown on aerial photographs and topographic maps.

## RESULTS

### Bear Captures

We trapped bears between 18 May and 30 September 1994 in areas 1 and 2. In area 1 we captured 8 bears 10 times in 393 trap nights, and in area 2 we captured 11 bears 13 times in 472 trap nights. We captured 7 bears 15 times in study area 3 during 20 May–15 July 1995 (296 trap nights).

### Resight Sessions

Our cameras took 2,586 photographs in 1995; 1,704 (66%) were of bears. In area 3 during 1996 our cameras took 2,130 photographs; 1,165 (55%) were of bears. Bear photographs in 1995 included 82 sightings of marked bears (18 different bears), 3 sightings of unidentified-marked bears and 113 sightings of unmarked bears. The proportion of radiolocations of marked bears within study area boundaries during resight sessions averaged 87% (SD = 6.43), 88% (SD = 13.11), and 94% (SD = 10.04) for areas 1, 2, and 3, respectively, during 1995. Ear-tag retention was 85% and 90% during 1994 and 1995, respectively.

### Population and Density Estimates

We estimated the highest black bear density in study area 1 during the first 2 resight sessions and estimated the lowest density in area 2 during resight session 3 (Table 2). Black bear density was greater in study area 1 than study area 2 ( $t_5 = 3.43$ ,  $P = 0.02$ ) or study area 3 ( $t_4 = 2.84$ ,  $P = 0.05$ ). Bear densities in study areas 2 and 3 were not different ( $t_2 = -1.52$ ,  $P = 0.27$ ). The weighted mean density estimate of the combined study areas in 1995 was 2.54 bears/100 km<sup>2</sup> (95% CI = 2.11–2.97).

The mean adjusted density estimate for study area 3 in 1996 (2.70 bears/100 km<sup>2</sup>; 95% CI = 2.33–3.06) and 1995 (2.63 bears/100 km<sup>2</sup>; 95% CI = 1.188–3.38) did not differ ( $t_5 = -0.36$ ,  $P = 0.74$ ). Despite the difference in sampling effort (4 resight sessions in 1995 and 6 in 1996),

coefficients of variation of confidence intervals were similar: CV = 0.16 and 0.17 for 1995 and 1996, respectively.

Although the 3 study areas differed in vegetative composition, the combined proportionate composition was similar to that of the entire Medicine Bow National Forest (Table 1), supporting our extrapolation of the mean density estimate of 2.54 bears/100 km<sup>2</sup> to the entire Snowy Range. We estimated 70 bears occupied the Snowy Range (MBNF plus 2-km buffer = 2,742 km<sup>2</sup>) during 1995.

## DISCUSSION

We estimated the Snowy Range supported 70 black bears during 1995, at a density of 2.54 bears/100 km<sup>2</sup> (95% CI = 2.11–2.97). Black bear density in the Snowy Range was 68% lower than in north-central Colorado (8 bears/100 km<sup>2</sup>), the lowest reported density in the mountains of western North America. Other estimates of density in the western mountains include 80 bears/100 km<sup>2</sup> in Idaho (Beecham 1980), 36 bears/100 km<sup>2</sup> in north-west Colorado (Beck 1995), 20–50 bears/100 km<sup>2</sup> in Montana (Jonkel and Cowan 1971), and 12–16 in west-central Colorado (Beck 1991). Although we believe our density and population estimates to be accurate, capture–recapture or capture–resight estimates can be subject to biases.

Marked bears may be less attracted to baits and less likely to be photographed than unmarked bears because of the capture experience. This would cause population estimates to be inflated. However, all marked bears available for resight during resight sessions in this study were photographed at least once, suggesting there was little avoidance of camera sites due to capture experience. This possible error may be reduced by using different techniques for capture and resight (e.g., using hounds for initial capture, and baits for resighting). Bears that avoid baits or have reduced movements so that they rarely encounter baits may not be captured or resighted, resulting in an underestimate of population size. We saturated each study area with traps to maximize the probability of encounter for all bears present. We also set camera sites at such a density that each bear would have a good chance of encountering  $\geq 1$  camera/resight session. Further, we estimated the expected number of females with cubs (the only uniquely identifiable cohort of unmarked bears) in 1995 based on the composition of our capture sample (Grogan 1997) and the population estimate of 70 bears and compared it to the actual number of females with cubs captured and photographed. We estimated 2.5 females with cubs within the study areas in 1995. We captured 1 and photographed 2 others, implying that this

cohort was not underestimated because of its reduced movements or wary behavior.

In addition, population size may be underestimated if different unmarked bears revisiting a camera site within a 24-hour period are treated as the same individual. We were confident in identifying individual unmarked bears within a 24-hour period because of the variety of color phases and low numbers of bears in this population. Also, by combining only consecutive photographs of a bear into a single sighting, the chance of recording  $\geq 2$  bears of similar color and size as a single sighting is reduced. However, when applying this technique in areas with higher bear density or little variation in color phases of bears, the time interval used to combine photographs of bears of similar color and size into a single sighting may need to be reduced. Another possibility may be to combine consecutive photographs of bears into a single sighting when groups of photographs are separated by a certain time. For example, if you chose 3 hours as the time interval, a group of consecutive photographs would be combined into a single sighting when separated from the next photograph by  $\geq 3$  hours. This interval could be chosen *posthoc* by calculating the average time between visits to a single camera site by marked bears.

The capture–resight method we used provided density estimates with reasonable precision (CV = 0.15). Our single comparison suggested that capture and resight efforts may be implemented in the same year with similar results as when capture and resight are done in separate years. Advantages of capturing and resighting bears in the same year include a reduction in labor and transportation expenses and reducing variation from 1 year to the next due to environmental conditions. Application of same year capture–resight efforts may be less appropriate in areas with high abundance of soft or hard mast crops as the technique relies on bears visiting bait sites, and bears may be less attracted to baits when natural foods are abundant. We conclude that this capture–resight method is an effective tool for estimating density and population size of low-density black bear populations.

## ACKNOWLEDGMENTS

We thank C.R. Anderson, J.D. Clark, and anonymous reviewers for review comments. Funding was provided by the Wyoming Game and Fish Department, and research was conducted through the U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, in cooperation with the U.S. Forest Service. Thanks to D. Carrol, B.L. DeBolt, J.C. Harper, H.J. Harlow, M. Hooker, J.H. Koloski, I.

Messinger, R.A. Olson, J. Mastel, D.S. Moody, K.M. Rompola, and M. Sanders for their assistance.

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