Brown bear den site concealment in relation to human activity in Sweden

Ellinor Sahle1, Ole-Gunnar Støen1,2,4, and Jon E. Swenson2,3

1Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences, SE-901 83, Umeå, Sweden
2Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, NO-1432, As, Norway
3Norwegian Institute for Nature Research, NO-7485, Trondheim, Norway

Abstract: Brown bears (Ursus arctos) in Scandinavia spend 5–7 winter months in dens. The denning period is a vulnerable time for bears because they are unable to escape from disturbances without losing valuable amounts of energy. Bears normally avoid human infrastructure when denning, but due to an expanding bear population some bears den relatively close to humans. We tested the hypothesis that bears denning closer to infrastructure selected more concealed den sites, as they do when selecting resting sites in the non-denning season. We analyzed horizontal cover and terrain ruggedness relative to distance from human infrastructure for 49 dens from 32 individuals differing in sex, age, and reproductive status. Bears used dens that were more concealed or located in more rugged terrain when closer to roads and settlements that had potential for high human activity. Our results suggest that human activity affects not only where bears den, but also the smaller-scale characteristics of den sites: cover and terrain. Increased knowledge about anthropogenic effects on bear denning behavior can add to a broader understanding of brown bear habitat use.

Key words: brown bear, concealment, cover, den site, human activity, rugged terrain, Scandinavia, Ursus arctos

Increased knowledge about the physiological adaptations of brown bears (Ursus arctos) to endure low food availability during winter has led to a greater understanding of their vulnerability in the denning season (Linnell et al. 2000). During hibernation, brown bears’ heart rate, metabolism, and body temperature decrease (Folk et al. 1972, Watts and Jonkel 1988, Hissa et al. 1994), accumulated fat reserves serve as an energy and water source (Linnell et al. 2000), and bears neither urinate nor defecate (Folk et al. 1972, Ramsay and Dunbrack 1986). During the denning period, male bears can lose up to 20% and females 40% of their body mass (Swenson et al. 1997). Brown bears in northern latitudes in Scandinavia spend 5–7 months in a den and lose more body mass than do bears in southern Europe, probably because they den for longer periods (Swenson et al. 2007). Thus, the denning period is a vulnerable time in the annual cycle when bears can be especially negatively affected by disturbance (Servheen and Klaver 1983, Swenson et al. 1997, Linnell et al. 2000).

The effects of disturbance on denning bears can vary depending on the degree and timing of the disturbance. Increased activity inside the den and den abandonment are possible outcomes (Schoen et al. 1987), with abandonment presumably having the greater cost. Swenson et al. (1997) showed that cub mortality was greater among females that abandoned their dens than for those that did not. This implies that there is a fitness cost of den abandonment, which emphasizes the importance of selecting a den site with a low probability of disturbance.

During the 19th century, Scandinavian brown bears were hunted extensively in an eradication attempt (Swenson et al. 1995). The brown bear population in Sweden is now expanding (Kindberg et al. 2011), but persecution in the past might be a factor causing the wary behavior of Scandinavian
bears today (Swenson 1999). Their wariness of humans and avoidance of anthropogenic disturbance occurs on both spatial and temporal scales. From previous studies, we know that bears avoid areas where humans are concentrated (Rode et al. 2006, Nellmann et al. 2007). Nellmann et al. (2007) showed that bears preferred rugged terrain far from human settlements and resorts, and that subadults were generally found closer to human activity than adults, suggesting sex and age differences in avoidance of human activity. Despite this documented general avoidance of human activity, some bears establish home ranges with human presence. Bears with high levels of human disturbance may compensate by using areas with more rugged terrain, especially during the times when they are likely to encounter people (Martin et al. 2010). Also, bears frequently avoid anthropogenic disturbance and its associated energetic costs by placing winter dens away from human infrastructure (Schoen et al. 1987, Linnell et al. 2000, Goldstein et al. 2010).

There is a free right of trespass on private lands in Sweden, and areas with easy access for people may be subject to considerable amount of human activity. In Sweden, bears have been shown to prefer to den in areas >1 km from roads and 3 km from villages (Swenson et al. 1996), and farther than expected from roads that combine a high traffic intensity with easy access to the surrounding areas (e.g., with possibilities to park along the road; Elfström et al. 2008). In the latter study, bears showed no avoidance of the international highway with the highest amount of traffic (E45), which the authors interpreted as resulting from the low level of access from surrounding areas for people traveling along that route. Correspondingly, bears are more prone to abandon their dens if they are located closer to snow-plowed roads (Elfström and Swenson 2009). Petram et al. (2004) found that denning bears used many types of caves for denning if they were situated in Rocky areas that people rarely visited, but only deep caves or caves with small entrances in areas more accessible to people.

Many wildlife species use cover to avoid human disturbance, presumably because of the reduced detection risk (see Sunde et al. 1998, Revilla et al. 2001, Støen et al. 2010). During the non-denning period, brown bears select resting sites that are more concealed when the risk of human encounters is higher and when resting closer to human settlements (Ordiz et al. 2011).

We hypothesized that Scandinavian brown bears would behave similarly when choosing den sites as when choosing resting sites in the active period (concealment of den sites and terrain ruggedness would increase as distance to human activity decreased). Knowledge about den site selection is important to avoid disturbing brown bears during their most vulnerable time of the year and also to help humans avoid surprising bears at den sites (which can result in human injury; Swenson et al. 1999).

Study area

The study area was situated in Dalarna and Gävleborg counties in south-central Sweden (61°N, 15°E), a topographically diverse landscape dominated by Scots pine (Pinus sylvestris) and Norway spruce (Picea abies) forests. The less abundant deciduous trees were mainly birch (Betula pendula and B. pubescens), mountain ash (Sorbus aucuparia), and willows (Salix spp.) and occurred mostly in early successional stages on plantations, near bogs, or as single trees interspersed in the conifer-dominated forests. The road network was well developed in the area, with many small gravel logging roads. Hunting cabins, summer houses, and smaller communities and villages were distributed throughout the area.

Methods

During 2009, we visited 53 dens used by 32 GPS-collared bears during 2002 to 2009. Visits were made during daylight hours, throughout June and July. Vegetation around dens can change over time or due to logging or thinning of the forest. Four of the den sites had changed since the bears had denned there, and were not measured. One den was in such rugged and steep terrain that sighting distance was not measured, and analyses regarding sighting distance therefore had 48 replicates.

Both vegetation and terrain can conceal a den. We measured horizontal cover at den sites using sighting distance, or visibility of a cover cylinder (60 cm high, 30 cm wide) at the den entrance from ground level (Ordiz et al. 2009). The minimum distance required for the device to be completely hidden was measured in all 4 cardinal directions, and the mean of these was used for analyses. We estimated terrain ruggedness as the loss of visibility due to landscape characteristics in a circle with a radius of 30 meters, with the den situated at the center, hereafter referred
to as a plot (Table 1). We analyzed sighting distance and terrain ruggedness relative to distance from roads and settlements (Table 2) using a geographical information system (GIS; ESRI® ArcMap™ 9.2, Redlands, California, USA). In conjunction with another study on brown bear resting sites, we visited 412 random plots in the study area from May to October 2007 and measured sighting distances (Ordiz et al. 2011).

**Statistical analyses**

We performed all statistical analyses in R (R Development Core Team 2009) after the data were checked for normality with a Shapiro test. Data were log$_{10}$ or square-root transformed when non-normal. We used generalized linear mixed models (lme in the nlme package in R) to investigate the effects of infrastructure on cover at den sites, with sighting distance as a response variable, distances to infrastructure as explanatory variables, and individual bears as random effects. We tested relationships between terrain ruggedness (flat, moderate, or rugged) at den sites and distance from infrastructure with two-way ANOVA and Tukey HSD (honestly significant difference) tests. Villages are situated along main roads, creating a correlation between the infrastructure classes “secondary paved road” and “villages,” because a den could not be close to a village and at the same time far from a secondary paved road. However, because a den could be close to a road but far from a village, both classes were used in the analyses. Similarly, we used both sighting distance and ruggedness, because sighting distances could be affected by terrain in both rugged areas and by vegetation in flat areas. We regarded statistical tests as suggestive if $\alpha < 0.10$ and as significant if $\alpha < 0.05$.

**Results**

Sighting distances at den sites had positive relationships with distance to villages (Table 3, Fig. 1), but we observed no relationship between sighting distance and distances from small communities, or summer houses and cabins (Table 3).

---

**Table 1. Classification of the degree of ruggedness used in the analysis of brown bear den sites in central Sweden, 2002–09. The plot is a 30-m radius circle centered on the den.**

<table>
<thead>
<tr>
<th>Ruggedness</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>Rocks $&gt;1$ m height spread over an area covering $\leq10%$ of the plot, no undulations which prevent direct line of sight to other part of the plot.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Rocks $&gt;1$ m height spread over an area covering $10%$ to $50%$ of the plot, or $1–2$ undulations which prevent direct line of sight to other part of the plot.</td>
</tr>
<tr>
<td>Rugged</td>
<td>Rocks $&gt;1$ m height spread over an area covering $&gt;50%$ of the plot, or $\geq3$ undulations which prevent direct line of sight to other part of the plot.</td>
</tr>
</tbody>
</table>

**Table 2. Classification of infrastructure used in the analysis of brown bear den sites in central Sweden, 2002–09.**

<table>
<thead>
<tr>
<th>Activity level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settlements</td>
<td></td>
</tr>
<tr>
<td>Villages</td>
<td>Communities with $&gt;50$ inhabitants and with constant human activity throughout the year</td>
</tr>
<tr>
<td>Small communities</td>
<td>Communities of $&lt;50$ inhabitants with constant human activity throughout the year, summer houses, hunting cabins, and forest cabins that are not inhabited permanently and have varying and unpredictable activity between and within seasons, usually with a higher activity during summer, berry season, and hunting season</td>
</tr>
<tr>
<td>Summer houses</td>
<td></td>
</tr>
<tr>
<td>Roads</td>
<td></td>
</tr>
<tr>
<td>E45</td>
<td>This major paved road is a European highway and the inland connection between northern and southern Sweden, with high speed and relatively constant traffic</td>
</tr>
<tr>
<td>Secondary paved roads</td>
<td>Main paved roads connecting larger communities; relatively high activity and opportunities to stop and park along the road</td>
</tr>
<tr>
<td>Main gravel roads</td>
<td>Well-maintained gravel roads that connect larger roads and smaller communities and have moderate, relatively constant traffic</td>
</tr>
<tr>
<td>Medium gravel roads</td>
<td>Gravel roads with a lower level of traffic than main gravel roads, typically connecting larger roads, smaller communities, and recreation sites</td>
</tr>
<tr>
<td>Minor gravel roads</td>
<td>Gravel roads of varying quality; associated with these are occasional and unpredictable activity such as forestry, recreation, berry picking, hunting, and fishing</td>
</tr>
<tr>
<td>Railroad</td>
<td>Railroad, mostly used for cargo transportation</td>
</tr>
</tbody>
</table>
Sighting distance at den sites also displayed positive relationships with distance to secondary paved roads (Fig. 2), but increased with decreasing distance to the railroad (Table 3). We found no relationships between sighting distance and other categories of roads. No relationship was found between sighting distance at random plots and distance to nearest settlement or road.

Den sites classified as being in rugged terrain were significantly closer to secondary paved roads than den sites in either moderate or flat terrain but tended to be farther from the railroad than den sites in moderate or flat terrain, and from the major highway (E45) than den sites in moderate terrain (Table 4). We found a suggestion that den sites in rugged terrain were closer to summer houses than den sites in flat terrain (Table 4).

**Discussion**

We found patterns suggesting that brown bears denned in denser cover when closer to villages. Swenson et al. (1996) showed that denning bears avoided villages to a greater extent than they avoided single houses. They concluded that the level of human activity, and not the actual buildings, was the determining factor for this avoidance. Because the level of human activity is probably several times higher within and around villages than in smaller settlements, villages likely have a larger effect on the

| Table 3. Linear mixed-effects models for the effects of distance from human infrastructure on sighting distance at 48 brown bear den sites in central Sweden, 2002–09. Shorter sighting distance implies more horizontal cover. All models had 15 degrees of freedom (df). |
|-----------------|--------|--------|-------|------|
| Variable        | β      | SE     | t     | P    |
| Settlements    |        |        |       |      |
| villages        | 1.7E-05| 8.7E-06| 2.008 | 0.063|
| small communities| 0.078 | 0.111 | 0.704 | 0.492|
| summer houses   | -0.048 | 0.130 | -0.367| 0.719|
| Roads           |        |        |       |      |
| E45 (major highway)| -0.002| 0.002 | -1.038| 0.316|
| secondary paved roads | 1.7E-05| 9.7E-06| 1.779 | 0.096|
| main gravel roads| -3E-05| 3.29E-05| -0.926| 0.369|
| railroad        |        |        |       |      |
| medium gravel roads| 0.024 | 0.071 | 0.343 | 0.736|
| minor gravel roads| -0.037| 0.098 | -0.375| 0.713|
| railroad        | -0.003 | 0.001 | -2.114| 0.052|

Fig. 1. Scatterplot of sighting distances at 48 brown bear den sites versus distance to villages in central Sweden, 2002–09. Shorter sighting distance implies more horizontal cover.

Fig. 2. Scatterplot of sighting distances at 48 brown bear den sites versus distance to secondary paved roads in central Sweden, 2002–09. Shorter sighting distance implies more horizontal cover.

_Ursus_ 22(2):152–158 (2011)
bears’ use of cover at den sites. Furthermore, some of the small communities only consist of single houses and cause less disturbance.

Dens closer to secondary paved roads were situated in more rugged terrain. However, there was a suggestion that dens closer to an even larger road (E45) and the railroad showed the opposite pattern. The secondary paved roads are roads with high human activity that connect permanent settlements (primarily villages) and smaller communities in the area. It is possible to park a vehicle along roads of this type, and as a result they allow for berry-picking and other recreational activities, because there is a free right of trespass on private lands in Sweden. In comparison, because of safety concerns, E45 presents few opportunities for parking a vehicle. Although traffic is more intense on E45, the access to the surrounding area is fairly low, resulting in low human off-road activity. The same is true for the railroad because its main use is transporting cargo. Thus, we speculate that bears used den sites in more rugged terrain closer to the road class that probably exposed its surroundings to the highest amount of human activity within forested habitats.

We found a suggestion that horizontal cover at den sites also was negatively related to distance from secondary paved roads. Elfström et al. (2008) similarly found that bears avoided denning near secondary paved roads in our study area, but selected den sites closer to the largest highway class. However, they found that bears denned farther 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 may either have too low human activity to affect bears in this manner, or bears may have placed their dens at suitable distances from these roads in relation to the low disturbance probabilities.

We found that den sites were in more rugged terrain when they occurred near secondary paved roads, but this pattern was not found for villages. It is possible that this was due to the distribution of rugged terrain, because secondary paved roads are roads with high human activity that connect permanent settlements (primarily villages) and smaller communities in the area. It is possible to park a vehicle along roads of this type, and as a result they allow for berry-picking and other recreational activities, because there is a free right of trespass on private lands in Sweden. In comparison, because of safety concerns, E45 presents few opportunities for parking a vehicle. Although traffic is more intense on E45, the access to the surrounding area is fairly low, resulting in low human off-road activity. The same is true for the railroad because its main use is transporting cargo. Thus, we speculate that bears used den sites in more rugged terrain closer to the road class that probably exposed its surroundings to the highest amount of human activity within forested habitats.

We found a suggestion that horizontal cover at den sites also was negatively related to distance from secondary paved roads. Elfström et al. (2008) similarly found that bears avoided denning near secondary paved roads in our study area, but selected den sites closer to the largest highway class. However, they found that bears denned farther 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 may either have too low human activity to affect bears in this manner, or bears may have placed their dens at suitable distances from these roads in relation to the low disturbance probabilities.

We found that den sites were in more rugged terrain when they occurred near secondary paved roads, but this pattern was not found for villages. It is possible that this was due to the distribution of rugged terrain, because secondary paved roads are roads with high human activity that connect permanent settlements (primarily villages) and smaller communities in the area. It is possible to park a vehicle along roads of this type, and as a result they allow for berry-picking and other recreational activities, because there is a free right of trespass on private lands in Sweden. In comparison, because of safety concerns, E45 presents few opportunities for parking a vehicle. Although traffic is more intense on E45, the access to the surrounding area is fairly low, resulting in low human off-road activity. The same is true for the railroad because its main use is transporting cargo. Thus, we speculate that bears used den sites in more rugged terrain closer to the road class that probably exposed its surroundings to the highest amount of human activity within forested habitats.

We found a suggestion that horizontal cover at den sites also was negatively related to distance from secondary paved roads. Elfström et al. (2008) similarly found that bears avoided denning near secondary paved roads in our study area, but selected den sites closer to the largest highway class. However, they found that bears denned farther 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 may either have too low human activity to affect bears in this manner, or bears may have placed their dens at suitable distances from these roads in relation to the low disturbance probabilities.

We found that den sites were in more rugged terrain when they occurred near secondary paved roads, but this pattern was not found for villages. It is possible that this was due to the distribution of rugged terrain, because secondary paved roads are roads with high human activity that connect permanent settlements (primarily villages) and smaller communities in the area. It is possible to park a vehicle along roads of this type, and as a result they allow for berry-picking and other recreational activities, because there is a free right of trespass on private lands in Sweden. In comparison, because of safety concerns, E45 presents few opportunities for parking a vehicle. Although traffic is more intense on E45, the access to the surrounding area is fairly low, resulting in low human off-road activity. The same is true for the railroad because its main use is transporting cargo. Thus, we speculate that bears used den sites in more rugged terrain closer to the road class that probably exposed its surroundings to the highest amount of human activity within forested habitats.

We found a suggestion that horizontal cover at den sites also was negatively related to distance from secondary paved roads. Elfström et al. (2008) similarly found that bears avoided denning near secondary paved roads in our study area, but selected den sites closer to the largest highway class. However, they found that bears denned farther 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 may either have too low human activity to affect bears in this manner, or bears may have placed their dens at suitable distances from these roads in relation to the low disturbance probabilities.

We found that den sites were in more rugged terrain when they occurred near secondary paved roads, but this pattern was not found for villages. It is possible that this was due to the distribution of rugged terrain, because secondary paved roads are roads with high human activity that connect permanent settlements (primarily villages) and smaller communities in the area. It is possible to park a vehicle along roads of this type, and as a result they allow for berry-picking and other recreational activities, because there is a free right of trespass on private lands in Sweden. In comparison, because of safety concerns, E45 presents few opportunities for parking a vehicle. Although traffic is more intense on E45, the access to the surrounding area is fairly low, resulting in low human off-road activity. The same is true for the railroad because its main use is transporting cargo. Thus, we speculate that bears used den sites in more rugged terrain closer to the road class that probably exposed its surroundings to the highest amount of human activity within forested habitats.
Our data collection during summer, when vegetation was lush, may have biased our results because the vegetation might have been denser in summer than in fall, when bears entered their dens. However, the forest in our study area is boreal, with a low shrub layer, and because bears rarely den in deciduous patches, we believe that the visual obstruction during summer was quite similar to conditions during fall. Snow provides cover during winter, presumably making dens even more concealed. However, snow cover normally is absent when bears select their den sites in the fall (Friebe and Swenson 2001). We thus believe that bears select den sites based on their vegetative and terrain characteristics, rather than their perception of possible future snow conditions, which also vary from year to year and would be difficult for the bears to predict.

Management implications

Scandinavian brown bears are wary and generally avoid denning in areas with high levels of human activity (Elfström et al. 2008). However, it is inevitable in a human-dominated landscape that some bears will have home ranges that include human infrastructure. In the non-denning season, bears seem to compensate for this by selecting resting sites with more cover and more rugged terrain when exposed to human disturbance (Martin et al. 2010, Ordiz et al. 2011). Similarly for denning bears, we found that they apparently compensated for higher human activity near roads providing human access by using den sites in more rugged terrain, and showed tendencies to use more horizontal cover and rugged terrain at den sites closer to villages.

Human activity may therefore not only affect bears’ large-scale selection of denning areas, but possibly also influence their use of terrain and cover at a smaller scale. Relatively dense vegetation and rugged terrain most likely provide bears with more opportunities to conceal den sites and thus tolerate more human activity relatively near their dens. In addition, rugged terrain and dense vegetation are often very difficult for humans to walk through, so selecting den sites with these features may reduce the probability of human encounters for bears denning relatively close to human activities. Increased knowledge about anthropogenic effects on bear behavior can add to a broader understanding of brown bear habitat selection.

Acknowledgments

We thank the Swedish Environmental Protection Agency, the Norwegian Directorate for Nature Management, the Norwegian Institute for Nature Research, the Swedish Association for Hunting and Wildlife Management, World-Wide Fund for Nature (WWF) Sweden, the Research Council of Norway, and the program Adaptive Management of Fish and Wildlife Populations for funding the Scandinavian Brown Bear Research Project, and S. Brünberg for technical assistance. This is scientific paper 118 from the Scandinavian Brown Bear Research Project.

Literature cited


Received: 27 March 2010
Accepted: 21 March 2011
Associate Editor: S. Ratnayeke