Population estimate of black bears (*Ursus americanus*) in Crater Lake National Park using non-invasive methods

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Introduction

Several non-invasive methods have recently been developed to estimate population size of uncommon or reclusive species. These approaches provide many advantages over traditional methods of abundance that either do not provide estimates of true population parameters (e.g. uncorrected visual surveys, track counts, scat counts), are expensive and labor intensive (capture-mark-recapture, radiotelemetry, satellite telemetry), or require harvest of a substantial number of individuals (population reconstruction). In order to obtain accurate estimates with non-invasive methods, however, it is important to use sampling methods that are unbiased and provide sufficient information to examine all potential sources of variation in detection probabilities. In this report, I examine data collected from a hair-snare survey conducted in to estimate the population size of black bears (*Ursus americanus*) in Crater Lake National Park. In addition, I provide recommendations to improve estimates in future surveys.

Methods

The overall sampling design was excellent given fiscal and time constraints. The spacing between the sample locations (2.5 km) was based on information on bear home-range size in the region coupled with recommendations from White (1982). Sites were not sampled if human habitation was present near the sampling location. The sampling design resulted in 75 sites that and included the entire park (approximately 741 km^2) (Holm 2009). Samples were collected during three, three-week periods from July-August 2009. Approximately one third of the sample locations were checked each week until all of the locations had been visited. Hair was collected at each site using a snare system that increased the probability of obtaining sufficient hair from each bear and reduced the chances of obtaining hair from more than one bear (Immel and Anthony 2006). Although only one sample was obtained during the first sampling period (Holm

2009), capture rates increased considerably during the second and third sampling periods when 13 and 20 individuals were identified from hair samples.

Data were analyzed using the Huggins Closed Capture model in program MARK (White and Burnham 1999). Sex was included as a grouping variable in the analysis. Because of the small sample size and limited number of sampling occasions, I only considered models with three or fewer parameters. Models that included heterogeneity in capture probabilities could not be considered because there were insufficient capture occasions (at least five capture occasions are needed). Models were ranked by Akiake's Information Criteria corrected for small sample size (AIC_c). Model names and abbreviations follow Otis et al. (1978). The model set included the null model with no variation in capture probabilities (M_0), variation in capture probabilities over time (M_t), variation in capture probability based on capture history (termed behavioral variation M_b), and variation in capture probability between sexes (gender variation M_g). Because the top model was strongly supported, only parameter estimates from the top model were considered.

Results

The time variation model (M_t) was strongly supported by the data, none of the other models received sufficient support to be considered competitive (Table 1). Capture probability increased dramatically from the first occasion to the second and third occasions (Table 2). The estimated number of males in the population was 12 (95% CI 9-25), the estimated number of females was approximately 2.5 times greater (29, 95% CI 22-52) (Table 2).

Discussion

Despite the limited effort, the hair samples provided sufficient data to get a reasonable estimate of the number of black bears in Crater Lake National Park. The estimate (41, 95% CI 31-72) was considerably higher than the minimum estimate obtained using the number of different individuals identified using genetic analysis (27). The model that included time variation in capture probability was strongly supported, which is not surprising given the low capture probability on the first occasion. Capture probability increased dramatically on the second and third occasions.

Because of the limited number of sampling occasions, the power to identify other sources of variation in capture probabilities was extremely low. Other studies of both black bears (Immel and Anthony 2006) and grizzly bears (*Ursus arctos*) (Boulanger et al. 2002) have indicated that capture probabilities are influenced by both behavioral variation and heterogeneity when using sampling methods similar to those used in this study. When capture heterogeneity (variation in the capture probability among individuals in the population) is present and is not accounted for in closed population models, population size is underestimated (White et al. 1982). The close proximity of sampling stations, however, likely reduced capture heterogeneity in this study. Heterogeneity becomes more severe when sampling locations are far apart relative to the home-range size of the bears. Behavioral variation can also bias estimates of population size. When animals are “trap happy” (recapture probability is greater than initial capture probability) population size is underestimated. Trap shy behavior (initial capture probability is greater than recapture probability) causes population size to be overestimated when it is not accounted for in the estimator (White et al. 1982). Bears generally show a “trap happy” response to the types of hair snares used in this study (Immel and Anthony 2006). Thus the combination of a “trap happy” behavioral response and possible capture heterogeneity likely resulted in an underestimate of the bear population. In order to identify whether capture heterogeneity or behavioral responses were occurring in this population, more capture occasions would be needed.

Another potential problem associated with estimating population size in far-ranging animals like black bears is violation of the closure assumption (Boulanger et al. 2002). The spatial extent of the sampling grid in this study was substantially smaller than other studies of bear populations (Boulanger et al. 2002), likely causing a substantial violation of the closure assumption. Because the objective was to estimate the number of bears within the park boundaries, the only way to address this problem would be to radio-collar bears in and adjacent to the park to assess the proportion of time that individuals spend within the park boundary. This information could then be used to adjust the population estimate to account for movement across the park boundary (Kendall et al. 2008).

Recommendations for future studies

If similar studies are conducted in the future, I recommend that the number of sampling occasions in a season be increased to five to allow examination of models that include behavioral variation and heterogeneity in capture probability. If resources are insufficient to increase the number of sample occasions, consider decreasing the number of sampling locations so that the stations can be sampled more frequently. If unbiased estimates of bear density are desired, CMR techniques should be combined with radio-telemetry to address the closure assumption.

Literature Cited

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Table 1. Comparison of closed population models used in analysis of black bear hair samples collected in Crater Lake National Park in 2009. See text for descriptions of each model. Models are ranked by AICc score.

Model Description	Parameter Constraints	AIC_c[1]	Delta AIC_c[2]	Model Likelihood[3]	AICc Weight[4]	k[5]	Deviance[6]
Time variation (M_t)	p(t)=c(t)	71.10	0	1	0.999	3	105.12
Behavioral variation (M_b)	p(.) c(.)	84.21	13.10	0.001	0.001	2	120.38
Constant (M_0)	p(.)=c(.)	93.62	22.51	0	0.000	1	131.90
Gender effect (M_g)	p(g)=c(g)	95.72	24.61	0	0	2	131.89

1- Akiake's Information Criteria corrected for small sample size.
2- Difference in AICc score from top model.
3- The likelihood of the model given the data, computed as $\exp(-0.5*\Delta AICc)$.
4- Relative likelihood of the model given the other models in the data set. Computed as the likelihood of the model divided by the likelihood of all models in the model set.
5- Number of parameters in the model.
6- Squared deviance between observed values and predicted values.

Table 2. Parameter estimates of capture probability and population size of black bears in Crater Lake National Park in 2009. Estimates are from the time variation model (M_t).

Parameter	Estimate	SE[1]	Lower 95% CI	Upper 95% CI
Capture prob. time 1	0.02	0.02	0.00	0.16
Capture prob. time 2	0.32	0.10	0.16	0.54
Capture prob. time 3	0.49	0.13	0.25	0.73
No. Males	12	3.4	9	25
No. Females	29	6.8	22	52
Total Population	41	9.1	31	72

1- Standard error of estimate.