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Brown bear *(Ursus arctos)* den site concealment in relation to human activity in Scandinavia

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Brunbjörnars (Ursus arctos) döljande av iden i förhållande till mänsklig aktivitet i Skandinavien

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Nyckelord: Brown bear, den site, denning habitat, cover, concealment, rugged terrain, human activity, infrastructure, sighting distance, villages, roads

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Abstract

As a hibernating species, the brown bear spend most of the winter months in a den as a strategy to avoid unfavorable conditions. The denning period is a vulnerable time for bears, making them unable to flee disturbances without losing valuable amounts of energy. Brown bears' wariness of humans and avoidance of anthropogenic disturbance often steer denning bears away from human infrastructure, and bears thereby avoid possible disturbance and its associated energetic costs. This study was carried out to test the hypothesis that bears denning closer to infrastructure select more covered den sites to compensate for the close distance. Dens from 32 individuals were visited and analyzed in terms of sighting distance (a measurement for den horizontal cover) and habitat ruggedness, in relation to distances to infrastructure. This study showed that bears tended to have more concealed dens and/or dens situated in more rugged terrain closer to roads and settlements with the highest human activity. Expanding human infrastructure might affect bear categories differently, since younger bears were shown to den closer to human activity areas than older bears. Close distance to human activity might therefore alter bears' natural behavior evolved to endure unfavorable conditions during winter. Undeveloped forest regions are important to decrease anthropogenic effects on bear denning behavior, and presumably also for the spatial distribution concerning different bear categories (e.g. age classes).

Sammanfattning

Som en övervintrande art så spenderar brunbjörnar de flesta av vintermånaderna i iden som en strategi för att undvika ogynnsamma förhållanden. Idesperioden är en känslig tid för björnar eftersom de då inte kan undvika störningar utan att därmed förlora värdefull energi. Brunbjörnars undvikande av mänskliga störningar driver björnar och deras idesområden bort från mänsklig infrastruktur och på detta vis undviker björnar möjliga störningar och de energimässiga kostnader som är förenade med dessa. Denna studie utfördes för att testa hypotesen att björnar väljer mer dolda idesplatser i de fall de är belägna närmare mänsklig aktivitet som en kompensation för det nära avståndet. Iden från 32 individer besöktes och analyserades med avseende på ”sighting distance” (ett mått för den horisontella täckhetssgraden) och graden av ojämn terräng, i relation till idenas avstånd från vägar och bebyggelse. Studien visade att björnar har mer dolda iden, och/eller iden belägna i mer ojämn terräng, närmare de bebyggelser och vägar med högst mänsklig aktivitet. Expanderande infrastruktur kan eventuellt påverka olika kategorier av björnar på olika sätt, eftersom yngre björnar i studien hade iden närmare mänsklig aktivitet i större grad än äldre björnar. Ett nära avstånd till mänsklig aktivitet kan därför förändra björnars naturliga beteende som selekterats för att utstå ogynnsamma förhållanden under vinterhalvåret. Obebyggda skogsområden är viktiga för att minska antropogena effekter på björnars beteenden när det gäller val av idesplatser och förmodligen också för den spatiella distributionen av olika björngrupper (t.ex. ålderklasser).

Introduction

Habitat choice theory and brown bear habitat choice

Habitat selection is defined as an animal's disproportionate use of various habitats in response to spatial heterogeneity (Morris & Brown 1992, Moe et al. 2007). There are many variables that determine the quality of a habitat. Food availability, distance to human settlements, predator occurrence and hiding cover are a few, and the constant trade-offs between using habitats with different proportions of these factors determines the derived fitness of an animal. Knowledge regarding habitat selection and spatial patterns can increase the understanding of evolutionary ecology and facilitate management of species (Morris & Brown 1992).
Brown bears (*Ursus arctos*) are often forest-dwelling animals (but their range also includes northern and alpine tundra). Throughout history, they have roamed the boreal and alpine forests across the northern hemisphere as large omnivores and top predators. In the Scandinavian countries, brown bear habitat is mainly constituted by conifer and mountain birch forests, often with abundant vegetation (Curry-Lindahl 1988). As a hibernating species, brown bears spend most of the winter months in a den as a strategy to avoid unfavorable conditions (Manchi & Swenson 2005; Friebe et al. 2001). Denning habitats as well as den structure varies among populations and areas across the brown bear range. In Scandinavia, the den is often made from an old ant hill, but other common types are for example caves, excavations in sloping ground or under the base of trees (Linnell et al. 2000; Ciarniello et al. 2005). According to Elfström (2008), the most preferred denning habitats in south-central Sweden are open canopy forests, like those of Scots pine (*Pinus sylvestris*), with rich vegetation and moist soils. Closed canopy forests are not preferred to the same extent, nor are clear-cuts, young forest or bogs. Habitat types being avoided are for example deciduous forests, alpine mountain-birch forests and exposed bed rock. Most likely, denning in or directly adjacent to bogs or swamps increase the risk of inundation of the den, and therefore also a possible abandonment (Hellgren & Vaughan 1989, Elfström 2008).

Brown bear denning physiology and associated costs

In the den during the winter months brown bears enter an energy-saving mode, with no intake of water or food (Folk et al. 1972). In the preceding late summer and fall bears enter hyperphagia, eating immense quantities of especially berries to accumulate fat reserves, which serve as an energy and water source during the whole denning period (Linnell et al. 2000). After den entry in the fall, all metabolic waste products are stored and no urination or defecation takes place (Folk et al. 1972; Ramsay & Dunbrack 1986). Denning bears, with a lowered heart rate, metabolism and body temperature (from 37°C to 33°C) (Folk et al. 1972; Hissa et al. 1994; Watts & Jonkel 1988), are adapted to endure low food availability during winter. Enclosed inside the den, with a bedding of mosses, twigs and branches, bears reduce the loss of body heat and lower their rate of energy loss, as the den itself and the trapped air inside functions as an insulating coating (Linnell et al. 2000; Ramsay & Dunbrack 1986). During the denning period bears lose an average of 0.4 kg/day (Watts & Jonkel 1988) or approximately up to 20% (males) to 40% (females) of the total body weight in one winter (Swenson et al. 1997). In Scandinavia, the loss in body mass seem to be higher compared to bears in southern Europe, probably because of the longer

denning period at northern latitudes (Swenson et al. 2007). Thus, the denning period is a vulnerable time in the bears' annual cycle, and is a period when bears are especially negatively affected by disturbances, since they are less mobile without any food source available (Linnell et al. 2000; Servheen & Klaver 1983).
Depending on the degree of disturbance and when during the denning period it occur, a disturbance can have different effects on bears. Increased activity inside the den or den abandonment are two outcomes (Schoen et al. 1987), where abandonment would be the one with the greatest cost. Swenson et al. (1997) showed that females with cubs of the year that abandoned their dens had an increase in mortality among their cubs compared to other females. This implies that there is a fitness cost to den abandonment, with a direct negative effect on reproduction, and might therefore act as an evolutionary force. Furthermore, a disturbed bear with repeated movements and increased activity inside its den is presumably also negatively affected in terms of increased energy use and accompanying stress (Linnell et al. 2000; Podruzny et al. 2002), making the selection of a reliable den rather critical.

Human effects on brown bear habitat selection and denning behavior

During the 19th century, Scandinavian brown bears were hunted extensively (Swenson et al. 1995), a persecution that might have caused the wary behavior of bears today. Swenson (1999) reviewed studies regarding this matter and concluded that there in some cases seemed to be tendencies for hunted populations to avoid human activity. The hunting and persecution seem to impose a change in brown bear habitat choice, making bears avoid humans and human infrastructure. If populations are hunted to a large extent, it is possible that the derived wariness may have a genetic component, increasing a population's wariness as bolder individuals are being removed and therefore causing a selection favoring the more wary individuals. However, in areas where brown bears have particularly large home ranges and therefore disperse readily, the wariness pattern is more likely to be of ontogenetic origin (Craighed et al. 1995), with individuals learning and developing the wary behavior during their life time.
Brown bears' wariness of humans and avoidance of anthropogenic disturbance occurs on a spatial as well as a temporal scale. From previous studies bears are known to avoid areas where disturbance is evident, leading to a displacement of their former selected home ranges or relocating to other, more undisturbed localities and terrains (Nellemann et al. 2007; Rode et al. 2006). A study conducted in Scandinavia (during the non-denning season) shows that bears preferred rugged terrain far from human settlements and resorts (Nellemann et al. 2007). In this study, subadults were in general closer to human activity than adults, presumably as a result of being forced out of the undisturbed areas occupied by older males and reproductive females. This indicates that there can be differences in relation to age, sex and social organization when it comes to effects of human activity. On a temporal scale, brown bears use different types of habitat depending on the time of day (Moe et al. 2007) and bears have been shown to select different habitats throughout the day depending on the degree of human activity. Roth (1983) showed that bear populations exposed to higher human activity were more nocturnal than other populations, indicating that bears were active at times when the chances of human encounters were lower.
Most often, denning areas are situated in areas away from human infrastructure, and bears thereby avoid anthropogenic disturbance and its associated energetic costs (Linnell et al. 2000; Schoen et al. 1987). Schoen et al (1987) showed that bears are influenced by human activity when they select den sites, as they chose undisturbed areas away from mining activities. In another study conducted in Slovenia on cave-denning bears, bears did not use

available caves if the caves were closer than 540 meters to villages (Petram et al. 2004) and in Scandinavia bears preferred denning in areas more than 1 km away from roads and 3 km away from villages (Swenson et al. 1996). Furthermore, bears have also been shown to den farther away than expected from roads that combined a high traffic-level with easy access to the surrounding areas (e.g. with possibilities to park along the road), (Elfström et al. 2008). High-traffic roads have in addition shown to be important for bears in terms of vehicle-related mortality and for their effect on home range boundaries (Kazcensky et al. 2003). Petram et al. (2004) concluded that denning bears tend to prefer landscape types with low chances of human encounters. In their study many types of caves were used for denning if they were situated in rugged areas, i.e. steep and rocky terrains, where people rarely go. In comparison, only deep caves or caves with small entrances were used in accessible areas. The general pattern is that denning bears avoid human activity and infrastructure.

Objective of Study

According to the literature cited above, bears are selecting den sites far from human activity. Depending on where bears have their home ranges, they might not have a choice to den far away from human activity. It is thus possible that bears forced to den closer to human activity select areas with more vegetation cover and undulating landscape types that would cover their dens than bears denning farther away. Bears would in this sense compensate for closer distances to settlements and roads with more concealed den sites.

This leads to the following prediction:

> Brown bear dens closer to human infrastructure and activity should be more concealed than dens farther away, i.e.; bears would compensate for a closer distance to human settlements or activity with increased horizontal cover around the den and more rugged terrain.

As human activities expand into undeveloped areas, it is becoming increasingly important to understand what kind of den sites brown bears select (Ciarniello et al. 2005). The brown bear population in Scandinavia is expanding into their former range and increasingly getting into contact with humans and human populated areas. Furthermore, denning bears can be aggressive and disturbances near den sites have earlier resulted in dangerous situations (Swenson et al. 1999). Knowledge about den site selection is important to avoid disturbance of brown bears during their most vulnerable time of the year, and to avoid conflicts with humans.

Methods

Study area

The study area was situated in Dalarna and Gävleborg counties in south-central Sweden (68^{o} N, 14^{o} E), (Figure 1). The dens visited were located in a topographically diverse landscape dominated by coniferous forest, mostly made up by Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) forests and a small fraction of Lodgepole pine (*Pinus contorta*) plantations. The less abundant deciduous trees are constituted mainly by birch (*Betula pendula* and *B. pubescens*), mountain ash (*Sorbus aucuparia*) and Salix (*Salix* spp.) and grow mostly in early succession stages on plantations, in connection to the frequent bogs or as single trees interspersed in the surrounding coniferous-dominated forests. The road network is well developed in the area, with many small gravel roads mainly constructed by the forest industry for logging. There are larger gravel roads connecting small communities, a sparse amount of paved roads and one large paved road dissecting the area from north to south (E45). Hunting cabins, summer houses and smaller communities are distributed across the area and there are also a few villages.

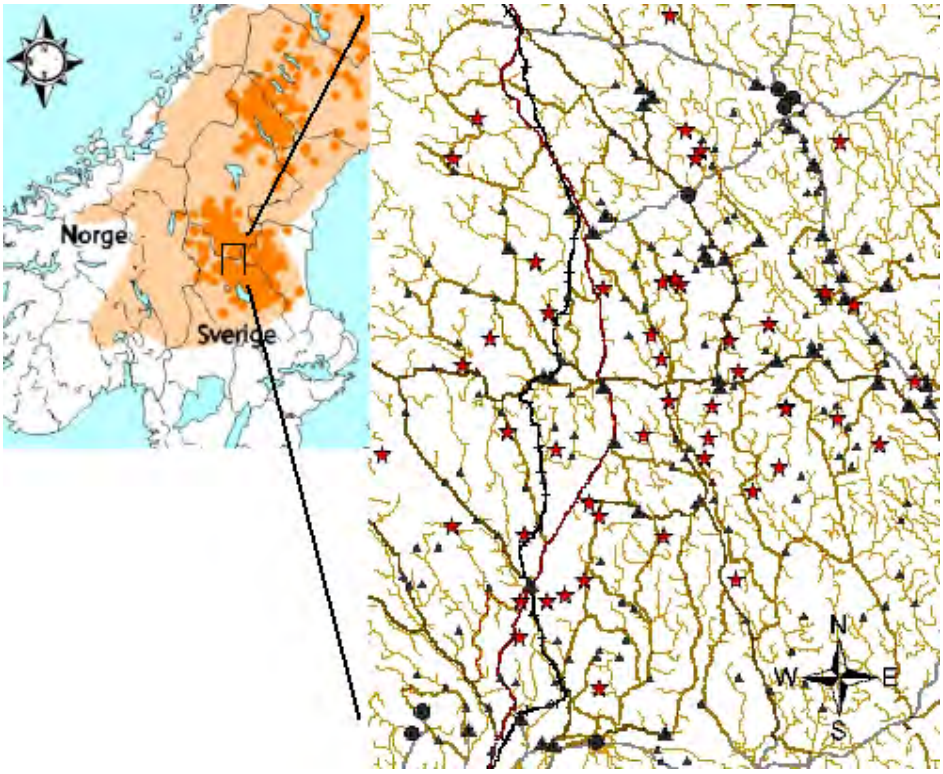

Figure 1. The study area in Dalarna and Gävleborg counties. Red stars represent dens visited, surrounded by the extensive road network and varying sizes of human settlements (round dots = villages, large triangles = smaller communities, small triangles = summer houses and cabins), (Insert map: Scandinavian Brown Bear Research Project).

Selecting dens to describe

Even if dens are constructions that can last several years, their surrounding environments are in an ongoing succession, changing characteristics as time goes by. Since there were a limited number of marked bears available for this study, there was a trade-off between the number of replicates and the age of the dens to collect data from. Dens from GPS-collared bears from winter 2002/2003 and onward were visited, and no data was collected from den sites if they were considered unrepresentative to the characteristics of those sites at the time when the bears were denning there, e.g. in case of apparent logging or thinning (Figure 2).

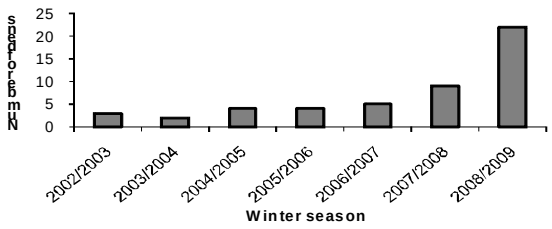

Figure 2. Distribution of the age of dens in the study.

Estimating den concealment and ruggedness of den sites

There are two factors that particularly reflect a forest site; the vegetation and the terrain. Both have an effect on the concealment of a den to a varying extent. The horizontal cover represents the visibility of the den from ground level. The horizontal cover was measured by placing a cylinder-shaped device (60 cm high, 30 cm wide) at the entrances of the dens and measuring the minimum distance required for the device to be completely hidden, hereafter referred to as sighting distance, in all four cardinal directions (Ordiz et al. 2009[1]). The mean of these four distances were later used for analyses. The ruggedness of the terrain was estimated and described as the loss of visibility due to landscape characteristics in a circle with radius of 30 metres, with the den situated at the center, hereafter referred to as a plot (Table 1). The general habitat type within the plots was also documented. Sighting distance and ruggedness were analyzed in relation to the distance to roads and settlements (Table 2). Distances to these different classes of infrastructure were measured in ArcGIS. Differences regarding age, sex, and female reproductive status (i.e. if they had cubs or not) were considered in the analyses. A total of 49 dens from 32 individuals were visited and analyzed (see Figure 1). One den was in such rugged and steep terrain that sighting distance was not measured and analyses regarding sighting distance therefore have 48 replicates. The general habitat was coniferous forests on mesic or dry soils.

[1] Ordiz, A., Støen, O.G., Langebro, L.G., Brunberg, S. & Swenson, J.E. 2009: A practical method for measuring horizontal cover. Ursus 20: In press.

Table 1. Classifications of the degree of ruggedness within the plots.

Ruggedness	Description
Smooth	Rocks > 1m height spread over an area covering < 10 % of the plot, no undulations which prevent direct line of sight to other part of the plot
Medium	Rocks > 1m height spread over an area covering > 10 % - < 50 % of the plot, or 1-2 undulations which prevent direct line of sight to other part of the plot
Rugged	Rocks > 1m height spread over an area covering > 50 % of the plot, or ≥ 3 undulations which prevent direct line of sight to other part of the plot

Statistical analyses

Statistical analyses were performed in R (www.R-project.org). All data was checked with a Shapiro test for normality. For analysis of the effects of infrastructure on sighting distance, generalized linear models were used. Since the models with individual bears as random effect only explained a small fraction of the variance, the simpler models with pooled data across individuals were used. The variables age, sex and females' reproductive status were tested for effect on cover. ANOVA analyzes were used to test if rugged terrain was used to a greater extent closer to infrastructure. Because pooling data across individuals or not gave different results in the ANOVA analyzes, individuals were included as a random effect. The same was true for the generalized linear models regarding distances in relation to age. To test if preferences for rugged terrain differed between males and females, and between single females and females with cubs, Fisher's Exact Test for Count Data was used. Because villages are situated along main roads there was an auto-correlation between the infrastructure classes "secondary paved road" and "villages", because a den can not be close to a village and at the same time far away from a secondary paved road. However, as the opposite can be true, both classes were used in the analyses. A significance level of 0.05 was accepted.

Table 2. The infrastructural classes used in the analyses of cover at brown bear dens in relation to distance to human activities in central Sweden.

Activity level	Description
Settlements	
Villages	Larger communities. Villages and towns.
Small communities	Permanent settlements used throughout the year. Single house to small communities.
Summer houses and cabins	Summer houses/hunting cabins/forest cabins. Varying and unpredictable activity between and within seasons.
Roads	
E45	Larger paved road through the area. European highway with generally high speed transportation. Inland connection between northern and southern Sweden.
Secondary paved roads	Main roads within the district. Connects larger communities.
Main gravel roads	High standard gravel roads. Connects larger roads and minor communities.
Medium gravel roads	Gravel roads of good standard with a relatively constant but minor traffic. Typically connecting larger roads, minor communities and recreation sites.
Minor gravel roads	Gravel roads of varying quality. The activities associated with these are occasional and unpredictable, e.g. forestry, recreation, berry picking, hunting and fishing.
Railroad	Railroad. Mostly used for cargo transportation.

Results

Sighting distance tended to decrease with decreasing distance to villages (β = 1.737e-05, Std. Error = 8.650e-06, t = 2.008, d. f = 47, p = 0.051, Figure 3), but no such effect was seen with distance to small communities or summer houses and cabins. The degree of ruggedness did however not change with distance to villages or to any of the smaller settlements. Sighting distance showed a tendency to decrease with decreasing distance to secondary paved roads (β = 1.731e-05, Std. Error = 9.734e-06, t = 1.779, d. f. = 47, p = 0.082, Figure 4), but no such effect was seen with distance to other road types or to the railroad. The degree of ruggedness increased with decreasing distance to secondary paved roads ($F_{2,29}$ = 4.01, p = 0.029, Figure 5), but not with distance to any of the other road types or to the railroad. No differences due to age, sex or females' reproductive status were found in terms of either sighting distance nor terrain in relation to distance to infrastructure. The distance from the den to the closest village and secondary paved road tended to increase with age of the denning bear (β = 476.9, Std. Error = 246.0, t = 1.939, d. f. = 16, p = 0.070, and β = 445.1, Std. Error = 237.6, t = 1.873, d. f. = 16, p = 0.079 respectively, Figure 6).

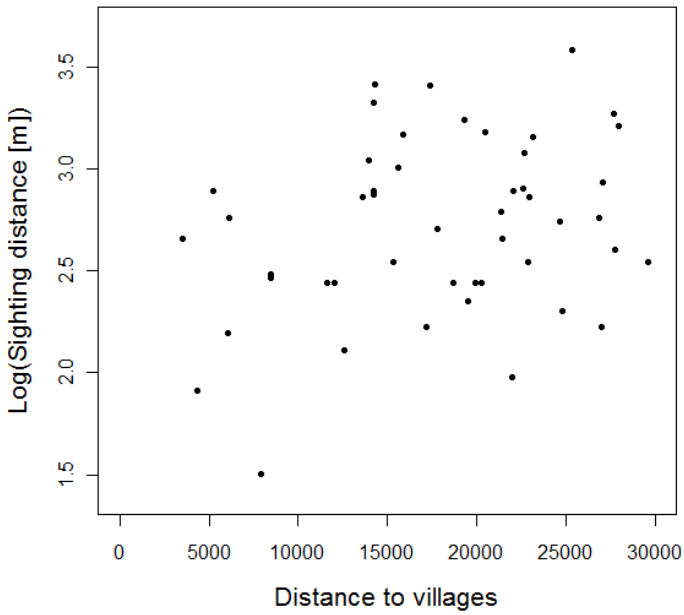

Figure 3. The sighting distance at brown bear den sites in relation to the distance (m) to villages in central Sweden.

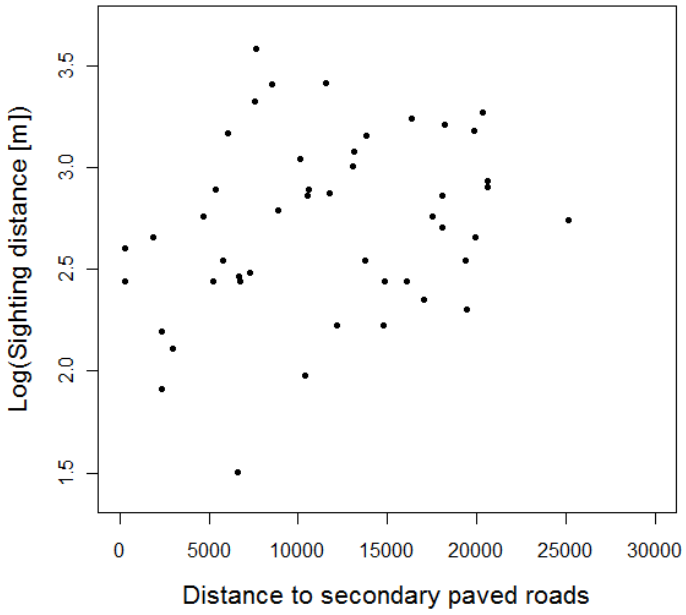

Figure 4. The sighting distance at brown bear den sites in relation to the distance (m) to secondary paved roads in central Sweden.

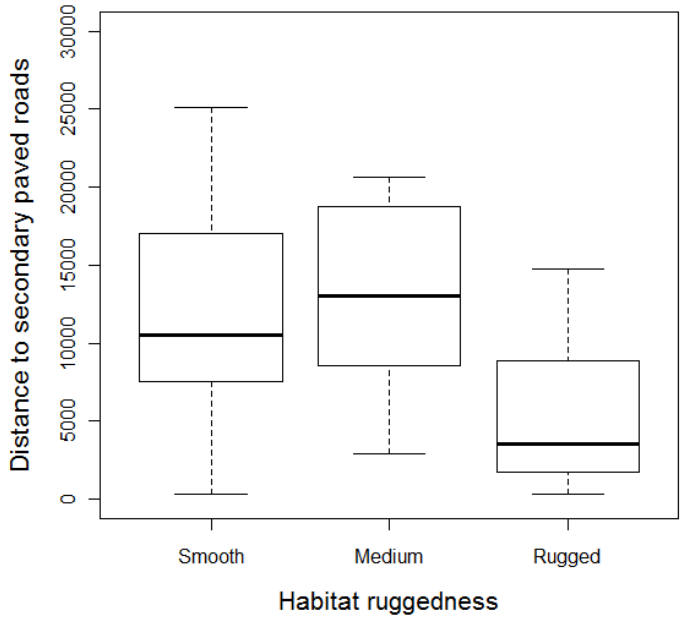

Figure 5. The degree of ruggedness at brown bear den sites in relation to the distance (m) to secondary paved roads in central Sweden.

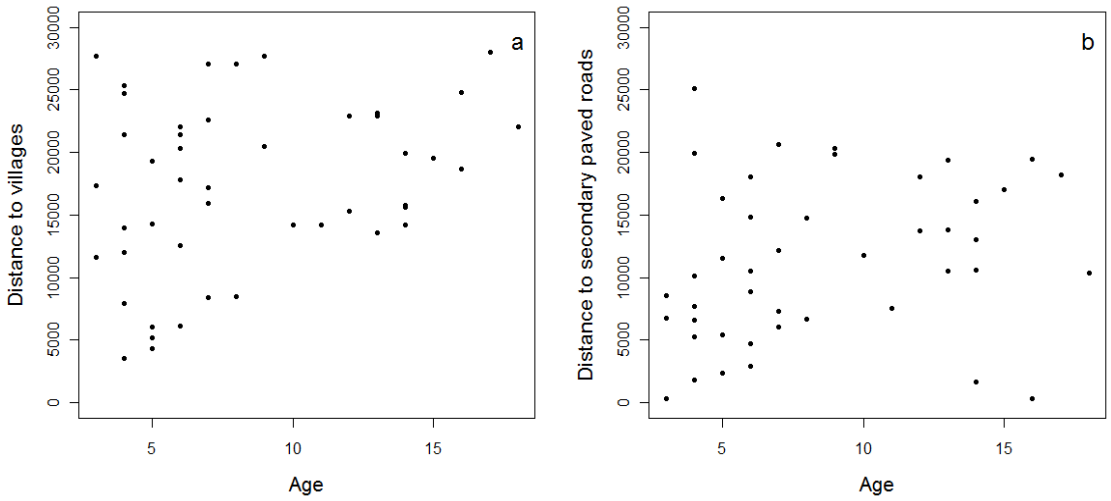

Figure 6. The age of denning brown bears in the study in relation to the distance (m) between their dens and the nearest village (a) and secondary paved road (b) in central Sweden.

Discussion

I found that brown bears selected den sites with shorter sighting distance closer to villages. This suggests that denning bears tended to select for more concealed den sites closer to these areas. No such relationship was found for the smaller settlements. Swenson et al. (1996) showed that denning bears avoided villages to a greater extent than single houses. From their results they further concluded that the level of human activity was the determining factor for this avoidance and not the actual buildings. Since the level of human activity is higher (and probably several times higher) within and around villages compared to the smaller settlement classes, villages do likely have a much larger effect on the bears' use of cover. Furthermore, some of the small permanent settlements only consist of single houses which give rise to less amount of disturbance.

Dens closer to the secondary paved roads were situated in more rugged terrain. However, dens closer to the even larger E45 did not show this pattern. The secondary paved roads are indeed roads with high human activity, connecting permanent settlements, primarily villages but also smaller communities, in the area. This road type is readily used, with the possibility to park along the side of the road for e.g. berry-picking and recreational purposes, in comparison to E45 where parking is almost impossible because of safety reasons. Even though the traffic is more intense, the access to the surrounding area is fairly low, resulting in low human off-road activity. The same is true for the railroad, as its main use is for transporting cargo. Thus, bears selected more covered den sites closer to the road class that probably exposed its surroundings to the highest amount of human activity. There was also a trend for sighting distance to be shorter closer to the secondary paved roads. Similarly, in a study conducted by Elfström et al. (2008), bears were shown to avoid secondary paved roads but to actually select den sites closer to the largest highway class than would be expected. However, in their study bears denned farther away from larger gravel roads than expected, a road class that did not affect the degree of concealment of dens in this study. The roads in this road class apparently either have too low human activity to affect bears in this manner, or bears simply placed their dens at satisfying

distances from these roads in relation to the low disturbance probabilities. In contrast to this study and the results from Elfström et al. (2008), Swenson et al (1996) found an increasing avoidance with increasing road standard, where highways were the road type that were avoided the most. Because all villages were situated on (or very close to) secondary paved roads, the auto-correlation that ensues makes it difficult to separate the effects of these infrastructure classes. On a broader scale, villages and larger roads like these will supposedly often occur together in other areas as well and affecting denning bears simultaneously. Effects posed by linear objects like roads can however be important to evaluate separately because they can function as extended barriers across the landscape (Kazcensky et al. 2003).

This study shows that human activity not only affects bear selection of denning areas but also a smaller-scale den site selection in terms of cover. Increased knowledge about anthropogenic effects on bear behavior such as this can add to a broader understanding of brown bear habitat selection. Bears can probably use vegetation and terrain in various ways to avoid human activity. Relatively dense vegetation and rugged terrain most likely provide bears with more opportunities for concealed den sites. However, such areas may also decrease the probability of people going there because of the demanding conditions, thus acting as another influencing factor bear den site selection. Bears might also have a varying need for cover due to obstacles situated between the den and human infrastructure, factors not possible to measure in this study. It would for example be possible for a bear to have its den site close to a road but with a separating creek, dense brush or precipice somewhere in between, decreasing the need for cover at the actual den site.

Even if preferences for more covered habitats closer to infrastructure were found in this study, no differences concerning age, sex or female reproductive status were found. However, previous studies have shown that younger bears often are forced away from remote occupied areas where older individuals dwell, into secondary, unoccupied areas closer to human activity (Nellemann et al. 2007). This pattern was also found in this study (see Figure 6) and is confirming that these particular high activity areas affect bear den site selection. Bears that might be more or less forced to den closer to these areas, possibly due to social organization among the bears, indeed seem to make the best out of a bad situation by covering their dens to a greater extent. Concerning females with cubs, it is possible that most of them, and especially older ones, den at a relatively longer distance from infrastructure as mostly younger bears are pushed close to human activity. Furthermore, in many of the cases when females with cubs were closer to high human activity they had their dens in rugged terrain. However, differences between bear categories in terms of increased cover closer to human activity were probably difficult to detect due to the low sample size.

Conclusions and implications for management

Scandinavian brown bears are wary and avoid high human activity areas. In previous studies it has been shown that bears avoid denning close to human activity, presumably due to the enhanced risk of human disturbance (Elfström et al. 2008). My study supports these findings, as I found that bears denning closer to villages and large roads compensated for high human activity in their surroundings by selecting den sites with more cover. Cover opportunities and terrain types not preferred by humans are thereby presumably important for bears denning relatively close to human activities. As villages expand and new roads are

built, human activity relentlessly expand into formerly undisturbed areas, affecting bear behavior. A continued fragmentation of present bear ranges inhibiting dispersal, together with an increasing bear population, might lead to bears denning closer to human activities than at present. This can alter the fine-scale den site selection for these bears, and therefore also their naturally evolved behavior to endure unfavorable conditions during winter. Therefore, undeveloped forest regions along with corridors for dispersal are probably important to decrease anthropogenic effects on bear denning behavior.

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