Monitoring and Management of the Swedish Brown Bear (*Ursus arctos*) Population

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Cover: Brown bear in its habitat.
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Abstract

For society, there is a constant need for scientifically based information to successfully manage bear populations. In Sweden, the brown bear (*Ursus arctos*) population is increasing and expanding after that successful conservation measures was employed during the 20th century. Two important issues in management are to understand how bears use their habitat, at different spatial- and temporal scales, and to estimate size and trend of the population at various scales. The central aim of this thesis was to provide management authorities with knowledge and methods for monitoring and managing the Swedish brown bear population. We have used radio-marked bears to determine the use of habitats at two different spatial- and temporal scales. To obtain population trends we used bear observations and to estimate population size we identified individual bears from DNA in collected scats and calculated the total number of bears with Capture-Mark-Recapture methods. These data were obtained with the help of volunteers and covered, in principle, the total bear range in Sweden. We estimate the Swedish brown bear population to 3,298 (2,968-3,667) individuals in 2008, and the yearly increase in the bear population to be 4.5% during the period 1998 to 2007. We show that bears prefer forest habitat in rugged terrain >10 km from towns or resorts. Bears located within 10 km of human settlements are mainly younger individuals. Bears habitat selection differs between active and resting periods. They are more active during nocturnal and crepuscular hours and rest during the daytime. My results provide management authorities with information on distribution, population size and trends of the brown bear population in Sweden, at national as well as regional scales. We have introduced and verified a method for monitoring bears, the Large Carnivore Observation Index, based on effort corrected observations of bears during hunting. We show that the bears use habitats that are further away from humans and that their use differs between sex and age groups. I recommend that the monitoring and management of bears should be carried out from an adaptive management perspective, where methods and the effects of different decisions should be continuously evaluated. For the future management of bears in Sweden, managers need good information about bear ecology, demography, and the perception of the human dimension.

Keywords: habitat, CMR, non-invasive, survey, DNA, trend, population size

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Dedication

To My Family
Tamisha, Jonathan and Noah

I should never have made my success in life if I had not bestowed upon the least thing I have undertaken the same attention and care I have bestowed upon the greatest.
Charles Dickens

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Nellemann, C., Støen, O.-G., Kindberg, J., Swenson, J., Vistnes, I., Ericsson, G., Katajisto, J., Kaltenborn, B.P., Martin, J. & Ordiz, A. (2007) Terrain use by an expanding brown bear population in relation to age, recreational resorts and human settlements. *Biological Conservation* 138, 157-165.

II Moe, T.F., Kindberg, J., Jansson, I. & Swenson, J.E. (2007) Importance of diel behaviour when studying habitat selection: examples from female Scandinavian brown bears (*Ursus arctos*). *Canadian Journal of Zoology* 85, 518-525.

III Kindberg, J., Ericsson, G. & Swenson, J.E. (2009) Monitoring rare or elusive large mammals using effort-corrected voluntary observers. *Biological Conservation* 142, 159-165.

IV Kindberg. J., Swenson, J.E., Ericsson, G., Bellemain, E. & Taberlet, P. Estimating population size and trends for the Swedish Brown bear (*Ursus arctos*) population. (Manuscript).

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1 Introduction

1.1 Brown bear management

Management of animal populations can be viewed as the desire to accomplish specific goals with a given population, with focus most often on population size. The goal can be to maintain the current population size or to increase or decrease it. Harvest of certain species is important and thus goals are set for achieving a certain yield (Caughley and Sinclair, 1994; Williams *et al.,* 2002a).

Until recently, management of large carnivores focused mainly on efforts for protecting and saving populations, reversing trends, and restoring habitats (Noss *et al.,* 1996). Large carnivore densities are ultimately regulated by the densities of prey species, which in turn are often regulated by humans (Carbone and Gittleman, 2002). The main threat to large carnivores is the increase and expansion of the human population, which has led to reduced availability of suitable habitats, persecution, and various conflicts with humans (Weber and Rabinowitz, 1996; Woodroffe, 2000; Gittleman and Gomper, 2001). An increasing awareness and changing attitudes in the 20th century led to conservation efforts, which have been successful in some areas, including reversal of negative trends for several of the large carnivore species (Mech, 1995; Kellert *et al.,* 1996; Linnell *et al.,* 2001; Enserink and Vogel, 2006).

The brown bear (*Ursus arctos*) declined and became locally extinct across large parts of North America and Europe during the 19th and 20th century; often due in part to state-sponsored extermination campaigns (Servheen, 1990; Swenson *et al.,* 1994; 1998a; Zedrosser *et al.,* 2001; Clark *et al.,* 2002). Several bear populations are now expanding or being reintroduced across most of their former ranges, but with highly variable success

(Swenson *et al.,* 1998b; Zedrosser *et al.,* 2001; Servheen, 1998; Clark *et al.,* 2002).

In Sweden the population has increased from very low levels, estimated to be only around 130 individuals in the 1930s, to a population size that today is larger than it was more than 200 years ago (Swenson *et al.,* 1995; Paper IV). Although this resulted in an increased distribution of bears, re-colonization, especially by females, has occurred in only a portion of the former range (Swenson *et al.,* 1994; 1998a). This is a problem commonly encountered in most places where reintroduced or expanding populations have been monitored (Clark *et al.,* 2002).

An expanding as well as increasing bear population introduces new challenges for the management organizations (Mech, 1995; Kellert *et al.,* 1996; Breitenmoser, 1998; Swenson *et al.,* 1998b). Recovering from low populations and expanding into areas where they have been absent for very long times, carnivores are once again encountering humans, with a high risk for conflicts. These conflicts range from the tangible such as lethal encounters, livestock depredation, and competition for game, to the intangible, such as fear (Linnell *et al.,* 1999; Swenson *et al.,* 1999b; Røskaft *et al.,* 2003; Schneider, 2006).

Managing a bear population requires a general understanding of the species' ecology and behavior, which means that basic ecological research is needed. Abundance estimates and trends are necessary for documenting population status, setting goals, and evaluating management decisions. Identifying habitat requirements, as well as understanding their functions, is also important, because habitat is one of the major factors that regulate bear populations.

The main objective of habitat selection studies is to identify important habitats. An animal must ensure that its basic requirements are fulfilled, such as food and protection. Because one habitat normally cannot fulfill all requirements, the selection of habitats will be a balance of different qualities. For managers it is therefore essential to know which habitats are used and why animals select some habitats over others. Habitat selection can be described as an animal's disproportionate use of a habitat in relation to its availability, and can operate at different scales, both in space and time (Johnson, 1980; Schooley, 1994; Apps *et al.,* 2004; Nielsen *et al.,* 2004).

1.2 The species

The brown bear occupies a wide range of habitats throughout its range, from lowlands in desert-like conditions, through boreal forests, and up to alpine areas. It has the widest distribution of any of the eight bear species, and occurs in parts of North America, Europe and Asia (Servheen, 1990; Schwartz *et al.,* 2003).

Brown bears are omnivorous, with an extensive variety of food sources and despite their carnivorous inclination, most of their energy is obtained from berries in addition to ants, moose (*Alces alces*), grasses and herbs, depending on the seasons. Males are 1.2 - 2.2 times larger than females (Schwartz *et al.,* 2003) and in the spring females weigh 80-110 kg and males 180-220 kg. In the fall, bears may have increased their weight by up to 20-40%. Bears hibernate in October and remain in hibernation until April. The mating season lasts from May to June (Dahle and Swenson, 2003), when a female may mate with several males and males with several females (Steyaert *et al.,* 2010). Females are sexually mature on average at 4.5 and 5.4 years of age in the southern and northern part of the bear range in Sweden, respectively (Swenson *et al.,* 2001).

The Swedish bear population has colonized Sweden after the last Ice Age from two directions, based on analysis of mitochondrial DNA. The population in the southern bear range is related to bears from the Iberian Peninsula, whereas the bears in the middle and the north of the bear range came from the Finnish-Russian population (Taberlet and Bouvet, 1994).

The politically determined minimum population goal in Sweden was set in 2001 to 100 yearly reproductions corresponding to about 1,000 individuals. This was supplemented by a parliament decision in 2008 stating that the population should be maintained at about current levels at the national scale, but allowed to increase or decrease at local scales, based on the local situation regarding conflicts, e.g. livestock depredation (including semi-domestic reindeer, *Rangifer tarandus*), competition for game, and problem individuals.

Hunting of brown bears has been allowed in Sweden since 1943 in a few areas and from 1981 as quotas over larger areas (Swenson *et al.,* 1995). Harvest quotas have increased from 55 in 1999 to 233 in 2008. From 2010 quotas are set by the county administration for each of the regions.

For more information on the Swedish brown bear population, visit the home page of the Scandinavian Brown Bear Research Project www.bearproject.info

1.3 Objectives

In this thesis I address questions which are of importance for monitoring and managing brown bear populations: methods for monitoring population trends and assessing population size, as well as habitat requirements at two different spatial and temporal scales.

My main objectives are to:

1. Study how bears use habitat at the landscape scale in relation to human disturbance (Paper I).

2. Study temporal and spatial habitat selection at the home range scale and to understand bear behavior in different habitats (Paper II).

3. Test if a method used in ungulate monitoring could be used as an index of bear density at large scales, and to validate this with an independent density estimate (Paper III).

4. Estimate population trends and to calculate bear population size at the national as well as regional scales (Paper IV).

2 Material and methods

2.1 Study areas

Brown bears are distributed throughout the northernmost two-thirds of Sweden, ranging primarily from Dalarna and Gävleborg counties and northwards. Bears occur south of these counties too, but they are comparably few and mainly males. The landscape is mainly covered by boreal forest dominated by Scots pine (*Pinus sylvestris*) and Norway spruce (*Pica abies*); other common tree species are lodgepole pine (*Pinus contorta),* birches (*Betula* spp) and European aspen (*Populus tremula*). The remaining area is covered by bogs and lakes; agricultural areas are rare. The Scandinavian mountain range is situated in the west and more populated areas are located along the eastern coast.

The 12,128 km^2 study area in paper I was located in the southernmost portion of the bear range, mainly in Dalarna County (61°N, 14°E) (see Fig.1). The area was delineated by municipality and county borders or natural terrain features, such as ridges and hills.

Figure 1. Map of Sweden with counties marked with name and gray border. The study area in paper I has a white background and black border and is marked with an (A). The study area in paper II is marked with a (B) and each home range is shaded in dark gray.

In paper II we used the area consisting of the home ranges (100% minimum convex polygons) of six bears equipped with GPS-radio collars, located in the eastern part of Dalarna and western part of Gävleborg counties (61°N, 15°E) (Fig 1.).

In papers III and IV we utilized all of the counties, as both DNA-scat surveys (except Norrbotten County) and bear observations (LCOI, see below) were conducted at that scale (Fig 1.). We consider the same areas as registered for moose hunting, with some modification in the mountainous regions, as the area that could potentially be used by bears

2.2 Geographical data

The study area for paper I comprised of 758 4 x 4 km squares classified as "forest" or "bog" if more than 50% of the coverage was forest or bog, respectively, estimated from 1:100,000 scale maps with contour intervals of 10 m. We further classified each grid cell according to a terrain ruggedness index (TRI; Nellemann and Thomsen, 1994) as well as to distance from towns and tourist resorts. There are six town and settlement areas, ranging in size from 3,000-11,000 inhabitants, and two major tourist resort areas with cabin resorts and down-hill skiing facilities, located within the study area.

In paper II we used habitat data from SMD (Svenska Marktäcke Data) with a pixel size of 25 x 25 m corresponding roughly to CORINE land cover maps, but with more detailed habitat classes (Engberg, 2002; 2003).

2.3 Radio-marked bears

In paper I we used a total of 106 (55 females and 51 males) brown bears, two years and older (i.e. post weaning), equipped with VHF-radio collars, and located within the study area from 1985 to 2002. We used positions approximated from weekly triangulations using standardized methods, from the ground or by air plane (Dahle and Swenson, 2003). To avoid locations influenced by denning behavior, we only used positions from June, July, August and September (Manchi and Swenson, 2005) and all positions were separated by at least 100 hours to avoid autocorrelation.

The six female GPS-collared bears in paper II were equipped with GPS-Plus-3 collars including activity loggers (five females), VHF units, and GSM modems (VECTRONIC Aerospace GmbH, Berlin, Germany). The position and activity status were recorded every half hour and every five minutes respectively, between 20 May and 24 August 2004. The activity index was an indication of the bears' head movement during these five minutes. The activity index (measurements summed to between 0 and 510) of a bear at a site, was the mean of the six recordings during the 30-minute interval surrounding the time of the GPS location. Based on the recommendations of Gervasi *et al.,* (2006), we defined all periods where the bears showed a mean activity of <50 as passive periods and ≥50 as active periods. We divided the study period into the pre-berry (20 May - 6 July) (Dahle and Swenson, 2003) and berry seasons (16 July - 24 August), with a break between periods when berries started to ripen, to correct for seasonal patterns in behaviour and diet (McLellan and Hovey, 2001; McLoughlin *et al.,* 2002).

2.4 Bear observations

We used effort-corrected bear observations made by moose hunters in papers III and IV, as an index of bear density. Since 1998, the Swedish Association for Hunting and Wildlife Management has collected observations of bears within the Large Carnivore Observation Index (LCOI) program during the first seven days of the moose hunt (starts in September or October, depending on county), as complementary information to their "moose observation" survey (Ericsson and Wallin, 1999; Sylvén, 2000; Liberg *et al.,* 2010).

The moose hunters record bear sightings of young-of-the-year and older animals, length of daily hunting activity in hours, and numbers of hunters, based on hunting unit and day. Hunting is conducted during daytime from one hour before sunrise to one hour before sunset. The LCOI is calculated as number of bear observations per 1,000 observation hours for each hunting management unit, and it has national coverage, as moose are hunted over practically all of Sweden and in all bear habitat, except for national parks. This program generates approximately 4.5 million observation hours yearly (Liberg *et al.,* 2010), of which more than 2 million hours are from the areas with bears.

2.5 Identified individuals using DNA from scats

In these studies (Paper I, III and IV), we used DNA extracted from scats to identify individuals, including their sex (Table 1.). Searches for bear scats were conducted for about 12 weeks in the autumn period starting in the end of August. Each of the counties with an established bear population has been sampled at least once, apart from Norrbotten. Samples were collected opportunistically, mainly by cooperating hunters, but even by other volunteers. Hunters picked up each scat sample with a stick of wood, and placed them into collection bottles. A different stick and bottle were used for each sample. For each scat sample, a sampling date, geographical location, co-ordinates (Swedish RT90 2.5 gon V), as well as the hunting team's name were recorded by the volunteers.

For every collected scat sample, DNA extractions and amplifications were performed at the Laboratoire d'Ecologie Alpine, Grenoble, France, as described in Bellemain *et al.,* (2005) and in paper IV. Briefly, each DNA extract was first screened for species-diagnostic amplification with one microsatellite marker (Paetkau and Strobeck, 1994). Next, 6 microsatellite markers (Paetkau and Strobeck, 1994; Taberlet *et al.,* 1997) and a sex marker (Bellemain and Taberlet, 2004), were amplified, following the multiplex pre-amplification method (Piggott *et al.,* 2004; Bellemain and Taberlet, 2004). Amplifications were repeated four times, samples were grouped according to their genotype, and unique genotypes were then identified.

In paper I we used scat data from the study in 2001 (Bellemain *et al.,* 2005) to verify bear habitat use in relation to distance to settlements obtained by VHF positioning. One randomly selected scat from each individual resulted in a total of 145 locations (88 female and 57 male locations) within the study area.

Table 1. Summary of brown bear scat surveys and genetic identification in studied counties in Sweden, i.e. the number of scat samples collected and analyzed, the number of samples successfully amplified for 5 to 7 loci (including the sex locus), sex ratio as percentage males and the number of unique genotypes identified.

County	Survey year	Number of analyzed scats	Number of amplified scats	Percentage males	Number of unique genotypes
Dalarna and Gävleborg	2001	1066	728	43%	311
Dalarna and Gävleborg	2002	838	665	42%	239
Västernorrland	2004	690	434	55%	140
Västerbotten	2004	940	524	63%	223
Jämtland	2006	*3000	2400	47%	684

* *3000 samples were randomly selected to be analyzed among the 5185 collected scats.*

2.6 Population estimation

In paper IV we used capture-mark-recapture (CMR) methods (Schwarz and Seber, 1999; Buckland *et al.,* 2000; Williams *et al.,* 2002a; Amstrup *et al.,* 2005) to calculate population size for different counties, from the number of individuals identified in each of the DNA-analyses. We used closed populations models in program MARK (White and Burnham, 1999) with each week (obtained from the collection date) used as a capture session in the analysis for capture and recapture rates. To choose the most appropriate among the defined models, we used model selection with Akaike's Information Criterion (AICc) values and model averaging where appropriate (Burnham and Anderson, 2002). All high-ranking models included individual heterogeneity in capture probabilities and time effects, which means that there are differences in the probability to capture a bear, as well as variation over the sampling period. Heterogeneity in capture probabilities usually arises from different age and sex classes and also reproductive status (Boulanger *et al.,* 2008). We can distinguish between females and males, but not age or reproductive status in the DNA-analysis, so differences among sexes is accounted for in the models.

3 Results and Discussion

3.1 Habitat use on the landscape level (Paper I)

Some of the major threats to brown bear populations are habitat loss and habitat fragmentation by infrastructure and human settlements (Servheen, 1990; Gibeau *et al.,* 2002; Nielsen *et al.,* 2004). We analyzed bear habitat use in a 12,128 km^2 area in the southern part of the bear range in Sweden, with data collected in 1985-2002 during the non denning period. We randomly selected 10 positions from each of 106 radio-collared bears (55 females and 51 males) and compared their habitat use in relation to resorts and towns, terrain ruggedness, sex and age of bears.

The area bears used during the non denning period increased substantially with increasing distances to towns or resorts ($R^2 = 0.94$, $p < 0.01$). The increase occurred regardless of the sex of the bears or if it was a resort or a town. The use of areas within 10 km from resorts or towns was significantly lower compared to what was available within the study area. Those bears which were observed in closer proximity to settlements (<10 km from resorts or towns) were, on average, 27 and 51% younger, females and males, respectively, than bears observed more than 10 km from any settlement (Fig. 2). This trend was most pronounced in males (mean 4.4 ± 0.4 versus 8.9 ± 0.8 years for males and 4.4 ± 0.4 versus 6.0 ± 0.2 for females).

The preferred habitat for bears encompassed forest and rugged terrain located more than 10 km from towns or resort. This habitat constituted 29% of the available area within the study area, yet we detected more than 74% of the females'-, as well as 57% of all male bears' locations in these areas. Flatter, forested terrain, far from human settlements, was used according to availability and all areas dominated by bogs were used less than expected by both males and females. Overall, 40% of the study area (4,864 km^2) was classified as <10 km from towns and resorts, but contained only 9% of the female bear locations and 15% of the male locations. Older males (>7 years) were generally located beyond 10 km from major towns or resorts, with only 8% within 10 km. Within the rugged forested habitat, female bears utilized areas which were <10 km from towns and resorts 81-95% less often than comparable areas further away.

Recreational resorts are developing rapidly, typically near national parks, and they may thus limit the bear population's expansion or fragment existing bear habitats. Together with active conservation, safeguarding undeveloped corridors of forest and rugged terrain may be important for the successful recolonization of the brown bear into its original range.

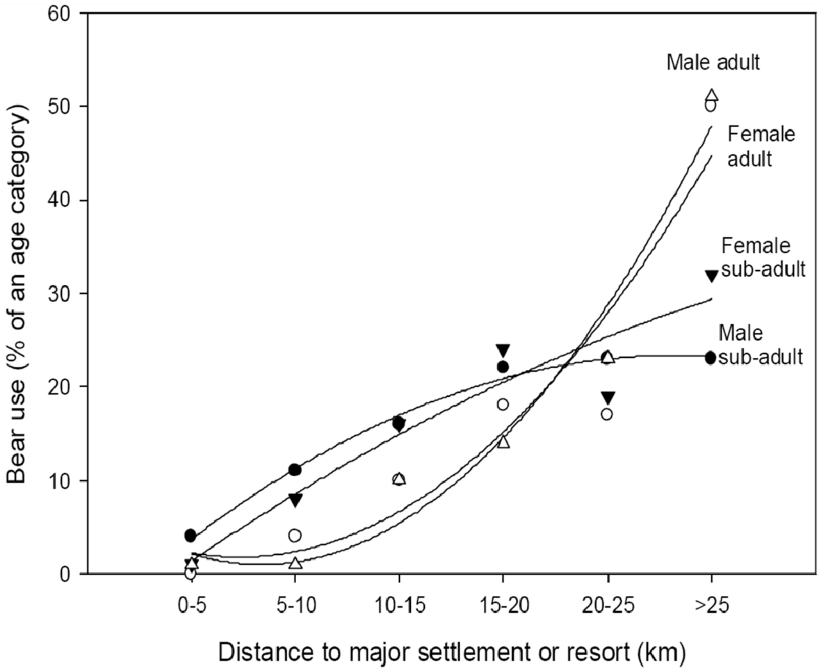

Figure 2. Proportion of locations of sub-adult (≤ 6 years) male and female, and adult (≥ 7 years) male and female brown bears along 5-km intervals from settlements and resorts, based on ten random bear locations per animal (n = 106) from June to September 1985-2003, Dalarna, Sweden (Paper I).

3.2 Activity and habitat selection at the local scale (Paper II)

We used 24-hour data from six female brown bears equipped with GPS-GSM collars incorporating activity loggers to analyze variations in habitat selection related to diel variations in activity (foraging and resting).

We found that the bears rested mainly during the daylight hours and foraged mainly during the crepuscular and nocturnal hours for both the pre-berry and berry season (Fig. 3).

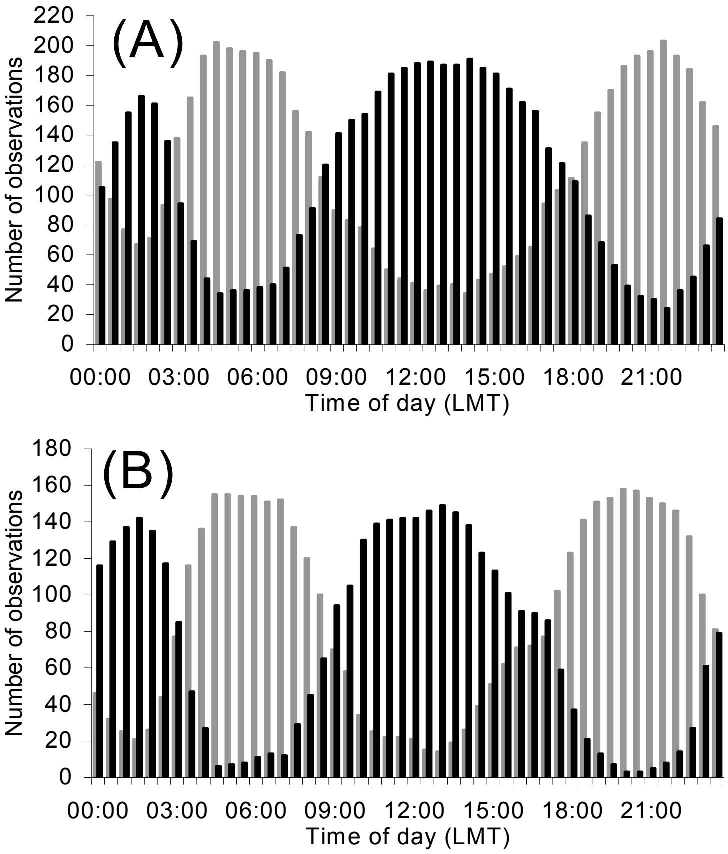

Figure 3. Mean activity for each half-hour period (local mean time) during a diel cycle for five female brown bears in Dalarna, Sweden during the (A) pre-berry and (B) berry seasons of 2004. Gray bars are active periods (mean activity ≥50; N_A = 5,692; N_B = 4,246), black bars are passive periods (mean activity <50; N_A = 5,285; N_B = 3,543).

The bears selected habitats differently when they were resting compared to foraging and the selection also differed between the two seasons (see Fig. 2 in Paper II). Poor conifers, open bog, and "Other" habitats were almost always avoided, and young forest was always selected. In the pre-berry season, active bears selected forested bogs, clearcuts and young forest, however the forested bogs where only used during early day activity period. During the berry season bears selected mixed forests, short conifer, and young forest during both active and resting periods and avoided clearcuts.

We compared the diel habitat selection (active and resting) with the overall 24-hours general selection, where we did not take activity into account. The 24-hour study showed that bears used the available habitats non randomly during both seasons, but the pattern was different when compared to the diel habitat selection, as both resting and active locations were used together.

Thus, for studies of habitat selection, our results show the importance of obtaining data from all 24 hours and dividing these data into relevant categories based on the diel activity pattern of the bears to understand their needs for food and shelter. This is crucial for the management of any species with diel behavioral differences.

3.3 Observations as a method for monitoring bears (Paper III, Paper IV)

Observations are a common method in the monitoring of brown bears in different populations (Eberhardt and Knight, 1996; Mattson, 1997; Ordiz *et al.,* 2007). However, these monitoring programs are rarely validated against true densities or other methods. Here we evaluated a method developed for monitoring populations of moose, based on voluntarily and systematically collected bear observations from hunters and corrected for effort, the Large Carnivore Observation Index (LCOI). We used regressions to obtain the relationship between bear observations per 1,000 observation hours and independent estimates of minimum brown bear densities from DNA-based scat surveys in a double sampling approach (Eberhardt and Simmons, 1987).

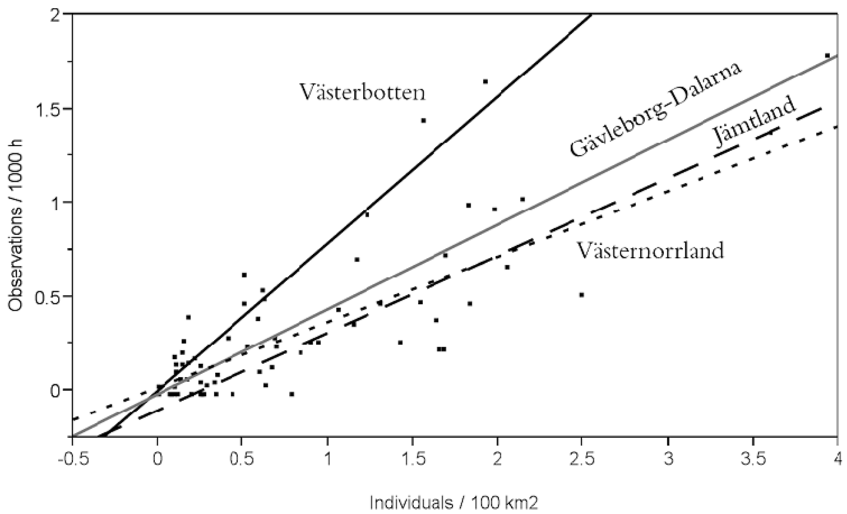

Figure 4. Comparison of the relationship between the LCOI and density of brown bears from DNA-based scat surveys. The slope was significantly different in Västerbotten County compared to the other counties.

We found strong linear relationships between bear observations in the LCOI and the independent density estimates for bears at the scale of local wildlife management units (each about 1,000-2,000 km^2) in four regional study areas (adjusted R^2 = 0.88-0.60) (Fig. 4). However, the slope of the regression lines differed significantly between Västerbotten and the three other study areas.

We also verified that the LCOI accurately reflected the distribution and the known minimum density of brown bears in Sweden. The distribution of brown bears, based on results from LCOI, compared well with the distribution of harvested bears within Sweden during the same period (Fig. 2, Paper III).

These 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. We also suggest that the relationship between the LCOI and density must be established for each area.

3.4 National and regional estimates of trend and population size (Paper IV)

Estimations of size and trends of bear populations are important for management. For population estimations, a DNA-based scat survey has been employed since 2001 in five of the six counties with established bear populations, and estimates have been calculated with CMR methods. The LCOI uses effort-corrected observations of bears by hunters during the moose hunt (> 2million observation hours/year) and has shown a good correlation with relative density of bears using the DNA-based method (Paper III). We calculated population trends from the LCOI for the period 1998-2007 and we estimated the yearly increase in the bear population (*r*) to be 0.044 at the national level, using an exponential model. In the different counties, the population trend varied between zero and 0.097 (Table 2). Dalarna and Västerbotten had no significant trend, whereas Jämtland and Norrbotten had relatively high rates of increase. The highest growth rates were found in Gävleborg and Västernorrland, which also are considered to be expansion areas.

We calculated the population size in each county with the point estimates obtained from the CMR of the DNA survey and extrapolating them using the trends from the LCOI in an exponential population model. To take the variation from both methods into account we used parametric bootstrapping (10,000 runs) of both the estimate of trend and population size. For the northernmost county, Norrbotten, a fecal survey was lacking, so we used assumptions based on data from the neighboring county to estimate population size (Table 2). The total population estimate for Sweden was calculated by randomly adding together all the 10,000 county estimates. The total estimate was a brown bear population of 3,298 (2,968-3,667) for 2008.

Table 2. Results from brown bear population estimates based on DNA in scats and trends estimated from the Large Carnivore Observation Index (LCOI) surveys in the different Swedish counties. The trends are based on data from 1998-2007 (1998-2006 for Gävleborg) and figures within brackets are confidence limits (95%).

County	DNA Survey year	CMR population estimate	Growth rate (*r*)	*p*	Estimated population 2008
Dalarna	2001	286 (251-337)	0	0.590	286 (251-337)
Gävleborg	2001	264 (232-311)	0.097 (0.036-0.157)	0.007	529 (352-759)
Västernorrland	2004	173 (148-249)	0.095 (0.022-0.169)	0.017	255 (171-364)
Västerbotten	2004	309 (265-401)	0	0.300	309 (265-401)
Jämtland	2006	906 (821-1043)	0.054 (0.019-0.088)	0.007	1009 (878-1151)
Norrbotten	*(2008)*	-	0.050 (0.021-0.079)	0.004	910 (713-1152)

The results from the population estimate show that the bear population in Sweden today is higher now than it has been for over 200 years (Swenson *et al.,* 1995). The population continues to grow and expand, but has not yet reached its maximal historical area of distribution. Both the LCOI and the scat sampling rely on a huge effort provided by volunteers that was crucial considering the large areas to be covered. Our results suggest that reliable information about the brown bear population can be obtained from volunteers, using standardized protocols for data collection.

4 General Discussion

4.1 Habitat

In this thesis I have covered the brown bear's habitat use at two different spatial scales and two different temporal scales. Both of these spatio-temporal scales are important for the management of brown bears (Gibeau *et al.,* 2002; Nams *et al.,* 2006; Ciarniello *et al.,* 2007).

To understand the population dynamics of brown bears we need to know where they are in the landscape, in relation to resources and disturbance. This is important for predicting future expansion areas and also hotspots for conflicts, e.g. livestock depredation, competition for game species, and the fear arising from bears occurring near people (Linnell *et al.,* 2001). Monitoring programs need information on distribution to design surveys. Bear densities can shift over short distances (Støen *et al.,* 2005) and not using large enough areas can bias the estimates (Woodroffe, 2000; Schwartz *et al.,* 2003).

Human disturbance may seem low in areas with few or small towns, but the more intensive use of outdoor activities in cabin areas or resorts can equal the disturbance from a town with a much larger permanent population size (Paper I). Some habitats are not as good as others. Bears avoid open habitats and areas closer to human disturbance. Bears living in these areas might have a lower probability of survival, due to legal hunting or the higher risk of coming into conflict with humans. Human disturbance might also affect reproduction. A female that is disturbed during the denning period and leaves its den has a higher chance of losing its cubs (Swenson *et al.,* 1997b). On the other hand, habitats closer to human settlements can be attractive both for reproducing females to avoid older males, to avoid infanticide (Mattson, 1990; Swenson *et al.,* 1997a) and by subadult individuals to avoid dominant adults, as well as to provide anthropogenic food resources (Mattson, 1990).

At the home range scale (Paper II) we studied how bears selected different habitats and how they used them, throughout the day and between seasons. The diel activity seems to be synchronized to avoid disturbance, with a short resting period during the night and a long during the day. The findings are in agreement with findings for adult brown bears in Slovenia and Croatia (Kaczensky *et al.,* 2006). Habitats used during the day rest period are in denser or more protected areas (Ordiz, 2010; Martin *et al.*, 2010). Brown bear populations in areas without or with low human disturbance in North America are more diurnal (Munro et al. 2006) than in Europe, but areas closer to humans in North America show the same nocturnal activity pattern (Gibeau *et al.,* 2002). A similar pattern has been observed in mountain lions (*Felis concolor*) (Van Dyke *et al.,* 1986). A way to explore this is to determine whether bears living in or close to national parks in Europe show a more day-active pattern. This should be possible to test in the future, as GPS-collared bears recently have been marked in these areas. For management authorities, this information is useful for informing the public about how to avoid unwanted bear contacts, for restricting activities that could cause disturbance, or to reducing the risk for livestock depredation.

Habitats are selected seasonally according to availability of food resources. In the pre-berry season, bears use clearcuts, which are a source of carpenter ants (*Camponotus spp.*) (Swenson *et al.,* 1999a) and forested bogs for predation on moose calves (Swenson *et al.,* 2007; Kindberg unpublished). In the berry season, mature mixed conifer forests are selected. If the main goal of habitat selection studies is to find which habitats are important to bears, it is crucial to differentiate between seasonal selection for active and resting habitats.

4.2 The role of volunteers in large carnivore surveys

The monitoring of bears presented in this thesis (Paper III and IV) could not have been accomplished without the help of a large number of volunteers, in our case mainly hunters. Almost 9,000 scats have been collected to be analyzed in the DNA-scat surveys covering over 160,000 km^2. In addition around 1,000 bear observations are made during seven days of moose hunting each year, during more than 2 million observation hours. This has enabled us to survey most areas where bears reside, even remote ones, as this is accomplished in combination with recreational activities (hunting). The costs for these surveys are mainly for administration and information in addition to genetic analysis (Schneider, 2006).

It is unusual for management authorities to rely on volunteers for large carnivore surveys but see Kojola *et al.,* (2006). Survey programs for other species relying on volunteers have mainly targeted bird species like the Breading Bird Survey (Johnson, 2007), large ungulates (Ericsson and Wallin, 1999; Solberg and Sæther, 1999), or, in the case of the Finnish wildlife triangles (Lindén *et al.,* 1996), both birds and mammals. It is also an advantage that an important group interested in the management of the species is directly involved in the data collection and therefore gains a higher trust in and understanding of the data (Newman *et al.,* 2003).

5 Conclusions

Based on the results from this study I conclude that:

1. The two independent methods, which we have developed and tested, are useful for monitoring the Swedish brown bear population and are able to provide management authorities with an index to follow the population trends in different areas over time and space, as well as distribution and statistically robust estimates of population size. These methods work on both a national and a regional level, the latter being where the management decisions are taking place nowadays.

2. The bear's habitat use differs spatially and temporally, at both the landscape and home range scales. Bears avoid human disturbance at the landscape scale, using habitats that are further away from human settlements. They avoid open areas and select resting and foraging habitats differently. Their diel activity pattern seems to be tailored to minimize contact with humans by resting during the day in dense vegetation and foraging at evening and night.

6 Future perspectives on management and research

From the LCOI we can obtain population trends of the bear population in different areas. According to available data, the population has increased in several counties (Paper IV). It is important that these trends are confirmed by a second DNA survey in each of the counties in an adaptive management manner, to test the reliability of the LCOI.

At the same time that the bear population has increased, harvest quotas have increased at an even higher pace. The effect of hunting cannot be seen immediately, as the effects of reduced reproduction or infanticide take time to come into effect. As the quotas for bear hunting increase, more hunters specialize in bear hunting and may become more effective (Bischof *et al.,* 2009). It is therefore important to target the effect of hunting on different groups of individuals, as well as where they are hunted. The presaturated dispersal in brown bears (Swenson *et al.,* 1998a) is one explanation for the fast expansion of the brown bear population, but if females are harvested in the expansion areas this can effectively stop the expansion.

Apart from increased livestock depredation, which today is a relatively small problem (Viltskadecenter, 2010), we can expect a higher mortality in game species as adult moose in the expansion areas are more susceptible to predation (Berger *et al.,* 2001). The Scandinavian Brown Bear Research Project has calculated the predation rate on moose calves (Swenson *et al.,* 2007) and the effect is a reduction in the number of moose calves by 22%. However, this figure probably will change if the ratio between numbers of moose per bear is reduced.

Large carnivore management is strongly influenced by the human dimension (Linnell *et al.,* 2001). Human attitudes are formed from several factors, usually involving education, urbanization, age, and income (Williams *et al.,* 2002b). A generally positive attitude towards bears in

Sweden was documented in 2004, with the lowest support in rural areas and where bear densities were highest (Ericsson *et al.,* 2008). Attitudes are more likely to change with personal experience (Williams *et al.,* 2002b; Ericsson and Heberlein, 2003). What will happen when bears expand into the areas with higher human densities and thus directly affect a larger part of the human population (see Fig. 5)? A repeat of the 2004 attitude study, made in 2009 (Sandström and Ericsson, 2009), showed a decreased support for bears in the counties with bear populations compared to the results from 2004. The fear of bears among people also has increased; especially in areas with a high bear density and with recent expansion (Ericsson *et al.,* 2010), suggesting that an increasing probability of encountering bears will affect the attitudes towards bears.

With bear populations expanding into areas with higher human densities, a reduced moose population, and a negative change in people's attitudes towards bears, the conflict between bears and humans is already increasing. Perhaps it is time to determine the "conflict-based carrying capacity" of bears in Sweden and where bears should be allowed to occur in higher densities to ensure population viability and public acceptance concurrently.

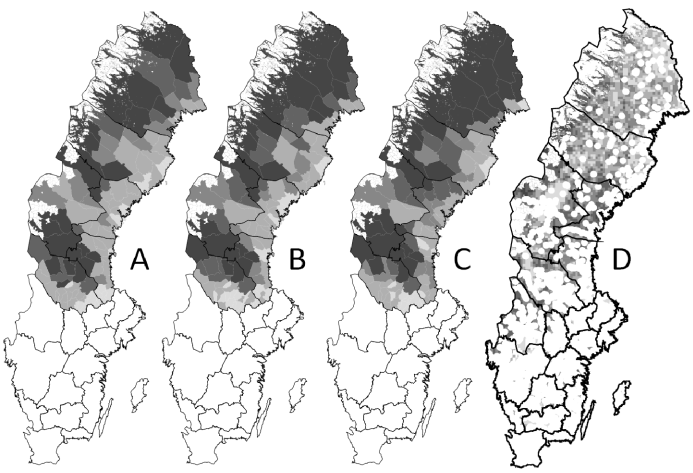

Figure 5. *Population expansion of brown bears in Sweden, based on effort corrected bear observations (the LCOI) for 1998-2000 (A), 2001-2003 (B) and 2004-2006 (C). Predicted suitable habitat using criteria from paper I, based on forest cover, terrain ruggedness, and areas > 10 km from villages, are shown as light gray to dark gray, where darker is better habitat for bears and areas < 10 km from villages as white (D).*

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All animal handling was approved by the Animal Care Committee and was carried out in accordance with the Swedish laws concerning animal research ethics. All personnel were certified according to the standards by the Swedish Animal Welfare Agency and the Swedish Board of Agriculture.

Swedish summary – Svensk sammanfattning

I samhället finns ett sort behov information om björnar baserat på vetenskapliga data. I Sverige har björnstammen, efter att den fredades i början av 1900-talet, ökat kraftigt. Två viktiga frågor i förvaltningen är förståelse för björnens val av habitat, i tid och rum och hur stor björnstammen är i olika områden. Det huvudsakliga syftet med denna avhandling har varit att bidra med kunskap och metoder för att hjälpa myndigheter och allmänheten med övervakning och förvaltning av den svenska björnstammen. Vi har använt radiomärkta björnar för att bestämma habitatanvändningen på två olika rumsliga skalor. För att se trender i björnpopulationen har vi använt oss av observationer av björnar som görs under älgjakten. Vi har identifierat antalet björnindivider i olika områden med hjälp av DNA från insamlade björnspillningar och gjort beräkningar av det totala antalet björnar med fångst-återfångst metoder. Dessa data kommer i princip uteslutande från ideella insatser och täcker i stort sett hela området där det idag finns björnar. Vi uppskattar den svenska björnstammen till 3298 (2968-3667) individer för 2008 och den årliga ökningen av björnstammen till att 4,5% för perioden 1998 till 2007. Björnar föredrar skogshabitat i kuperad terräng >10 km från tätorter eller stugbyar. De björnar som finns inom 10km från tätorter är i huvudsak yngre individer. Björnarnas habitatval på hemområdesnivå skiljer sig mellan perioder då de är aktiva och då de ligger i lega. De är mer aktiva under natten samt i gryning och skymning medan de i huvudsak vilar under dagen. Mina resultat i den här avhandlingen förser förvaltningen med information om utbredning, populationsstorlek och trender i den svenska björnstammen, på nationell såväl som regional skala. Vi har infört och testat en metod baserad på björnobservationer för att följa björnstammens utveckling och som bygger på observationer av björn under älgjakt, korrigerade med antalet

observationstimmar. Vi visar också att de bästa livsmiljöerna för björnar är områden som ligger långt bort från människor men att nyttjandet av olika områden skiljer sig mellan björnarnas ålder och kön. Jag rekommenderar en adaptiv förvaltning av björn i Sverige där man kontinuerligt utvärderar resultatet av populationsövervakning och förvaltningsbeslut mot uppsatta mål. För den framtida björnförvaltningen i Sverige, behövs bra vetenskapligt baserad information om björnens ekologi, demografi, samt att man inte glömmer bort människan i systemet.