Possibilities to estimate the population size of brown bears in Norway area based on the number of annual reproductions

Report No. 2008-5 from the Scandinavian Brown Bear Research Project
Prepared for the Directorate for Nature Management, Trondheim

Jon E. Swenson[1,2] and Ole-Gunnar Støen[1,3],
Scandinavian Brown Bear Research Project

[1]Department of Ecology and Natural Resource Management
Norwegian University of Life Sciences
Box 5003
NO-1432 Ås, Norway
jon.swenson@umb.no

[2]Norwegian Institute for Nature Research
NO-7486 Trondheim

[3] Department of Animal Ecology,
Swedish University of Agricultural Sciences,
SE-901 83 Umeå, Sweden

Introduction

Sweden and Norway express political goals for brown bear population size as annual reproductions. Using annual reproductions is useful for managers, because this is a concrete number that is easier to document than the actual total number of bears, and is biologically relevant, because it concentrates on reproduction. The number of reproducing adult female bears is a very important parameter when evaluating the long-term viability of a bear population. Nevertheless, there is great interest among managers and the public to translate the number of annual reproductions into the actual total number of bears.

Swenson and Katajisto (2005) carried out a modeling study to evaluate the feasibility of calculating the total number of bears by extrapolating from the number of annual reproductions in Sweden. The “extrapolation factor” refers to a number that one multiplies the number of reproductions to obtain a total population estimate. Swenson and Katajisto (2005) pointed out that this is not necessarily as straightforward as it may seem at first. The primary reason is that bear populations can experience different rates of cub-of-the-year mortality and different litter intervals.

Thus, the extrapolation factor for an annual reproduction will increase during the season as the mortality of cubs continues. On the other hand, this extrapolation factor might be higher and more stable throughout the year in a population with low cub mortality, because there will be a longer period between the litters born to females, but little loss during a given year. If the litter mortality rate is high, females will give birth more often.

Based on Swenson and Katajisto's (2005) modeling, they cautioned managers about using extrapolation factors to calculate the total number of bears in an area based on the number of annual reproductions. The main reason was that little is known about how much the cub-of-the-year mortality varies within Scandinavia. Therefore it is difficult to know which factor to recommend for any given area. If it is deemed important enough that managers wish to use an extrapolation factor to estimate the total population size from the number of annual reproductions, Swenson and Katajisto (2005) recommend the following: 1) calculations should only be made for large areas, such as all of Sweden, or perhaps an entire subpopulation. 2) If extrapolation factors are to be used over all of Sweden, they recommended using the mean value they found, i.e. 9 or 10 as a factor. If they are to be used within and adjacent to the study areas of the Scandinavian Brown Bear Research Project, the appropriate factors that they reported could be used, i.e. about 7 in the south and about 11 in the north. 3) It would be advisable to calculate the total population size based on two relevant extrapolation factors, to give a range in the calculated total population size. 4) Extrapolation factors cannot be used in peripheral areas, such as Norway. 5) Extrapolation factors should only be used on annual reproductions that are based on litters present in early spring before the mating season. Much of the cub mortality occurs during the mating season.

Although Swenson and Katajisto (2005) recommended that this method not be used in peripheral areas, such as Norway, the Norwegian Directorate for Nature Management has asked us to estimate extrapolation factors that could be used in Norway. We stress at the outset that these factors will be less accurate than those calculated for Sweden, because of the spatial change in sex ratio from the core reproductive areas and outwards towards the edge of the species' range (Swenson et al. 1998). The reason for this pattern is that females are more philopatric than males, so the dominance of males increases as one moves towards peripheral areas (Støen et al. 2006).

Methods

This study is based on the locations of individual brown bears and brown bear sex ratios in Norway. The data are from genetically-based determinations of bear scats, hairs, and tissue samples collected in Norway during 2006 and 2007 for a population estimate (Eiken et al. 2007, Bjervamoen et al. 2008). Individual locations were the center point of the samples of these individuals, provided to us by the Norwegian Institute for Nature Research (NINA). We had a sample size of 122 individuals with known sex (29 females and 93 males) and locations that allowed us to determine distance to the national border.

First, we used a logistic regression to determine whether the sex ratio of the brown bears in Norway changed with distance from the national border. We expected the

proportion of females to decline with increasing distance from the border, based on the results presented in Swenson et al. (1998) and Støen et al. (2006). If this were the case, we would have to calculate different extrapolation factors for varying distances from the border.

We based our estimates of extrapolation factors on the model presented by Swenson and Katajisto (2005), which was based on actual data from radio marked bears in the Scandinavian Brown Bear Research Project. They used demographic data from two periods, 1984-1995, when the legal hunting mortality was generally low, and 1984-2004, which included periods of lower and higher hunting mortality. In addition, they analyzed the data separately for two subpopulations, the south (northern Dalarna and western Hälsingland in Sweden), with high rates of cub mortality, and the north (in and around Sarek National Park in Norrbotten, Sweden), with low cub mortality rates. The extrapolation factors also change during the year. This is because cub mortality is occurring throughout the year. In areas with lower cub mortality (the upper lines in the figure, see figure 2), the change is less steep, because fewer cubs die. Where the cub mortality is higher, the extrapolation factors increase very rapidly during the year.

The results of the modeling effort from Sweden showed clearly that it was very difficult to use any single extrapolation factor to accurately estimate the total number of bears from the number of reproductions, due to the great variation described above. Thus, Swenson and Katajisto (2005) recommended using extrapolation factors only for litters present in early spring before the mating season. We have therefore calculated new extrapolation factors using the four combinations of time period and study area (see Swenson and Katajisto 2005) for early spring only. All calculations were based on litters of young-of-the-year. The methods and parameters of the population model are presented in the report by Swenson and Katajisto (2005), and we refer interested people to that report for the details. The model output "average proportion of bears with a litter" (p) was used to calculate the extrapolation factor, which was simply the inverse of this proportion (1/p). The average proportion of bears with a litter included all bears, including males and cubs of the year, so 1 could be divided by p to estimate the total number of bears.

The populations modeled by Swenson and Katajisto (2005) had an overall sex ratio very close to 50:50 (Bellemain et al. 2005). Our modification of Swenson and Katajisto's (2005) modeling results involved recalculating the extrapolation factors they reported with sex ratio data from Norway. We assumed that the parameters reported in Swenson and Katajisto (2005) were also valid for Norway, except for the sex ratios. We recalculated extrapolation factors presented in Swenson and Katajisto (2005), using the sex ratios at increasing distances from the national border corresponding to the distributions of 70, 80, 90 and 100% of all individual females discovered in Norway, in addition to the entire data set. We recognize that actual sex ratios will vary throughout Norway. For example, some females are found especially far from the national border in the Anarjohka Area of Finnmark (Eiken et al. 2007). However, there were not enough data to make these analyses for each predator management area.

The method to calculate extrapolation factors was straightforward. We obtained the extrapolation factors from Table 1 in Swenson and Katajisto (2005). The

extrapolation factors (1/p) were the inverse of the "average proportion of females with a litter in the population" (p). This was for an entire population with a 50:50 sex ratio. Therefore $2p_t$ would be the proportion of females with a litter, taken from the table, when considering only females. We estimated the average proportion of females with a litter in the population with varying sex ratios as:

$p_c = F * 2p_t$,

where p_c is the corrected p (portion of females with a litter in the entire population with a sex ratio differing from 50:50),
F is the proportion of all females in the sample from the population of interest, and p_t is the portion of females with a litter calculated from Table 1 in Swenson & Katajisto (2005); the table gives 1/p.

Results

The logistic regression showed that the probability that a sample came from a female bear declined significantly with increasing distance from the national border (β= -0.03276, z = -2.741, p = 0.006, Fig 1), thus there was a need to calculate different extrapolation factors for varying distances from the border. The probability that a sample was from a female declined from 40% at the national border, to 25% at 21 km from the border, to 10% at 54 km, and 5% at 77 km. The logistic model gives results as statistical probabilities. Actually, the farthest female recorded in the samples was 47 km from the border. Removing the samples from Anarjohka would have made this gradient even steeper and the maximum distance for females shorter (31 km rather than 47 km).

Our results showed that the range of extrapolation factors was quite stable within the area where females were detected in Norway, generally within 10-20 (Table 1). The reason for this was that the proportion of males in the sample was stable within this area, varying only between 67 and 69%. The range of extrapolation factors for all of Norway, however, was higher, 13.4-24.2, because of the higher proportion of males (76%).

It is important to point out that these extrapolation factors would be very much higher if litters observed later in the season were used to determine the number of annual reproductions. To illustrate this, we present Swenson and Katajisto's (2005) Fig. 1 (as our Fig 2); note that these rates were calculated using Swedish data and are not valid for Norway.

Discussion

Swenson and Katajisto (2005) cautioned that their extrapolation factors could not be used in peripheral areas, such as Norway. We have calculated extrapolation factors that are more valid for Norway, but we caution that these factors are less accurate than those calculated for Sweden. The reason is that, at the periphery of the bear's range, the sex ratio is very different from that in the reproduction core areas, and it varies spatially and probably also temporally. Nevertheless, the extrapolation factors we calculated were relatively stable up to 47 km from the national border. For that reason, we believe that a careful use of the rage of extrapolation factors we report,

when based on unduplicated observations of female bears with young-of-the-year (see Ordiz et al. 2007) early in the spring (before mid-May), can give an indication of the total minimum number of bears within the zone containing females near the border. Such an estimate will include many bears that have a portion of their home range outside of Norway, as home-range diameters average about 20 km for females and 32 km for males (Dahle and Swenson 2003, Støen et al. 2006).

Extrapolation factors will be higher if observations from periods after the start of the breeding season are used, but we cannot estimate what they might be, because we know nothing about mortality rates of cubs at the periphery of the bear's range, and cub mortality is an important factor affecting extrapolation factors (Swenson and Katajisto 2005). Because of the low number of females in this zone, there can be large annual variations in the number of females giving birth to young, so an average of several years should be used. Also, annual variations in dispersal of males and females and killing of bears on both sides of the border will induce variation. If females are younger on average in Norway than in Sweden, our calculated extrapolation factors might be somewhat low.

Recommendations

It seems that the minimum total number of individual bears within the zone containing female bears in Norway will be between 10 and 20 times the number of reproducing females. Any estimate using this method must be based on unduplicated observations of females with cubs-of-the-year during the early spring. It is important to remember that most bears this close to the border will probably have a portion of their home ranges outside Norway. Therefore, one would obtain an inflated estimate of bear density if the total estimate were divided by the land area in Norway. We do not recommend using the extrapolation factors to estimate the number of bears in Norway outside the zone with females with cubs, as the number of males can vary greatly based on many factors, including management killings.

References

Bellemain, E., J. E. Swenson, D. Tallmon, S. Brunberg & P. Taberlet. 2005. Estimating population size of elusive animals using DNA from hunter-collected feces: comparing four methods for brown bears. Conservation Biology 19:150-161.

Bjervamoen, S.G., H. G. Eiken, M. Smith, H. Brøseth, P. Aspholm, E. Maartmann, P. Wabakken, P.M. Knappskog, & I. Wartiainen. 2008. Populasjonsovervåkning av brunbjørn 2005-2008: Rapport for Sør-Norge 2007. Rapport Nr. 52/2008, Bioforsk, Svanhovd, Norway.

Dahle, B., and J. E. Swenson. 2003c. Home ranges in adult Scandinavian brown bears *Ursus arctos*: effect of population density, mass, sex, reproductive status and habitat type. Journal of Zoology 260:329–335.

Eiken, H.G., S.G. Bjervamoen, M. Smith, H. Brøseth, S. Wikan, L. Jensen, P. M. Knappskog, T.-A. Bjørn, L. Ollila, & P.E. Aspholm. 2007. Populasjonsovervåkning av brunbjørn 2005-2008: Rapport for Sør-Trøndelag, Nord-Trøndelag, Nordland, Troms og Finnmark 2006. Rapport Nr. 47/ 2007, BioForsk, Svanhovd, Norway.

Ordis, A., C. Rodríguez, J. Naves, A. Fernández, D. Huber, P. Kazcensky, A. Mertens, Y. Mertzanis, A. Mustoni, S. Palazón, P. Y. Quenette, G. Rauer, C. Rodríguez, & J. E. Swenson. 2007. Movement patterns of female brown bears with cubs in Europe:

application to population monitoring. Ursus 18 :158-167.
Støen, O.-G., A. Zedrosser, S. Sæbo, and J. E. Swenson. 2006a. Inversely density-dependent natal dispersal in brown bears *Ursus arctos*. Oecologia 148:356–364.
Swenson, J. E. & J. Katajisto. 2005. Estimating the total population size of brown bears in an area based on the number of annual reproductions. Report No. 2005-1 from the Scandinavian Brown Bear Research Project.
Swenson, J. E., F. Sandegren, & A. Söderberg. 1998. Geographic expansion of an increasing brown bear population: evidence for presaturation dispersal. Journal of Animal Ecology 67:819-826.

Table 1. Extrapolation factors used to calculate the total number of brown bears that correspond to one reproduction, calculated based on study periods and study areas in Sweden (from Swenson and Katajisto 2005), and sex ratio as reported from the scat surveys in Norway, 2006 and 2007. These factors correspond to litters of young-of-the-year observed early in the spring, before the mating season begins in mid-May.

Study Period	1984-2004		1984-1995	
Area	Southern	Northern	Southern	Northern
Distance from the Norwegian border corresponding to				
70% of the females (18 km) (68.3% males)	10.1	18.1	11.9	16.6
80% of the females (25 km) (69.3% males)	10.5	18.8	12.4	17.2
90% of the females (31 km) (67.1% males)	9.7	17.5	11.5	16.0
100% of the females (47 km) (67.8% males)	10.0	17.8	11.8	16.3
All data (76.2% males)	13.4	24.2	15.9	22.1

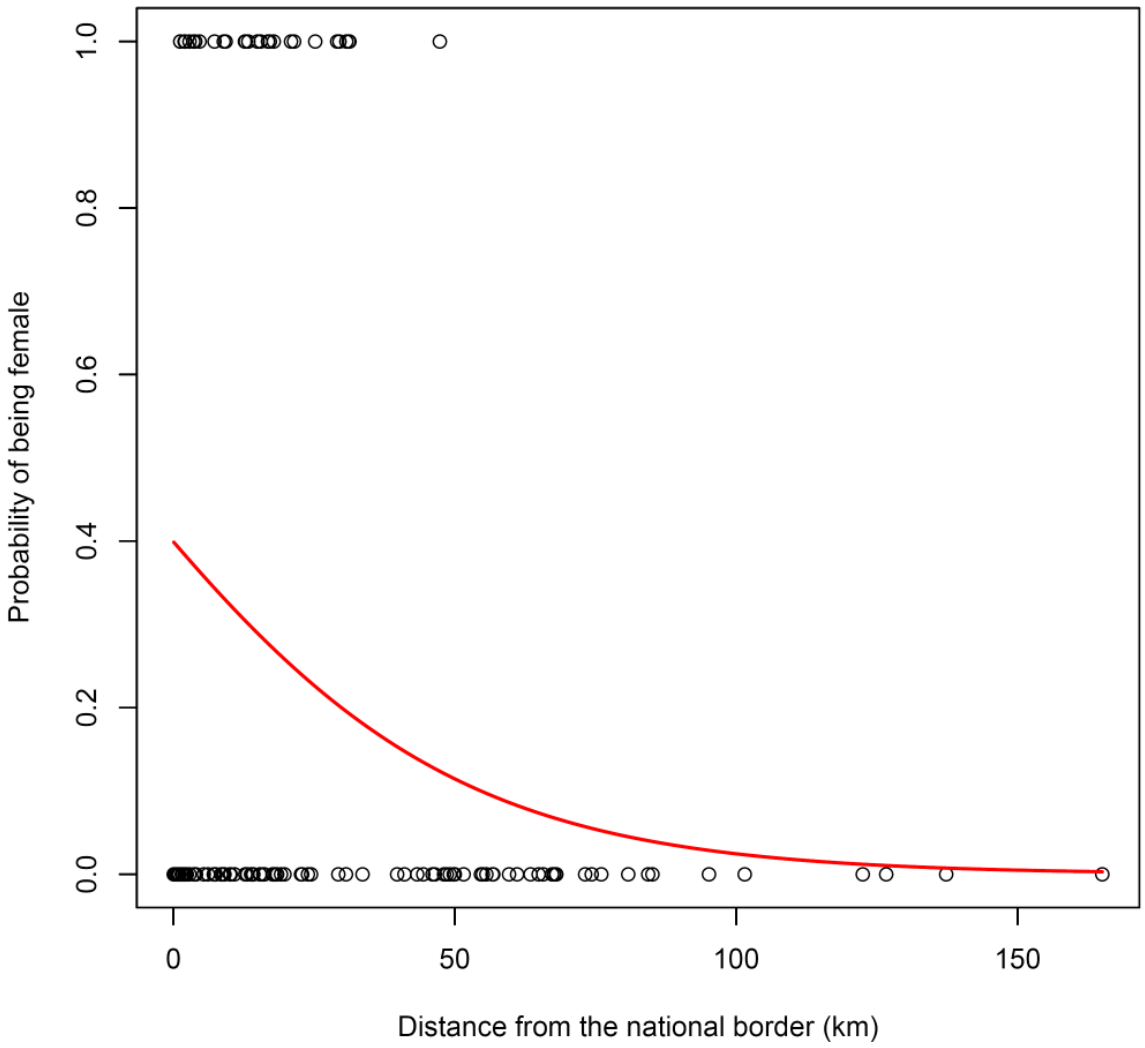

Fig. 1. Decline in the proportion of females in the samples of bear scats in Norway as a function of the distance from the national border. This figure is based on expected probabilities from a logistic regression. Thus, the probability of 0% females occurs at about 100 km, whereas no females were found beyond 47 km. Circles on the top (1.0) are samples from females and those on the bottom (0.0) are from males.

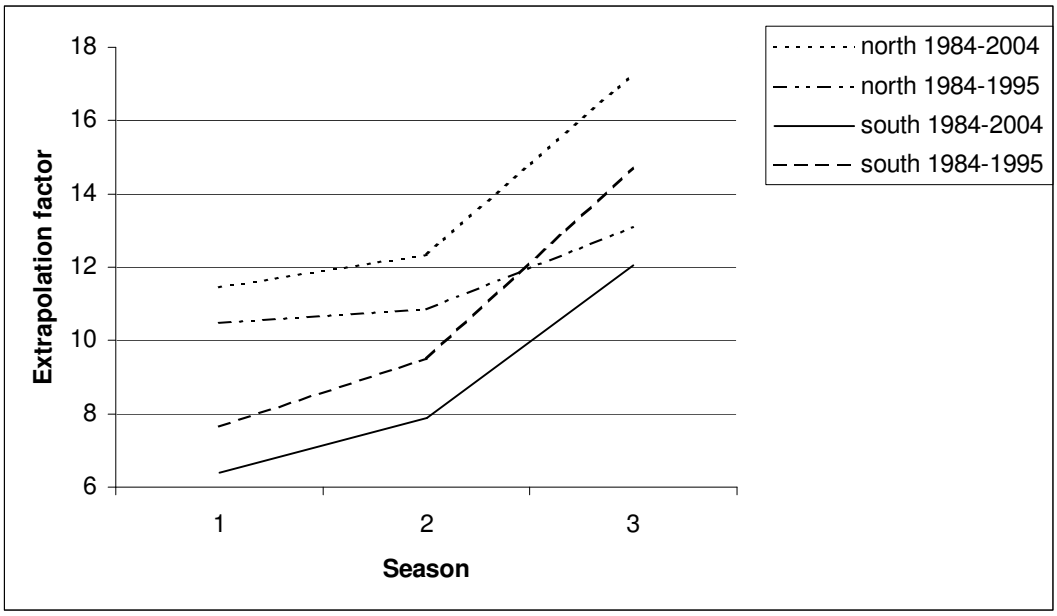

Fig. 2. Extrapolation factors (from Swenson and Katajisto 2005, their Fig 1) used to calculate the total number of brown bears that correspond to one reproduction, depending on the study period, study area, and season of the year in **Sweden**. Seasons are: 1) early spring after denning, 2) midsummer after the mating season, and 3) late autumn prior to denning. This figure is only for illustrative purposes, as these extrapolation factors are not valid for Norway.