An Evaluation of Two Censusing Techniques to Estimate Black Bear Population Size on White River National Wildlife Refuge, Arkansas

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Abstract: Expansion of the black bear (*Ursus americanus*) population outside White River National Wildlife Refuge, Arkansas, has caused local citizens to request reduction of the population. An estimate of black bear population size is necessary before any management recommendations can be made. We used 2 census methods to estimate population size. Hunter surveys of bear sightings during the 2-day firearm deer hunt were used in 1994 to estimate population size with a Petersen-Lincoln estimator. The survey yielded a population estimate of 213 bears (95% CI = 129–297). We used cameras triggered by infrared monitors to photograph bears visiting bait sites over a 7-day period during August 1995. Infrared monitors recorded 176 events, resulting in 87 photographs of 23 different bears. We used 2 separate models to calculate population sizes using data from cameras. Program CAPTURE calculated a population size of 348 (95% CI = 300–396) bears for the refuge. A Minta-Mangel mark-resight model calculated a population size of 464 (95% CI = 348–638) bears for the refuge. The hunter survey population estimate was low even with the probable violation of the assumption that tags were not lost. Population estimates based on the photographs were different because the actual number of bears on the study area of sampling is unknown. Problems with the hunter survey and Minta-Mangel population estimates provided evidence that the program CAPTURE population estimate is the most reliable.

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The black bear, which once inhabited the entire southeastern United States, has been reduced to areas of remnant habitat (Maehr 1984, Wooding et al. 1994). In

Arkansas, bears were extirpated from the state by 1910, except for a small remnant population in southeastern Arkansas now managed as White River National Wildlife Refuge (WRNWR) (Smith et al. 1990). A 1942 estimate placed the WRNWR bear population at 40–50 individuals (Smith et al. 1990) and by 1980, the population had increased to 130 (Smith 1985). Private hunting clubs near WRNWR reporting bears doubled in number from 1984 to 1994 (White et al. 1995). Recently, bear damage to agricultural crops and personal property in areas surrounding WRNWR has increased to the point that local residents are requesting a reduction in bear numbers. A better understanding of the population density on WRNWR is necessary before any program mitigating damage can be recommended. In addition, data collected by Miller (1995) suggested that this population may be genetically similar to the Louisiana black bear (*U. a. luteolus*), which is a federally threatened subspecies.

A bait station survey is used on WRNWR to monitor trends in the population, but no estimate of the population size is obtained (Miller 1993). Capture-recapture has been used frequently to determine population size in black bears, but often assumptions are not met or small sample sizes are a problem (Lindzey 1982). Mace et al. (1994*b*) used a mark-resight model to estimate grizzly bear (*U. arctos horribilis*) population size. Mark-resight models do not require actual recapture and allow for heterogeneity of sighting probabilities, often an advantage over capture-recapture models.

The main objective of our study was to test the feasibility of using cameras triggered by infrared monitors to census black bear populations. In addition, we investigated the feasibility of using data from hunter surveys to assess population size. The actual population size on WRNWR is unknown, thus accuracy of each method is difficult to assess. However, addressing possible biases can lead to a better understanding of the applicability of these methods.

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Methods

Study Area

The 62,700-ha WRNWR is located in eastern Arkansas and extends 87 km along the lower White River. It is composed primarily (85%) of bottomland hardwoods with bayous and sloughs comprising the remainder (15%). Dominant overstory species include nuttall oak (*Ouercus nuttallii*), overcup oak (*O. lyrata*), sugarberry (*Celtis* *laevigata*), green ash (*Fraxinus pennsylvanica*), and black willow (*Salix nigra*) (Smith 1985). Prominent understory species include poison ivy (*Rhus radicans*), dewberry (*Rubus* spp.), greenbriar (*Smilax* spp.), and swamp privet (*Ligustrum acuminata*) (Smith 1985). The refuge is surrounded by agricultural land planted primarily in soybeans, rice, cotton, and winter wheat (Smith 1985). Topography is generally flat with poorly drained clay soils. Annual precipitation averages 128 cm and the climate is characterized by hot, humid summers and mild winters (Smith 1985).

Bear Capture and Monitoring

Twenty-five bears were captured with Aldrich foot snares during 1993–1994. Each captured bear received ear-tags and a radio-collar (Advanced Telemetry Systems, Inc., Isanti, Minn.), and was released at the capture site. Bears were located at least monthly as part of an ongoing research project. Twenty and 19 bears were transmitting during 1994 and 1995, respectively.

Hunter Survey

A restricted gun hunt for white-tailed deer (*Odocoileus virginianus*) is conducted each year on WRNWR. When hunting permits were issued in 1994, hunters were requested to report bear sightings. After the completion of the hunting season, hunters who reported a bear sighting were sent a questionnaire, which requested information on number of bears, number of groups of bears, and number of marked bears seen. Additionally, a refuge map was provided to record the location of each bear sighted.

Infrared Monitors and Cameras

Bait stations baited with fish were used to attract bears for resighting. Seven bait stations were established in the southeastern quarter of the refuge, where collared bears were captured, and monitored in August 1995. Locations for the stations were determined by placing stations near the White River and in areas that were accessible. Stations were placed in these areas because most capture attempts and collared bears were in these areas. Each station was prebaited for 2 days with 15–25 kg of fish/day. After the prebaiting period, stations were monitored for 7 days. Five Trail Monitor passive infrared monitors (Gryphon Eng., Richmond, Mich.) and 2 Trailmaster active infrared monitors (Goodson & Associates, Inc., Lenexa, Kans.) attached by a remote release cable to cameras (Olympus Infinity Twin) were used to photograph bears visiting bait sites. Passive monitors and cameras were mounted 3 m above ground on the bole of a tree to prevent bears from damaging monitors or cameras, and pointed at the bait site. Active monitors were camouflaged with sticks and aligned over the center of the bait pile. Stations were checked daily to replenish bait and film, and to record events from monitors. Infrared monitors were triggered by a combination of heat and motion which resulted in an event being recorded in the memory of the monitor. Time and number of events were recorded from monitors daily. Cameras were set with a 2-minute delay between photographs to prevent excessive photographs of any bear.

A bear was counted as sighted only once within a 24-hour period. Extra photographs were used to help differentiate individual bears. If family groups were observed, cubs were not included in analyses. Body size, color, pelage patterns, and unique marks (including tags if present) were used to identify individual animals. All photographs were analyzed by 2 researchers (Bowman and Chamberlain). To test researcher identification of bears, 10 photographs were randomly selected and shown to 20 reviewers, many with little or no bear experience. These reviewers were asked to identify the bears to determine if their identification matched that of the original 2 researchers.

Data Analysis

Three population estimates were calculated. Hunter survey data were analyzed with a Petersen-Lincoln estimator (White et al. 1982) and a sample of 20 marked animals. Photograph data were analyzed with both program CAPTURE and the Minta-Mangel estimator (White et al. 1982, Minta and Mangel 1989). Program CAPTURE includes a Petersen-Lincoln based estimator with models for biases from behavior, time, and heterogeneity of capture probabilities (White et al. 1982). A bear was not considered to be marked until its photograph was taken and was "recaptured" by photography during a successive sample period (day). We assumed that all bears could be identified by body size, color, pelage pattern, and unique marks. The Minta-Mangel estimator is a mark-resight model (Minta and Mangel 1989). Nineteen marked animals were used for this analysis. Due to radio-telemetry failure, the exact number of marked individuals on the study area could not be determined. Thus, 19 radio-collared bears known to be alive 2 weeks before that sample period and verified as alive after the study were used as the marked sample size.

Effective sample area of our design varied by method. We assumed that we sampled all of WRNWR for the Petersen-Lincoln estimate derived from hunter surveys. For the infrared monitors with camera data, we realize that varying the effective sampling area of our design substantially changes our population estimates. Thus, we calculated several population estimates based on various sampling areas. However, for data comparison purposes, we assumed camera coverage/site to equal the average summer home range size of females (1,040 ha) on WRNWR (Smith 1985). One site was not included in the analysis because of equipment failure.

Results

The hunter survey was mailed to 306 permit holders who reported sighting a bear while hunting during the 2-day firearm deer season. Two hundred fifteen surveys (70%) were returned. Respondents sighted 365 bears, but 120 sightings were discarded because the bears were reported as "too far to tell if marked." Twenty-three marked bears and 222 unmarked bears were sighted, yielding a Petersen-Lincoln estimate of 213 bears on WRNWR with a 95% confidence interval of 129–297 bears. The estimated density of bears on WRNWR was 0.34 bears/km^2 with a 95% confidence interval of 0.21–0.47 bears/km^2.

One of the passive infrared monitors malfunctioned during the sampling period and data from that bait station was discarded from the analysis. Of the 176 events recorded, 151 resulted in photographs and 87 of those contained a bear in the photograph. Twenty-three individual bears were identified, 7 were radio-collared animals. The precision test of photograph identification resulted in 98% of the photographs being identified equally to the identification made by the original 2 researchers. Program CAPTURE found a bias due to behavior and calculated population size based on a model corrected for a behavioral response (White et al. 1982). The resulting density estimate was 0.56 bears/km^2 (348 bears refuge-wide) with a 95% confidence interval of 0.48–0.63 bears/km^2 (300–396 bears refuge-wide). The Minta-Mangel estimator yielded a higher density estimate of 0.74 bears/km^2 (464 bears refuge-wide) with a 95% confidence interval of 0.56–1.02 bears/km^2 (348–638 bears refuge-wide).

Discussion

Hunter surveys assumed that hunter distribution and effort were the same across the entire refuge. This assumption was necessary because all hunters had to have the same chance to see a marked or unmarked bear. However, access varied throughout the refuge and may have affected hunter density. In addition, we assumed that bear densities were constant throughout the refuge. Maps attached to the questionnaire allowed us to locate sightings. Bears (marked and unmarked) were sighted throughout the refuge, but most sightings occurred in the southern half of the refuge, which violated the assumption of bear densities being equal throughout the refuge.

Another important assumption is that tags were noted when a bear was observed. Hunters did not know what to look for, thus a hunter may see a bear without seeing its tag or collar. The probable violation of this assumption alone poses serious questions as to the validity of this method. Additionally, violation of this assumption would bias the population estimate upward and this method already produces the lowest population estimate. We assumed both demographic and geographic closure. Demographic closure was assumed because of the extremely short sample period. Geographic closure was assumed because collared bears usually remained on the refuge during this time period (T. H. White, unpubl., data).

The estimate derived from program CAPTURE was based on 3 assumptions. Because of the short duration of the sample period, we were able to assume demographic closure. Geographic closure could not be assumed. The assumption of equal probabilities of capture was addressed using a model corrected for behavior. This model accounts for trap-happy and/or trap-shy animals. Trap-happy animals appeared to be a problem because of the fish reward. We allowed a reward in contrast to Mace et al. (1994*b*). The reward of fish allowed an increased opportunity for photographs. Bears would take a fish from the bait pile and carry it away to eat it. Bears returned for more fish a few minutes later which allowed enough time to elapse so another photograph would be taken. Multiple photographs, often from several different angles, greatly aided in identifying individual bears. The assumption that tags were not lost, was probably true because of the short duration of the study. The precision test of photograph identification provided strong evidence that we could identify individual bears correctly.

The Minta-Mangel estimator assumed a closed population and no tag loss while allowing for heterogeneity of capture probabilities (Minta and Mangel 1989). A demographically closed population is assumed because of the short duration of the sample period. However, geographic closure was violated because all marked bears may not have been available for sampling. This violation caused the population estimate to be biased upward. Also, all bears sighted that had been captured prior to the sample period ($N = 7$) had ear-tags in each ear, suggesting no tag loss.

Differences in estimators for the cameras triggered by the infrared monitor data can be explained. The Minta-Mangel estimator was based on total number of marked animals in the population, which probably were not all available for sampling. Thus, by overestimating the marked individuals in the population available for recapture, we artificially inflated the population estimate. The program CAPTURE estimator is probably more valid because it is based only on animals "captured" during the sample period. The camera triggered by the infrared monitor method could be improved in the future by placing cameras in a grid pattern similar to Mace et al. (1994*b*). Additionally, if radio-telemetry is used to determine which marked animals actually are present on the study area during the sample period, the program CAPTURE and Minta-Mangel estimators should be similar.

Assuming geographic closure was a problem for both the Program CAPTURE and Minta-Mangel estimators. Actually, geographic closure is a function of the effective sample area of our design. Over- or under-estimating our sample area would cause a violation of geographic closure. Estimates were calculated based on 5 different effective sampling areas, so that the reader could decide which is most appropriate (Table 1). Mace et al. (1994*a*) estimated grizzly bear population size based on cameras placed in a grid pattern of 12.5–20 km/camera and found that this density of cameras was not sufficient to photograph all bears within the sampling area. Further, Jacobson et al. (1997) reported that as the effective sample area of the grid decreased, precision of population estimates increased. Thus, future research should focus on determining optimal effective sampling area.

Several problems encountered during this study need to be refined to improve

Table 1. Black bear population estimates at different effective sample areas on White River National Wildlife Refuge, Arkansas, 1994–1995.

Assumed sampling area (ha)	Assumption involved (Summer home range)	Population estimate (95% CI)[a]	Density estimate (95% CI) (bears/km^2)[a]
3,540	Subadult female	640 (552–727)	1.02 (0.88–1.16)
	No site overlap	853 (640–1166)	1.36 (1.02–1.86)
6,240	Adult female	348 (300–396)	0.56 (0.48–0.63)
	No site overlap	464 (348–638)	0.74 (0.56–1.02)
28,000	Weighted mean	81 (69–94)	0.13 (0.11–0.15)
	Site overlap	107 (81–150)	0.17 (0.13–0.24)
58,200	Adult male	38 (31–44)	0.06 (0.05–0.07)
	Site overlap	50 (38–69)	0.08 (0.06–0.11)
61,800	Subadult male	38 (31–44)	0.06 (0.05–0.07)
	Site overlap	50 (38–69)	0.08 (0.06–0.11)

[a]Top estimates are based on Program CAPTURE and bottom estimates on Minta-Mangel (1989).

the accuracy of the estimates based on data from cameras triggered by infrared monitors. Large amounts of bait are needed to use this method on a large scale. Mace et al. (1994*b*) hung bait above the bait site, which reduced the amount necessary. Future research should investigate using a combination of bait piles and hanging bait. Using less bait on the ground would allow a reduction in bait consumption. By hanging baits, an attractant would still be available should all bait on the ground be consumed. Another problem encountered was the infrared monitors. Sunlight and the resulting heat may cause reduced sensitivity of a monitor to the body heat of a bear. Placing monitors in areas with full canopy closure may reduce problems with sunlight.

Management Implications

Other researchers have shown the effectiveness of using infrared cameras for censusing populations of grizzly bears (Mace et al. (1994*b*) and white-tailed deer (Jacobson et al. in press). We demonstrated that this method may be effective in estimating population size of black bears. Identification of individual bears by physical characteristics was a benefit of this method; bears did not have to be marked, thereby reducing cost. Thus, infrared monitors can yield population estimates without the cost of capture or violation of the model assumptions.

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