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Monitoring rare or elusive large mammals using effort-corrected voluntary observers

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ABSTRACT

Populations of rare or elusive large mammals are difficult to monitor, because they usually are secretive, solitary, occur at low densities, and have large home ranges. The global trend of generally decreasing large carnivore populations necessitates new, feasible, reliable, and cost-effective monitoring methods. We evaluate an index method developed for monitoring populations of moose (*Alces alces*) based on voluntarily and systematically collected observations from hunters, corrected for effort, for use in monitoring populations of large carnivores in Sweden. For our evaluation, we used independent estimates of minimum brown bear (*Ursus arctos*) densities from DNA-based scat surveys and brown bear distribution from mandatory reports from successful bear hunters. We verified that the index correctly reflected bear distribution. We also found strong linear relationships between the indices and the independent density estimates for bears at the scale of local management units (about 1000–2000 km^2) in all three regional study areas (adjusted R^2 = 0.88–0.60). Our results suggest that systematic, effort-corrected reports of observed animals can be an alternative and accurate monitoring method for the conservation and management of large mammals occurring over large areas when large numbers of willing volunteers are available (effort >30,000 h).

1. Introduction

Monitoring can be defined as the process of gathering information about variables in some systems, such as a population, at different points in time and space to characterize their status (Yoccoz et al., 2001). Density and distribution are considered key parameters for the conservation and management of most animal species (Wilson and Delahay, 2001). Large carnivores are typical examples of rare and elusive mammals that are vulnerable or endangered with declining habitat or numbers (Weber and Rabinowitz, 1996; Gittleman and Gomper, 2001). Their secretive characteristics and low

abundance make monitoring a difficult task for this group (Kendall et al., 1992; Linnell et al., 1998; Thompson, 2004).

Although there are many available methods for monitoring (Schwarz and Seber, 1999; Williams et al., 2002), few are suitable for low-density mammals or other elusive species (Mills et al., 2000). Many of these methods either are too expensive or not suitable to cover large areas, at least on a regular basis (Link and Sauer, 1997; Schwarz and Seber, 1999; Zhou and Griffiths, 2007). Because it normally is difficult to determine absolute densities, managers often must rely upon indices to determine abundance and trends (Eberhardt and Simmons, 1987; Skalski et al., 2005). When detection

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probability is unknown, counts are normally treated as indices. Indices are usually cheaper than other methods of monitoring trends, and can be very useful for managing populations, if they accurately reflect relative abundance. Several studies have shown that indices can be highly correlated with abundance (Hochachka et al., 2000; Slade and Blair, 2000; Wilson and Delahay, 2001; Romain et al., 2004), but indices also have received much criticism (Anderson, 2001).

In Scandinavia direct or indirect observations of primarily family groups, and snow tracking, have been used to monitor lynx (*Lynx lynx*) and wolf (*Canis lupus*) populations (Andrén et al., 2002). These methods are often time consuming, costly, may have serious biases, and/or rely on favorable weather conditions (Elgmork, 1991; Linnell et al., 1998; Andrén et al., 2002). Analyses of standardized observations of female brown bears (*Ursus arctos*) with cubs made by approved observers have been used successfully to estimate the minimum population size and population growth rate in the Yellowstone Ecosystem, USA (Knight et al., 1995; Eberhardt and Knight, 1996; Mattson, 1997; Keating et al., 2002; Harris et al., 2007; Schwartz et al., 2008). However, Solberg et al. (2006) evaluated observations of female brown bears with cubs that were reported by the general public (i.e., not an organized effort) to the hunters' organization in Sweden and found that it greatly underestimated the population size. Solberg et al. (2006) considered compiling unorganized reports of females with cubs by the general public, as practiced in Sweden, to be inadequate for population monitoring. In addition, brown bear litter sizes reported by the general public in Sweden were lower than those documented in the same area by researchers (Zedrosser and Swenson, 2005).

A simple, straight-forward method, such as observations combined with a measure of effort, has been used to monitor moose (*Alces alces*) populations since the mid-1970s in Norway, mid-1980s in Sweden, and in parts of North America (e.g. Ericsson and Wallin, 1999; Solberg and Sæther, 1999). Substantial research effort has been invested in testing and verifying the theoretical and the practical assumptions of observation indices. For example, we know that effort-corrected observations of moose accurately, and linearly, reflect annual reproduction or recruitment (Fryxell et al., 1988; Crête and Courtois, 1997; Ericsson and Wallin, 1999; Solberg and Sæther, 1999; Sylvén, 2000).

A similar method could potentially give valuable information about population size, distribution, and trends of large rare or elusive mammals (i.e., large carnivores). Although Elgmork (1991) and Swenson et al. (1994) suggested using effort-corrected bear observations collected by hunters during moose hunting as a method for estimating relative densities of bears that was independent of harvest data, the applicability of this method remains to be verified with independent data.

The large carnivore observation index (LCOI) was introduced in Sweden in 1998 as an add-on module to the nationwide monitoring program for moose (Linnell et al., 1998). During the first 7 days of the moose hunting season (during September–October), hunters register observed large carnivores (i.e., brown bears, lynx, wolves, and wolverines [*Gulo gulo*]) and the total observation effort in hours. We evaluate the general applicability of these systematically and effort-corrected observations as a means of monitoring populations of large rare or elusive mammals. As a case study, we use observations of brown bears from the LCOI program in Sweden. We focus on two central questions; can the LCOI be used as an accurate index of the density and of the spatial distribution of brown bears? We test these questions using independent data from on-going research and management.

2. Materials and methods

2.1. Study areas

We used data from the provinces (län) in Sweden with established bear populations and with available independently collected density estimates (Fig. 1). We analyzed data at the scale of the local management unit (LMU), which is the scale where hunters collect data and implement general wildlife management strategies decided by the regional authorities. A LMU usually consists of $\geqslant 1$ parishes within a municipality or an en-
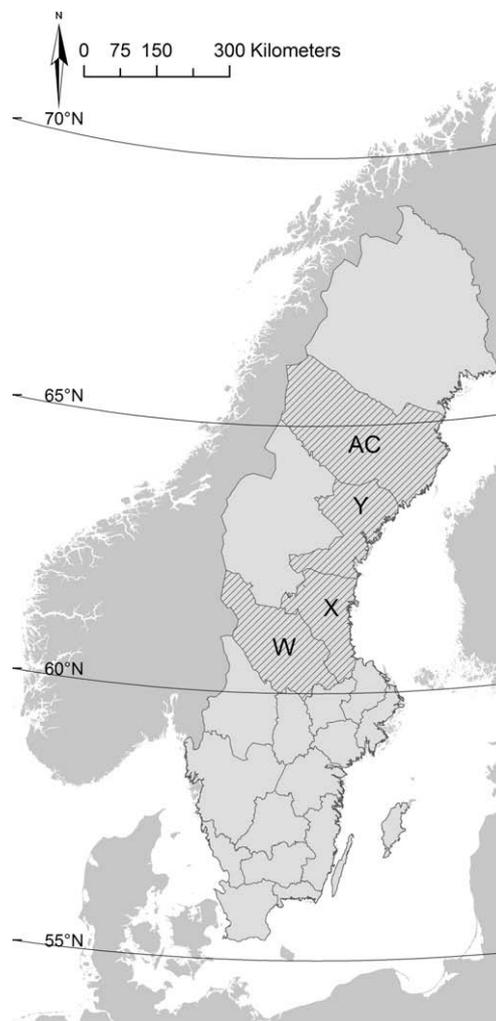

Fig. 1 – The map of Sweden (light gray) showing province (län) borders. The large carnivore observation index data for brown bears used in this study were from the provinces marked with hatched lines; Dalarna (W), Gävleborg (X,) Västernorrland (Y), and Västerbotten (AC).

tire municipality. The study provinces were Dalarna and Gävle-borg (combined), with 48 LMUs and an area of 47,747 km^2 (mean size of 995 ± 831 km^2 (SD), Västernorrland with 19 LMUs and 21,499 km^2 (1131 ± 582 km^2), and Västerbotten with 21 LMU and 54,002 km^2 (2572 ± 1615 km^2). Reported areas are the areas available for moose hunting (primarily forest), with a smaller adjustment in Västerbotten to remove inaccessible mountain areas without observations or scat sampling.

The habitat consists mostly of managed boreal forest, mainly coniferous, and an increase in alpine areas towards the western border to Norway. The road network is well developed and the area has a generally low human population density (4.7–15.2 inhabitants/km^2 in the study provinces). For a more detailed description of the habitat see Dahle and Swenson (2003).

2.2.　*The large carnivore observation index*

The LCOI methodology is simple and easy to use, with its basic design following that of Ericsson and Wallin (1999) and Solberg and Sæther (1999). In Sweden the management authorities use the about 200,000 organized moose hunters to voluntarily monitor large carnivores. Moose hunters usually hunt together in a stable party and rent a specific hunting area for many years (Thelander, 1992; Heberlein, 2000). The season starts in September or October depending on province, and is conducted during the daytime from one hour before dawn to 1 h before dusk. During the first 7 days the moose hunters are hunting, they record all sightings of moose, in addition to those of brown bears, wolves, lynx and wolverines. The reports record sightings of young-of-the-year and older animals, length of daily hunting activity in hours, and numbers of hunters, all by hunting unit and day. From this, we calculated an index (observations per 1000 h). The LCOI allows almost national coverage, as moose are hunted over practically all of Sweden and in all bear habitat except for national parks. This program generates around 4.5 million observation hours yearly (J. Kindberg, unpublished data) with about 2.5 million hours in the areas with bears and an average of around 1000 bear observations annually.

2.3.　*Independent data*

The independent data on brown bear distribution and population size come from population estimates based on the DNA-based identification of individual bears from hunter-collected bear scats in the provinces of Dalarna and Gävleborg in 2001 (Bellemain et al., 2005) and from similar surveys in Västerbotten and Västernorrland provinces in 2004 (Bellemain, 2005; Kindberg and Swenson, 2006) (Table 1, Fig. 1). The participating hunters were primarily moose hunters who collected scats throughout the entire provinces during the entire fall hunting season. Thus, the sampling included areas where bears were rare and areas where bears were relatively numerous (Bellemain et al., 2005). We used these datasets to determine the known minimum number of individual bears obtained from the DNA analysis in each LMU. The index was calculated as the number of unique bears per square kilometer, found in each of the LMUs. In cases where an individual was encountered in more than one LMU, it was assigned to each of them. We did not find any patterns suggesting a positive correlation between estimated search effort (h per km^2) and density of detected individual bears ($r = -0.40$).

In addition, the distribution of bears was estimated from the locations of hunter-killed bears. Bear hunting is allowed for all qualified hunters, with no license restrictions or number of bears that an individual hunter can kill, but family groups are protected. Bear harvest is limited by a quota for each province. Due to the lack of a specific license requirement to kill a bear, 55% of the bears are harvested by hunters hunting primarily for other species (Bischof et al., 2008). Thus, potential bear hunters are not just concentrated in areas with high bear densities. Successful bear hunters are required to submit an extensive report about the harvested bear, including coordinates of the kill site (Bischof et al., 2008). From that database we produced a map of harvested bears from 1998 to 2006 and compared that with the average observation rate of bears the LCOI from the same period.

3.　Statistics

We performed all statistical analyses in SAS software and we considered results to be significant at $\alpha \leqslant 0.05$. For regressions we used Proc GLM and for tests of differences among areas we used it with the Contrast statement. All reported correlation coefficients were adjusted for sample size. For estimating variance in bear observations in relation to effort, we used all observational data from Dalarna province (2001) and calculated confidence intervals for 1000 randomizations (Manly, 1997).

4.　Results

The LCOI accurately reflected the distribution and the known minimum density of brown bears in Sweden. The distribu-

Table 1 – The dataset on brown bears; censuses based on individual identifications from DNA in collected scats in three provinces in Sweden and effort-corrected observations of bears by voluntary hunters (LCOI). Scats samples are the total number of collected scats, DNA (%) successfully identified samples, and Est. pop. size the estimated population using Capture-Mark-Recapture.

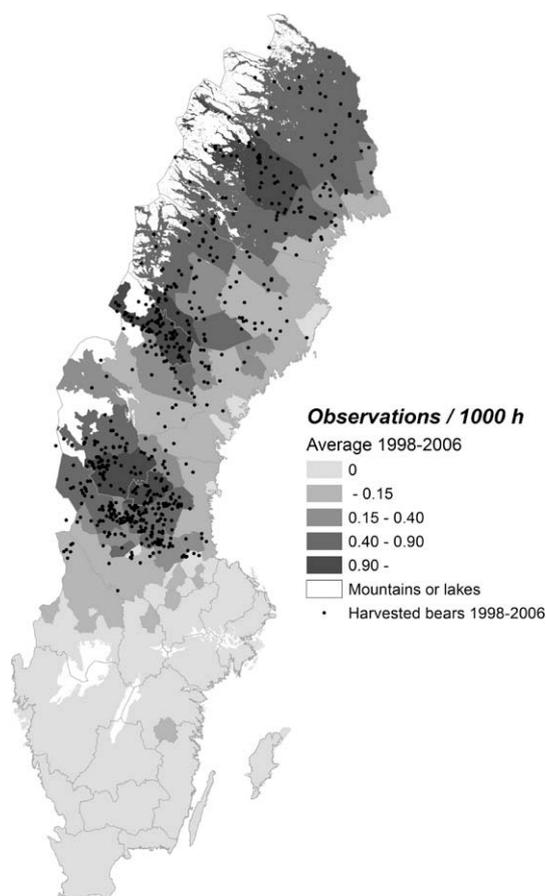| Province	Year	Scat surveys (DNA)				LCOI (observations)	
		Scat samples	DNA (%)	Unique individuals	Est. pop. size	Observation hours	Bear observations
Gävleborg–Dalarna	2001	1066	68	311	550	809,202	212
Västernorrland	2004	690	63	140	159	352,016	106
Västerbotten	2004	940	56	223	272	530,506	150

Fig. 2 – Densities of observations of brown bears by big-game hunters (darker color indicates a higher density) in relation to the sites of hunter-killed bears (black dots) in Sweden during the period 1998–2006.

Fig. 3 – Regression between the number of brown bear observations per 1000 observation hours by big-game hunters (LCOI) and the minimum number of bears (identified from DNA in scats) per 100 km² in local management units (LMUs) in Gävleborg and Dalarna provinces, Sweden, 2001. The dotted line shows the 95% CI.
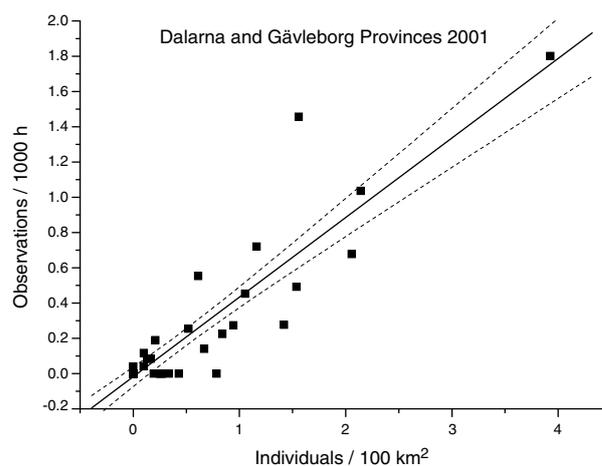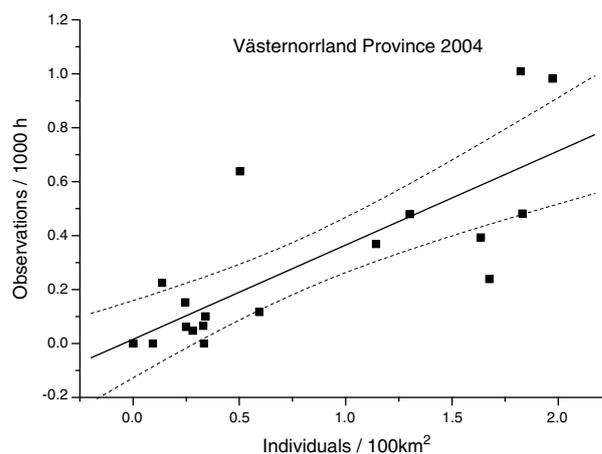

Fig. 4 – Regression between the number of brown bear observations per 1000 observation hours by big-game hunters (LCOI) and the minimum number of bears (identified from DNA in scats) per 100 km² in local management units (LMUs) in Västernorrland Province, Sweden, 2004. The dotted line shows the 95% CI.

tion of brown bears, based on results from LCOI, compared well with the distribution of harvested bears within Sweden during the same period (Fig. 2). Secondly, and more importantly, we found a strong statistical relationship between densities of individually identified bears in each LMU and the LCOI for all three study areas. The regression results had a high explanatory power for Gävleborg and Dalarna in 2001 ($P < 0.0001$, $R^2 = 0.82$, $N = 48$ LMUs); for Västernorrland in 2004 ($P < 0.0001$, $R^2 = 0.60$, $N = 19$ LMUs); and for Västerbotten in 2004 ($P < 0.0001$, $R^2 = 0.88$, $N = 21$ LMUs). Thus, the known density of bears explained between 60% and 88% of the observed variation in observation per hour at the lowest spatial scale, i.e., the LMU (Figs. 3–5). However, the slopes of the relationships between observations/1000 h and minimum bear density differed significantly among the three regions. A trend towards a difference was found between Dalarna–Gävleborg and Västernorrland ($P = 0.11$), but Västerbotten was highly significantly different from the other two study areas (both $P < 0.001$).

Furthermore, we found that the LCOI stabilized at the scale of larger LMUs, at around 30,000 observation hours (Fig. 6). However variance was still high, ±40%, at 130,000 observation hours.

5.   Discussion and conclusions

Monitoring programs are crucial for adequate conservation and management of most species, because baseline information is needed to understand their status. For species that are rare, elusive, and occur over large areas, large sample sizes are required for density or abundance estimates. However, this makes more preferred methods, such as capture–recapture or distance-based methods, very expensive. In some situations, an index method could be the solution to provide information about density and distribution for these species. However, to be useful for managers, index methods must have sufficient statistical power to detect significant changes
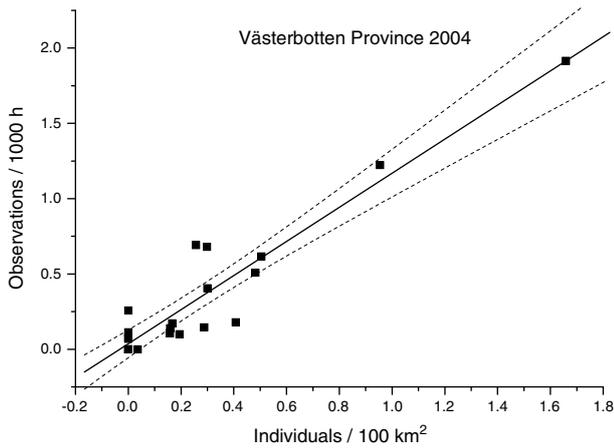
Fig. 5 – Regression between the number of brown bear observations per 1000 observation hours by big-game hunters (LCOI) and the minimum number of bears (identified from DNA in scats) per 100 km² in local management units (LMUs) in Västerbotten Province, Sweden, 2004. The dotted line shows the 95% CI.

in population size (Clevenger and Purroy, 1996; Field et al., 2005; Brodie and Gibeau, 2007). We used effort-corrected observations of brown bears from organized volunteer hunters and found that the resulting index accurately reflected distribution and relative local densities. We suggest that the LCOI, as used in Sweden, allows the possibility for continuous monitoring, even with scarce resources. Nevertheless, some methodological aspects must be addressed.

First, when using observations, it is important to know that there is considerable variance in the estimation of the parameters related to effort (Harris et al., 2007). Thus, one needs many observers to actually have the statistical possibility to detect a change. Hochachka et al. (2000) showed that relatively few hours (average 7700 h yearly) were sufficient for trend and density estimates of common species, but suggested that the method possibly would not work for uncom-

mon species. We have shown that, with enough observation effort, we can estimate a density index for an elusive species (brown bear) at a scale that is useful for management. To obtain such an effort almost requires the use of voluntary input, as was possible in Sweden.

A few studies have investigated what actually causes the variance when using volunteers, such as hunters and bird watchers, as reporters in monitoring programs (Link and Sauer, 1997; Newman et al., 2003). Ericsson and Wallin (1999) and Sylvén (2000) have shown that most of this variation is due to variation among the individual observers. Ball et al. (1999) showed that also extreme (warm–cold, dry–wet) weather situations may temporarily change the behaviors of the hunters and thus create outliers in a monitoring time series.

Because of the relatively large variation in our data, especially on the local scale, we suggest that the LCOI needs a considerable minimum observation effort and should be used with caution at scales smaller than provinces. Also due to this variation, combined with the possible effect of extreme events in a single year, we recommend that one be cautious in drawing conclusions about population trend based on results from a few years. Therefore, we stress that, if observation programs are implemented to monitor trends of large and elusive mammals, a long-term commitment is essential. We believe that a major strength of an observation program for monitoring purposes, such as we describe, is that the managers obtain annual data, which can allow the detection of a trend relatively quickly. Even in a situation with perfect data, managers will not react immediately. Solberg and Sæther (1999) found that it took managers approximately 2 years to change moose hunting quotas as a response to either an increasing or decreasing trend. Thus, an inexpensive monitoring program using effort-corrected observations may alert management faster than expensive monitoring methods that are conducted less often.

There are several problems associated with relying on voluntary work for wildlife monitoring. First, the observers must to be in the habitats where the animals occur. Second, be-
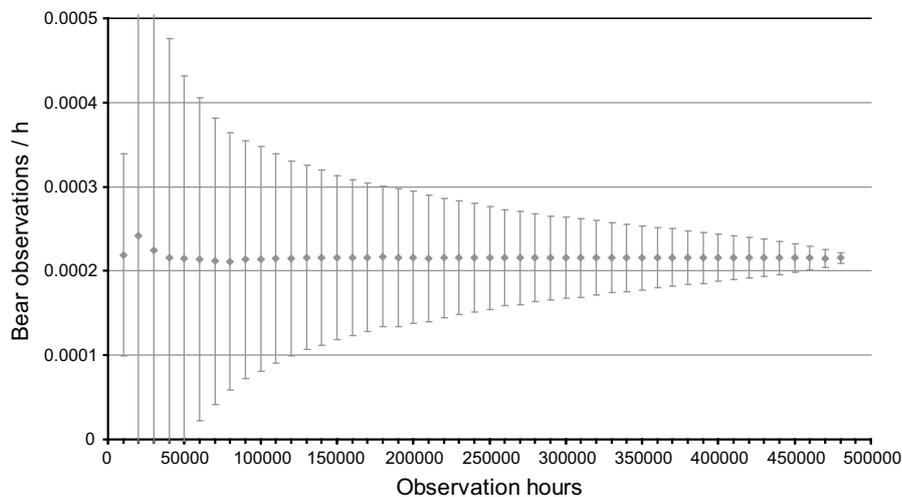

Fig. 6 – Results of a stabilization test of brown bear observations per hour for groups of observation hours as the mean and 95% CI for 1000 re-sampling events, using the data from Dalarna province, Sweden, in 2001.

cause of individual variation, the number of observers must be large. Third, the observers must carry out the observation program in a systematic and comparable fashion year after year. Fourth, the observers must be linked to an organization that mediates the data to nature-resource managers. Fifth, and this is crucial for an observation method and the ability to detect a change, is that the observers must record their observation effort accurately (Link and Sauer, 1997; Hochachka et al., 2000). The method should be carried out in a manner that allows one to detect and correct for spatial differences in effort and changing effort and area use between years. Systematized observations could be used in many areas and utilize different groups of people as a base for monitoring trends of elusive large mammals. In national parks or recreational areas, tourists and guides could be used and in more managed areas perhaps wardens.

A general problem with index methods in wildlife monitoring is the question of their comparability among areas and habitats (Eberhardt and Simmons, 1987; Slade and Blair, 2000; Williams et al., 2002). Our results showed a linear relationship between observations and density within the range of data we obtained, but that the slopes of these relationships differed among provinces. As pointed out by Ericsson and Wallin (1999), the regional differences in the relationships are not crucial per se, at least for monitoring population size within a region. However, to convert observation values into relative or estimated densities, for example to compare among regions or make a national estimate, it is necessary to understand the factors causing the regional differences in slopes. Future studies should investigate both this and the consistency of the relationship between the methods over years in the same province. This will be possible in the near future, because the management authorities plan to repeat the scat surveys.

Acknowledgements

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