BEHAVIOR OF THE SCANDINAVIAN BROWN BEAR (*URSUS ARCTOS*) WHEN APPROACHED BY PEOPLE ON FOOT

DEN SKANDINAVISKE BRUNBJØRNENS (*URSUS ARCTOS*) ATFERD I MØTE MED MENNESKER TIL FOTS

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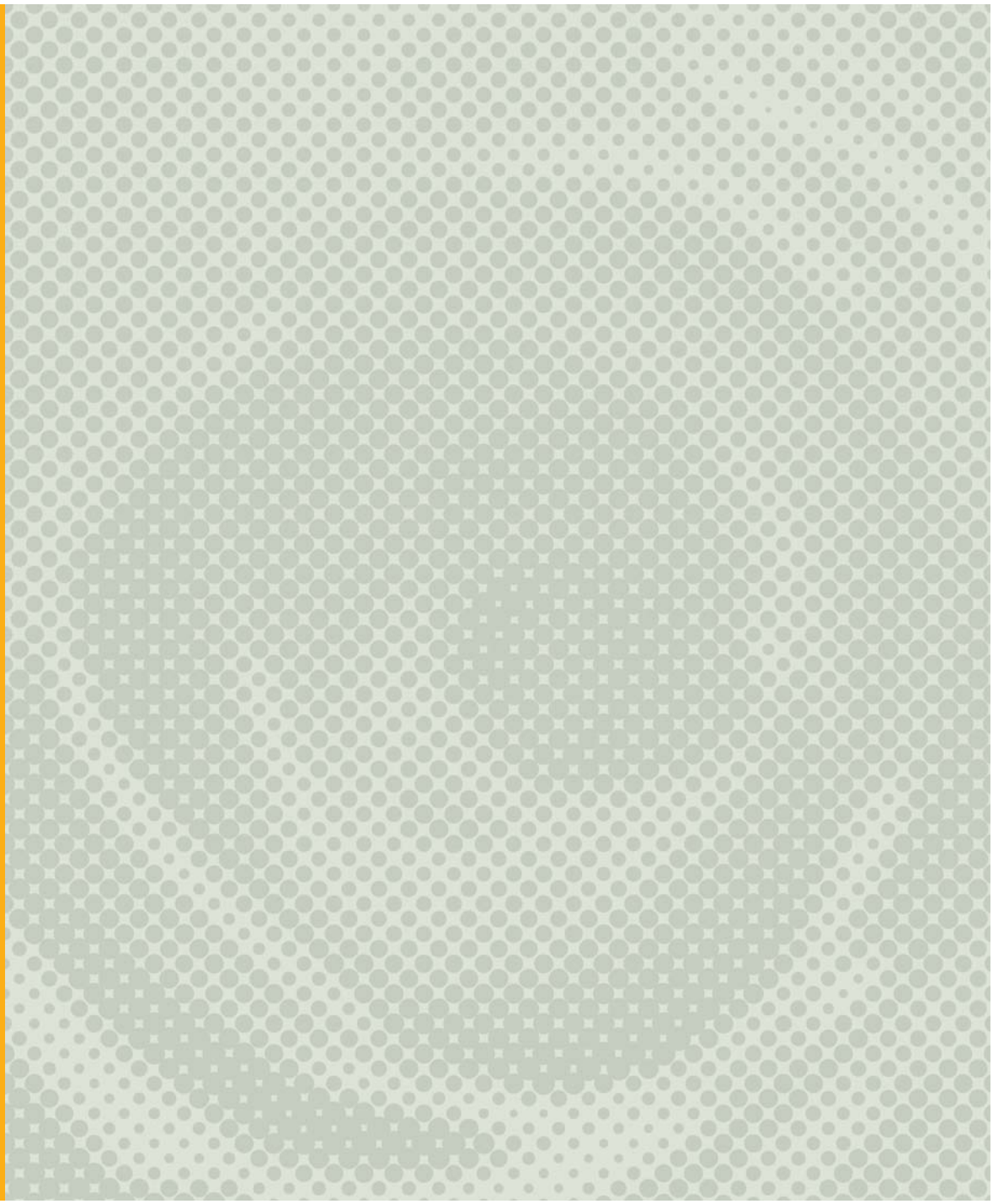

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Abstract

Human activities affect brown bears (*Ursus arctos*) directly through increased mortality and indirectly by reducing the availability of the brown bears' preferred habitats and nutritional resources. This may affect the bears' behavior. Humans almost eradicated the Scandinavian brown bear population at the beginning of the 20th century. The primary cause of death for an adult Scandinavian brown bear still is human-caused mortality, which may trigger a response similar to an anti-predator response in the bears when encountering humans. The behavior of the brown bear varies geographically. North American and Russian brown bears are more aggressive than the Scandinavian. Nevertheless, many people fear the Scandinavian brown bear even though the chance of being hurt by one during an encounter is minute. This fear may be explained by the fact that it probably was a valuable trait in our evolutionary past. Knowledge about the behavior of the brown bear when encountering people may reduce peoples' fear and result in more positive attitudes towards the animal. A positive attitude in the public is important for the successful management of the brown bear population. To address this need for information, I conducted field research on the behavior of brown bears when encountered by people. In this paper I present the result of 102 approaches on Scandinavian brown bears conducted by people on foot. The study was conducted in Gävleborg and Dalarna counties in south-central Sweden in a portion of the southernmost reproductive core area of the Scandinavian brown bear population. A total of 22 bears (4 males and 18 females) were approached during the summer and early fall of 2006 and 2007, with the approacher(s) walking past them at a distance of approximately 50 meters. The aim of the study was to determine the behavior of the bears and to reveal possible factors influencing their behavior. I found great variation in the behavior of the bears. Both the distance between the bears and the approachers at the time of the bears' response to people, the type of response, and the distance moved after the approach varied among individuals and between approaches on the same individual. Three-fours of the bears left their initial resting site before or as the approachers passed. Half of those that stayed left the resting site shortly after the approachers had passed. None of the approaches resulted in any kind of aggressive behavior from the bears and only about one-tenth of the bears were seen, even though the approachers knew the location of the bears and tracked any movement they made. The variable behavior made it difficult to define a 'normal behavior' of the Scandinavian brown bear, but the results indicate that when approached by people on foot they prefer to avoid a confrontation. This supports the conclusion of previous studies, that the Scandinavian brown bear is normally not an aggressive bear.

Sammendrag

Menneskelig aktivitet påvirker brunbjørner (*Ursus arctos*) direkte gjennom økt dødelighet og indirekte ved å redusere tilgjengeligheten av bjørnenes prefererte habitat og næringskilder. Dette kan ha en innvirkning på bjørnenes atferd. Mennesker utryddet nesten den skandinaviske brunbjørnpopulasjonen på begynnelsen av det 20. århundre. Majoriteten av dødsfall blant voksne skandinaviske brunbjørner kan fortsatt relateres til mennesker. Dette kan utløse en anti-predator atferd hos brunbjørnen. Atferden til brunbjørnen varierer geografisk og brunbjørnen i Nord-Amerika og Russland er mer aggressiv enn i Skandinavia. Mange mennesker frykter den skandinaviske brunbjørnen, selv om sannsynligheten for å bli skadet hvis man treffer en bjørn er minimal. Denne frykten kan forklares ved at den trolig var en verdifull egenskap i vår evolusjonære fortid. Kunnskap om atferden til den skandinaviske brunbjørnen i møte med mennesker kan redusere menneskers frykt og skape mer positive holdninger til brunbjørnen. En positiv holdning i befolkningen er en forutsetning for en vellykket forvaltning av brunbjørnpopulasjonen. For å møte dette kunnskapsbehovet utførte jeg feltstudier på brunbjørnens atferd i møte med mennesker. Studiet ble utført i Gävleborg og Dalarne fylke i Sverige, i en del av det sørligste reproduktive kjerneområdet til den skandinaviske brunbjørnpopulasjonen. I 102 forsøk gikk en eller to personer til fots mot bjørnen og passerte bjørnens dagleie på cirka 50 meters avstand. Totalt 22 individ (4 hanner og 18 hunner) ble brukt i studiet. Målet med studiet var å kartlegge brunbjørnens atferd i møte med mennesker og å avdekke mulige faktorer som påvirker atferden. Det var stor variasjon i brunbjørnens atferd. Avstanden mellom bjørnene og menneskene da bjørnen reagerte på menneskenes nærvær, typen respons og avstanden bjørnene beveget seg etter forsøket, varierte mellom individene og mellom ulike forsøk på samme individ. Tre av fire bjørner forlot dagleiet før eller da vi passerte dagleiet. Halvparten av de som ble liggende forlot dagleiet kort tid etter at vi hadde passert. Ingen av forsøkene resulterte i aggressiv atferd hos bjørnene. Omtrent en av ti bjørner ble sett, selv om bjørnens posisjon var kjent og vi kunne registrere bevegelse ved hjelp av radiotelemetri. Den store variasjonen i atferd gjør det vanskelig å definere en ”normalatferd” for den skandinaviske brunbjørnen, men resultatene indikerer at den skandinaviske brunbjørnen foretrekker å unngå møter med mennesker. Dette støtter konklusjonen i tidligere studier om at den skandinaviske brunbjørnen vanligvis ikke er en aggressiv bjørn.

Introduction

Human activity affects the brown bear (*Ursus arctos*) populations in several ways. Roads and railways have a direct effect on the mortality rate, due to traffic-related deaths (Benn & Herrero 2002; Kaczensky et al. 2003), and the presence of roads, railways and human settlements also alters the behavior and terrain use of the bears (Gibeau et al. 2002; McLellan & Shackleton 1988; Nellemann et al. 2007). Anthropogenic disturbances, like forestry and tourism, alter the temporal and spatial availability of preferred habitats and nutritional resources (Nielsen et al. 2004; Rode et al. 2006). In this way humans may provoke changes in the bears' behavior. Gibeau et al. (2002) showed that the effect of disturbances may differ between sex and age classes.

Bear populations are vulnerable to hunting due to a relatively low rate of population increase (Bischof et al. 2008) and harvesting may have an effect on the demography of the populations (e.g. Bischof et al. 2008). At the beginning of the 20th century, intensive hunting had almost eradicated the population of brown bears in Scandinavia. The population around 1930 has been estimated to have been 130 animals (Swenson et al. 1995). The primary cause of death for an adult Scandinavian brown bear still is human caused mortality (Sahlén et al. 2006), which may trigger a response similar to an anti-predator response in bears when encountering humans. If a disturbance is perceived as a risk by the animal even non-lethal human disturbance may have a cost equal to an anti-predator response. Applying an economic cost-benefit model Frid and Dill (2002) argued that this is a valid assumption, because the time spent responding to the disturbance, like time spent responding to a predator, reduces the time available for fitness-enhancing activities (e.g. foraging, parental care, or mating display). They suggested that the economic principles used by prey when encountering predators will most likely also be used when exposed to disturbance stimuli. A trade-off between responding to the predator/disturbance and maintaining the fitness amplifying activities must be conducted (Frid & Dill 2002). Rode et al. (2006) found support for this theory in an experimental study conducted on the Alaskan brown bear. Bears not acclimated to the presence of humans were exposed to experimentally introduced tourism. The results indicated that the bears' response to human activity was analogous to prey responding to the risk of predation. Thus employing predator-prey theory may be a useful way of interpreting the brown bears responses to human disturbance.

Some studies have shown that brown bears may react aggressively when approached by people. In an analysis of 270 bear-human researcher encounters in Kamchatka, in the Russian Far East, the researchers were attacked by the bears in two incidents and signs of aggressive behavior were documented in eight incidents (Revenko 1994). McLellan and Shackleton (1989) never experienced any attacks, but aggressive behavior from grizzly bears was observed in two of 165 incidents in a study conducted in British Columbia, Canada and Montana, USA. The aggressiveness of the brown bear varies geographically. Both Russian and North-American brown bears are believed to be more aggressive than the Scandinavian (Swenson et al. 1996), which is relatively not an aggressive bear as long as it is not wounded (Swenson et al. 1999). The Scandinavian brown bears' greater weariness towards people may be a result of high hunting pressure (Swenson 1999). Post-incident analyses of bear-human encounters and literature studies have provided some knowledge about the behavior of the Scandinavian brown bear when encountering people (Swenson et al. 1999). Unlike the Scandinavian wolf (*Canis lupus*) (Karlsson et al. 2007; Wam 2003) and the Scandinavian lynx (*Lynx lynx*) (Sunde et al. 1998) no experimental studies have previously been conducted.

Knowledge about the behavior of the large carnivores in Scandinavia is important for influencing the public attitudes towards the animals and for a proper management. Many people fear the brown bear (Røskaft et al. 2003; Røskaft et al. 2007) even though studies have shown that the chance of being hurt by a Scandinavian brown bear during an encounter is minute (Swenson et al. 1996). The fear of large carnivores may be explained by the fact that it was a valuable trait in our evolutionary past (Røskaft et al. 2003). In a study conducted in Norway, Røskaft et al. (2007) found that people with the strongest fear also had the most negative attitudes towards large carnivores, and people living closer to the presence of the carnivores often express more negative attitudes (Karlsson & Sjöström 2007; Røskaft et al. 2007). A premise for a successful management of the large carnivores is social acceptability and public support for the relevant policies (Røskaft et al. 2003; Røskaft et al. 2007). More knowledge about the behavior of the Scandinavian brown bear when encountering humans is important for the understanding of when the bears may be dangerous to humans. This knowledge could influence peoples' feeling of fear and consequently affect peoples' attitudes towards the animal.

The aim of this study was to determine the behavior of Scandinavian brown bears when approached and passed by people on foot and to reveal possible factors influencing their behavior.

Materials and methods

Study area

The study was conducted in Dalarna and Gävleborg counties in south-central Sweden (61°N, 18°E) in a portion of the southernmost reproductive core area of the Scandinavian brown bear population (Fig. 1). The gently undulating landscape is covered with coniferous forest, dominated by Scots pine (*Pinus sylvestris*) or Norway Spruce (*Picea abies*), mixed with deciduous tree species like birch (*Betula pubescens*), sliver birch (*B. pendula*), aspen (*Populus tremula*), European mountain ash (*Sorbus aucuparia*) and gray alder (*Alnus incana*). The field vegetation consists of common juniper (*Juniperus communis*), willows (*Salix spp.*), heather (*Calluna vulgaris*) and different forbs, grasses and sedges. Bilberry (*Vaccinium myrtillus*), cowberry (*V. vitis-idea*) and crowberry (*Empetrum hermaphrodium*), important food sources for the brown bear especially during autumn (Dahle et al. 1998), are widespread in the area.

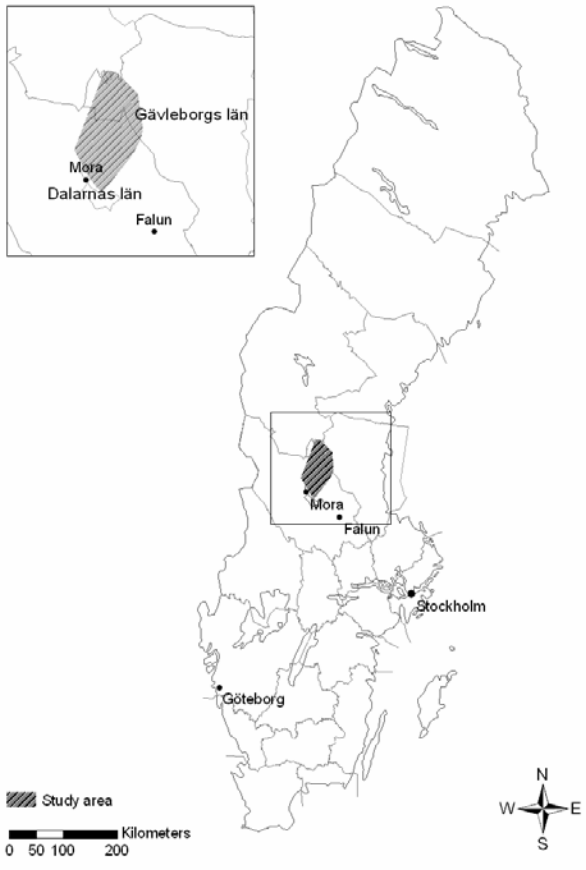

Figure 1: Map of Sweden showing the study area. The area indicated on the map is the aggregated home range of the animals used in the study.

The study area is below the timberline and ranges from about 200 to 700 m above sea level. As part of the northern boreal forest region lakes, rivers and large bogs are common. Effects of intensive forestry are evident. Large clear cuts and tree monocultures are important components of the landscape and an extensive road system has been established. The area is sparsely populated. Only a few villages and some scattered cabins are present. The population of brown bears has been estimated to 30 bears per 1000 km^2 (Solberg et al. 2006). The area is open for bear hunting between the 21 August and 15 October.

The bears

Fieldwork was carried out in 2006 and 2007. A total of 22 different individuals were studied in the study (4 males and 18 females). Of the 11 bears studied in 2006, 6 individuals were also studied in 2007. The age of the brown bears varied from 2 to 18 years. If an animal had not been followed from birth, its age was determined by counting the annuli on a cross-section of one of the premolar roots (See: Jonkel 1993; Matson et al. 1993). All bears were solitary. In 2006 only females were approached. A maximum of five approaches were conducted on the same individual per season. The bears were captured and marked or remarked in late April to mid-June by darting from a helicopter. The anesthetic used was a mixture of tiletamine-zolazepam and medetomidine (See: Arnemo et al. 2006; Arnemo & Fahlman 2008). During marking the animals were equipped with either a GPS Plus-3 or a GPS Pro-4 neck collar and GSM lateral modems (Vectronic Aerospace, Berlin, Germany). Most of the animals also had an implanted VHF radio transmitter operated into their body cavity. During the marking measurements of the bears size and weight were recorded. The marking was conducted by a professional team with wide experience in the field. Dahle et al. (2006) have in detail explained the methods used during the marking.

The approaches

A total of 102 approaches were conducted between 30 June to 8 August 2006 and 31 May to 4 October 2007 (28 in 2006 and 74 in 2007). The approaches were conducted before and during the berry season. The first day of the berry season was defined as the day we first noted berries in the bear scats. In 2006 the berry season started on 20 July and in 2007 the first day of the berry season was 13 July. All approaches were carried out between 11:00 and 14:00 GMT (13:00 – 16:00 local time) because at this time the bears are usually inactive at a resting site (Moe et al. 2007). The GPS modules in the collars were normally scheduled to fix a position every half hour. During the approaches the schedule was changed to one position every minute. Hence the theoretical number of positions that could be received from the collar during the approach was 180 positions. The positions were stored in the collar and transmitted via SMS to a base station in packages of seven positions.

One or two people, hereafter called the approachers, approached and passed, hereafter referred to as approached, the bear on foot at a speed of 1.4 to 4.6 km/h. The goal was to simulate hikers; hence the approachers conversed like hikers would during the approach. When only one person approached the bear, he or she simulated a normal conversation. To avoid disturbing the bear prior to the approach, the approachers started at least 500 m from the position of the animal. The bear was approached in a straight line passing the bear upwind at a distance of approximately 50 meters (Fig. 2). When passing the bear the direction of the wind was about 90° to the route of the approachers. The approachers walked towards the last GPS position obtained from the bear or towards a position obtained by VHF triangulation prior to the approaches. VHF radio signals from the bear's collar were used during the approach to adjust the route to the position of the bear and to monitor changes in the behavior of the bear. Sudden changes in the VHF signal strength or direction, indicating changes in the bear's behavior, were recorded. A handheld GPS receiver (Garmin GPSMAP 60CSx (Garmin Ltd., USA) or Magellan SporTrack Color (Thales, Santa Clara, California, USA)) was used to track the route of the approachers and to adjust the route during the approach. The GPS receiver was programmed to fix a position every 10 meters along the route. If the bear was seen or heard during the approach the time and place of the observation was recorded and a waypoint was stored in the GPS receiver. After every approach we downloaded the positions from the bear's collar and the approacher's GPS receiver into the computer at the field station. GIS software was used to plot the positions on a map.

Figure 2: Scandinavian brown bears were approached in a straight line passing the bear upwind at a distance of approximately 50 meters, with the wind about 90º to the route of the approachers. This approach of a three year old female took place 5 July 2007. She settled in a resting site in the morning of the day of the approach. The bear stayed at the initial resting site until the approachers had passed, and then left. The red line shows the route of the bear and the blue line the route of the approachers.

Habitat characteristics

If the bear was at a resting site prior to the approach and/or stopped at a resting site after the approach, a cluster of positions indicated the approximate location of the bear's daybed. We chose the center point of the cluster of positions as the location where we were going to start the habitat analyses. If the bear moved after the approach, the habitat analysis was only conducted in the before-approach cluster. In the field the first thing we did was to look for a daybed. The criterion for determining a daybed was that hairs from the bear had to be detected in the bed. In addition we noted whether the bear had made an effort to make a bed out of mosses, branches etc., or if it had scraped away the vegetation to lay on soil. If a bed was found the position of the bed was used as the

center point of the habitat analysis. If no bed was found the center position of the GPS position cluster was used as the center point of the habitat analysis. An area within a radius of 30 m from the center point was searched looking for signs of the bear's activity (e.g. beds, scats, excavated ant hills and scratch marks) and to register habitat characteristics. The horizontal vegetation cover of the location was estimated using either an umbrella (in the 2006 season) or a cylinder (in the 2007 season). The measurement device was placed in the bed or the center position of the cluster of GPS positions if no bed was available. When using the umbrella the visible area of the umbrella was estimated from a distance of 10 m in all the four cardinal directions. The umbrella was 95 cm in diameter and divided into 8 equal sectors (Fig. 3). Every second sector was blue and the rest white. Each sector was given a value depending on its visibility (0 = 0-33% visibility, 0.5 = 33-66% visibility and 1 = 66-100% visibility). The score for all directions were summed, giving a maximum total value of 32 if full visibility, indicating zero horizontal cover in all directions. For the 2007 season the umbrella was replaced by a 60-cm tall and 30-cm wide cylinder (Fig. 3). The cylinder was divided in two equally large parts, a lower white part measuring the cover at the height of a laying bear and an upper red part measuring the cover at the height of a standing bear. We measured the sighting distance, defined as the minimum distance (in meters) required for each part of the cylinder to be completely hidden. To test the comparability of the 2006 and 2007 data, the umbrella was used parallel with the cylinder in 53 habitat plots in 2007. The sum of the umbrella score in all cardinal directions was compared with the sum of the cylinder sighting distance score in all cardinal directions in the same habitat plot. A regression analysis showed that the data were comparable (R^2 = 56.9%, n = 53, p = 0.000) (Fig. 4). The regression equation was used to estimate a sighting distance of the 2006 umbrella data. To minimize the chance of disturbing the animal again, the habitat analysis was conducted a minimum of two days after the approach. The average number of days between an approach and the habitat analysis was 7.23 days and the median value was 5 days (n = 180). The maximum was 41 days. The high maximum value was due to the fact that sometimes long periods passed before we received enough positions from the bear's collar to decide where to do the habitat analysis.

Figure 3: An umbrella, 95 cm in diameter, and a 60cm tall cylinder was used to measure the sighting distance at Scandinavian brown bears' resting sites in south-central Sweden in 2006 and 2007 (Photo by: Gro K. Moen).

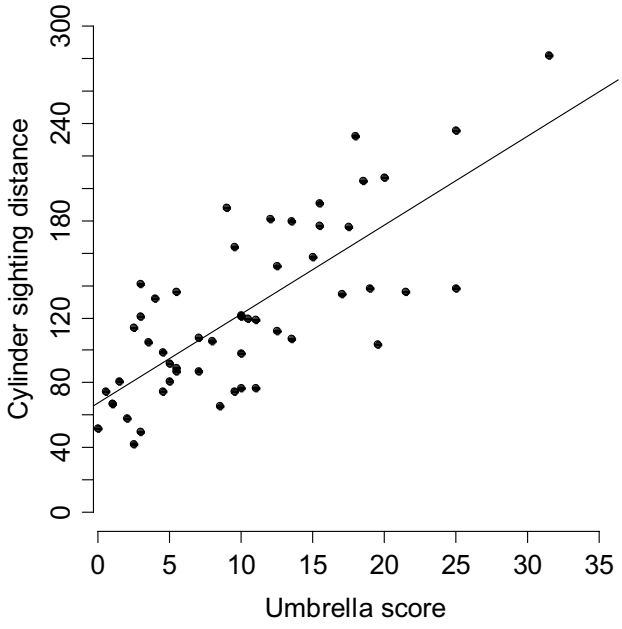

Figure 4: Habitat analyzes were conducted at the resting sites of Scandinavian brown bears in south-central Sweden in 2006 and 2007 using an umbrella and a 60cm tall cylinder as measuring devices. The sum of cylinder sighting distance score correlated to the sum of the umbrella score in the same plot (R^2 = 56.9%, n = 53, P = 0.000).

The analyses

Only passive bears were used in the further analyses. An animal was deemed active if the positions formed a successive line indicating that the animal was moving and no bed was found when we visited the location of the positions in the field. Two bears in 2006 and nine bears in 2007 were deemed active. For two of the approaches too few positions were received from the bears' collar to determine whether the bear was active or passive.

Detecting a reaction

Due to GPS location errors, i.e. the difference between the recorded location and the true location (D'eon & Delparte 2005), the coordinates of two successive positions received from a GPS unit may not be exactly the same even though the GPS unit has not been moved. Hence a GPS position with coordinates diverging from the preceding position does not necessarily indicate a movement of the GPS unit. The GPS data showed that the bears tended to move close to their bed when at a resting site. While conducting the habitat analyses we found several signs of the bear's activity (see Table 5). This movement is a natural behavior and not necessarily a response to human presence. Bears showing this kind of movement were still deemed passive. To determine when the bears had reacted to our presence I had to be able to distinguish between 'movement' caused by GPS errors or the bears' movement in close to their resting site and the movement of the bears as a response to our presence.

To accomplish this, I identified a *Prior-to-Approach Resting Site Area* (PARSA), defined as the average size of the resting site area used by the bears prior to the approaches. The one-minute positions received before the start of the approach were used to calculate the diameter of a circular area around the resting site bounding all of the bears locations received in this period (mean 38.02 m, 95% CI: 31.9 – 44.1 m, n = 58). A pooled estimate of the area used by all the passive bears in both years was used. The upper 95% confidence interval (44.1 m) was used as the limit of the bears' PARSA. When conducting the GIS analyses, the center of the PARSA circle was placed in the position of the bed that was used as the center point of the habitat analysis (Fig. 2). If no bed was found the center point of the cluster defined prior to the habitat analysis was used. In one case all the positions from the bear were outside the PARSA when the center of the circle was placed in the bed position. Most likely the bed I found was not from that bear or had been used by the bear at a different time. Hence the center point of the GPS positions was used. All positions received within

this circular area were considered as natural movement around the resting site or GPS errors. The first position received outside the PARSA was considered to be a reaction to our presence.

The *Prior-to-Approach Rate of Movement* (PARM) was defined as the bear's average rate of movement between two successive positions when in the resting site prior to the approach. A pooled estimate of all the bears' rate of movement was used to estimate an average rate of movement (mean 0.397 km/h, 95% CI: 0.368 – 0.426 km/h, n = 994). The upper 95% interval (0.426 km/h) was used as a maximum rate of movement. Any movement faster than this after the start of the approach was considered to be a bear's response to the presence of the approachers. The time difference between two successive positions varied greatly (7 sec to 54 min). Most likely the bears do not move in a straight line between two positions. Consequently the accuracy of the estimated rate of movement will decrease as the time between the positions increases. For this reason a maximum time limit of five minutes between two successive positions was set. Two outliers were removed, as they were obvious GPS errors. In the first case the time difference between two successive positions was only seven seconds. In the other case one position was recorded 128 meters from a cluster of positions. These two observations resulted in measurements of a speed of 19 km/h and 13 km/h respectively. The speed calculated from the other 994 observations ranged from 0 – 4.86 km/h with an average of 0.397 km/h.

In some cases the bear was active after 11:00 GMT, but settled in a resting site before the start of the approach. The positions between 11:00 GMT and until it settled in a resting site were then excluded from the analysis. Only the approaches consisting of more than five positions received between 11:00 GMT (or when the bear settled) and the approach start were used.

Measurements

The PARSA and PARM values were used to calculate the distance between the approachers and the bear at the time the bear reacted to our presence. The *Initial Reaction Distance* (IRD) was defined as the distance between the approachers and the bear when the bear started the movement out of the PARSA or when the bear's rate of movement started to increase above PARM, whichever came first. The distance at the time when the first of either of these two occurred was chosen as the IRD. The *Tolerance Distance* (TD) was defined as the distance between the approachers and the bear when the

bear moved out of the PARSA and did not return or when the bear's rate of movement started to increase and stayed above the PARM during the movement out of the PARSA, whichever came first.

If the bear settled in a second bed after the approach the distance the bear moved between the first and the second resting site was measured. The *linear distanced moved* was defined as the linear distance between the position of the bear the first time it reacted to the presence of the approachers and the second resting site. The *total distance moved* was calculated by summing the distance between the successive GPS positions from the position of the bear when it first reacted to the approachers and the second resting site. *Maximum rate of movement* was defined as the maximum speed the bear obtained between two successive GPS positions during the movement between the two resting sites. If the bear stayed put in the first bed while the approachers passed, the closest distance between the bear and the approachers was recorded using GIS software.

When there were large time differences between the last bear position inside the PARSA or below PARM and the first position outside the PARSA/above PARM, it was difficult determine exactly when the bear reacted, which increased the uncertainty of the reaction distance estimate. Thus, the approaches with time differences between the first and second bear positions larger than three minutes were excluded from further analyses. This threshold included 78 % of the available IRD and 64 % of the available TD observations. Due to the varying temporal resolution the reaction distances should be interpreted as the minimum of maximum reaction distances. In other words the bears did not react at an earlier point of time (and a longer distance), but the time of reaction may have been closer in time to the second bear position and hence at a shorter distance from the approacher.

Statistical analyses

A GIS project file was created for each of the 102 approaches using ESRI® ArcMAP™ 9.2 (ESRI Inc. 1999-2006) with the Tracking Analyst extension and Hawth's analysis tools (Beyer 2004). Microsoft Office Access 2003 (Microsoft Cooperation 1992-2003) and Microsoft Excel 2002 (Microsoft Cooperation 1985-2001) were used in the data analyses.

A Generalized Linear Mixed Model (GLMM) was used initially to test the effect of various variables on the reaction distances (IRD and TD) and whether a bear stayed in the initial resting site or fled

before or as the approachers passed (Table 1). The final model was fitted using a stepwise backward elimination procedure where the least significant variables ($P > 0.05$) were removed.

I chose to use a GLMM to be able to add a random variable to avoid biases caused by pseudo replicated data (Schall 1991). Each individual bear was used as a random effect to account for correlations between observations on the same individual over time. The result of the GLMM models showed that the estimated variance for the random variable was effectively zero in all the models. Thus, the random variable had no effect. Hence I conducted three generalized linear models (GLM) with the same explanatory variables (Table 1). The analyses were conducted using the statistical programming language and environment R version 2.7.0 (R Development Core Team 2008). I used the glmmPQL (MASS library) and the glm (stats library) modules.

A paired-sample t-test was conducted to test for differences between the sighting distance in the initial resting site and the second resting site and to test whether the IRD was longer than the TD. I conducted a two-sample t-test to detect possible differences in reaction distances measured using PARSA compared to those measured using PARM, and a linear regression to investigate the relationship between IRD and TD. These and the umbrella vs. cylinder analyses were carried out using Minitab 15 (Minitab Inc. 2007). Non-parametric data were log transformed.

Table 1: The explanatory variables included in the generalized linear model when testing for effects on the initial reaction distance, the tolerance distance and if the GPS-marked brown bear stayed in the initial resting site or fled before or as the approachers passed when Scandinavian brown bears were approached by people on foot in south-central Sweden in 2006 and 2007.

Response variable	**Explanatory variables**
Initial reaction distance (IRD)	Sex of the animal, season (berry season or not), weather conditions (categorized from poor to good), sighting distance at the initial resting site, time difference between the two bear positions used, distance between the approachers and the bear at the start of the approach.
Tolerance distance (TD)	Sex of the animal, season (berry season or not), weather conditions (categorized from poor to good), sighting distance in the initial resting site, time difference (between the two bear positions used), distance between the approachers and the bear at the start of the approach.
Stayed in resting site/fled from initial resting site before or as the approachers passed	Sex of the animal, season (berry season or not), weather conditions (categorized from poor to good), sighting distance in the initial resting site, the shortest distance between the approachers and the bear during the approach.

Results

The approaches started 15 to 133 min after the collar had started to obtain one-minute positions. The variance in starting time was due to difficulties in locating some animals and that some days two animals were approached by the same approacher. The average distance between the bear and the approachers at the start of the approach was 855 m ± 292 m. The temperature measured at the start of the approaches ranged from 8 to 28 C. The dominant weather type was fair weather or partly cloudy, but rain and rain showers were also relatively frequent. The actual number of positions received during the three-hour period when the collars were scheduled to obtain a position every minute averaged 63.93 ± 23.79 (36 ± 13% of theoretical maximum) positions in 2006 and 103.22 ± 39.20 (57 ± 22% of theoretical maximum) positions in 2007.

The average IRD was 532 ± 394 m (range 7 – 1840 m, n = 46). The average TD was 127 ± 132 m (range 26 – 695 m, n = 29). There was a large variance in the reaction distances (Fig. 5) and the variance in the reaction distances measured for the same individual was large for both the IRD and the TD (Fig. 6).

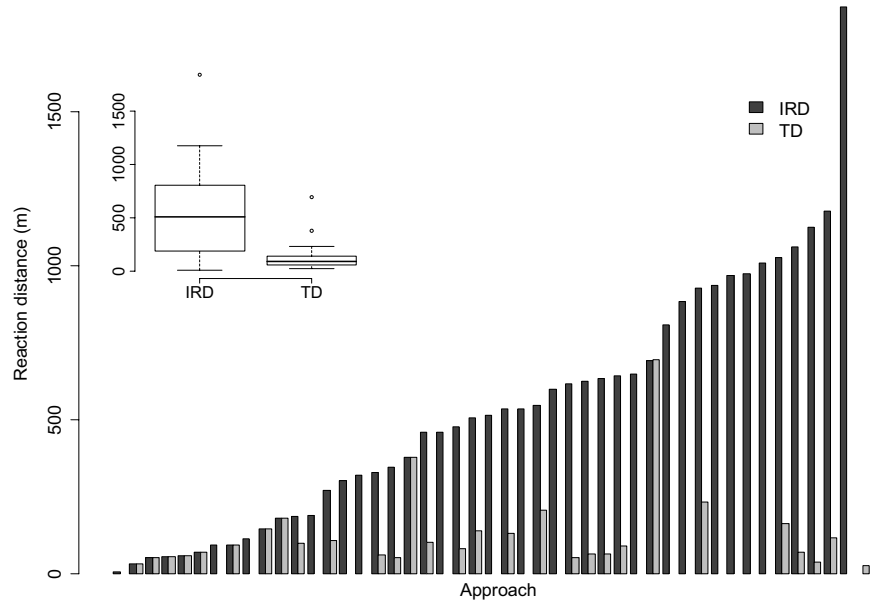

Figure 5: The Scandinavian brown bears' initial reaction distance (IRD) and tolerance distance (TD) when approached by people on foot in south-central Sweden in 2006 and 2007. Each double column represents an individual.

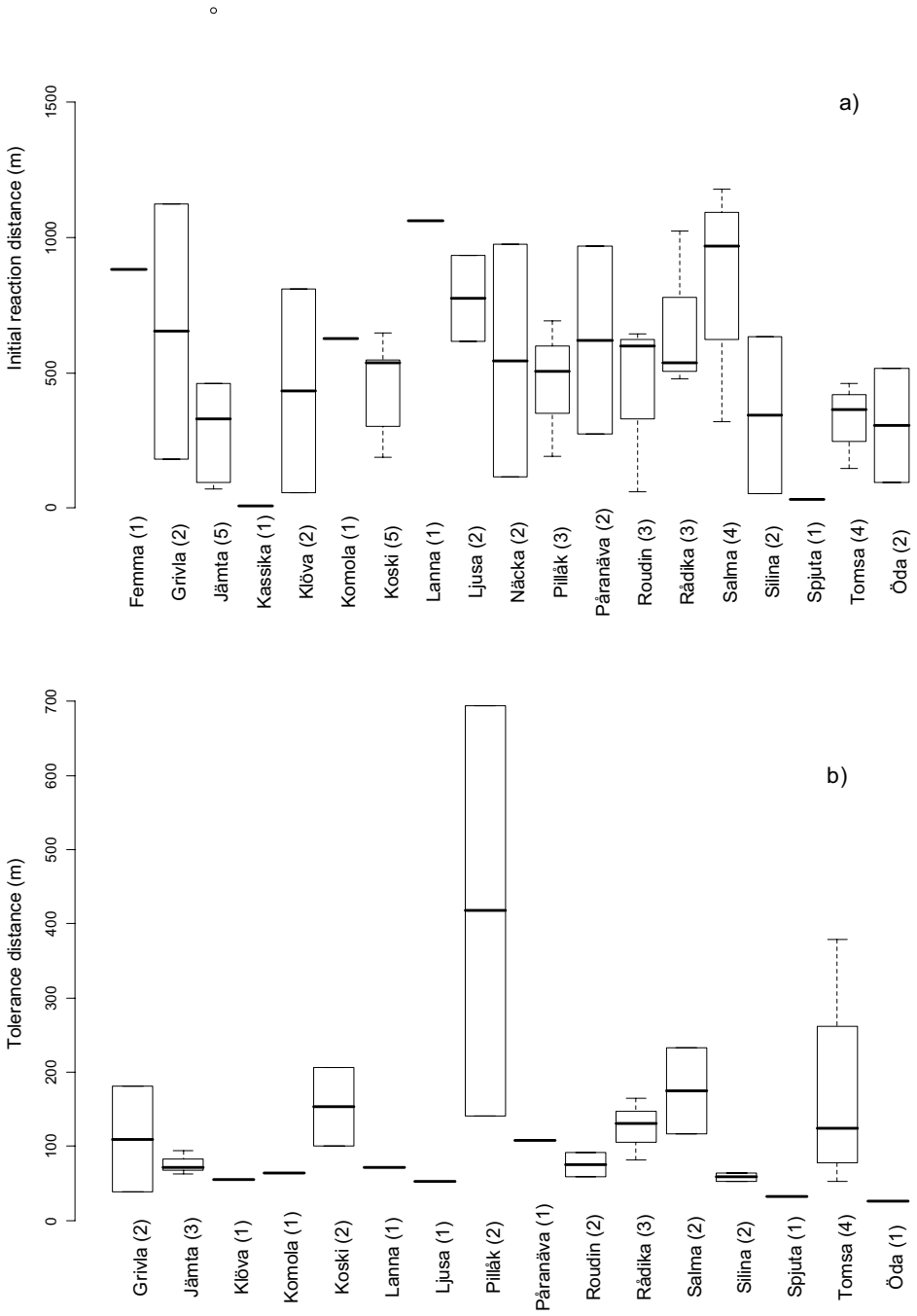

Figure 6: The initial reaction distances (a) and tolerance distances (b) measured for the same individual when Scandinavian brown bears were approached by people on foot in south-central Sweden in 2006 and 2007. Numbers in brackets after the bear names indicates the number of approaches where data was available for the analyses.

There was no difference between the IRDs (t=-1.62 , n=36 , P=0.182) or the TDs (t=0.10 , n=15 , P=0.927) measured using PARSA compared to those measured using PARM. The IRD was identical using either method in 22% of the approaches and the TD in 48% of the approaches. The IRDs were significantly longer than the corresponding TDs (t = 5.93, n = 28, P = 0.000) and there was no significant correlation between them (R^2 = 12.1%, n = 28, P = 0.070) (Fig. 7).

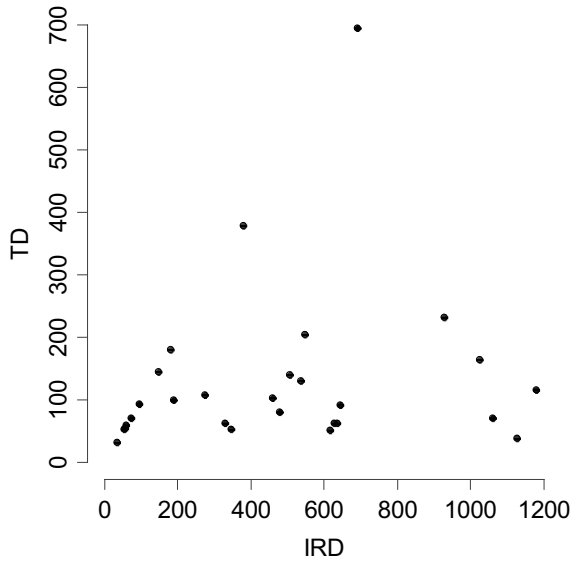

Figure 7: The bears' initial reaction distance (IRD) plotted against the bears' tolerance distance (TD) during the same approach when Scandinavian brown bears were approached by people on foot in south-central Sweden in 2006 and 2007.

The GLM analysis showed that the IRD was affected by the sighting distance at the initial resting site, the distance between the bear and the approachers at the start of the approach, and by the time difference between the last position of the bear inside the PARSA/below PARM and the first position outside the PARSA/above PARM (Table 2). The sighting distance and the distance between the bear and the approachers were positively correlated to the IRD, indicating that a longer sighting distance or a longer starting distance increased the IRD. The time difference between the two bear positions was negatively correlated to the IRD, indicating that an increase in the time difference decreased the IRD. The variables had a significant explanatory effect on the IRD, but the variance within each variable was large (Fig. 8). None of the explanatory variables explained a significant amount of variation in the TD (Table 3).

Table 2: Test statistics for the generalized linear model explaining the initial reaction distance of Scandinavian brown bears when approached by people on foot in south-central Sweden in 2006 and 2007 (n = 46). Test statistics are given for the final model and for the other variables at the time they were eliminated from the model. A backward elimination procedure was used to fit the model excluding the least significant variable with a P-value <0.05.

Explanatory variables	**β**	**SE**	**t**	**P**
Start To Bear	0.561	0.147	3.809	0.000
Sighting distance	2.184	0.838	2.607	0.013
Time difference (sec)	-2.426	1.071	-2.265	0.028
Weather conditions	-21.977	26.926	-0.816	0.419
Season	-67.299	98.293	-0.685	0.497
Sex	-46.846	142.76	-0.328	0.745

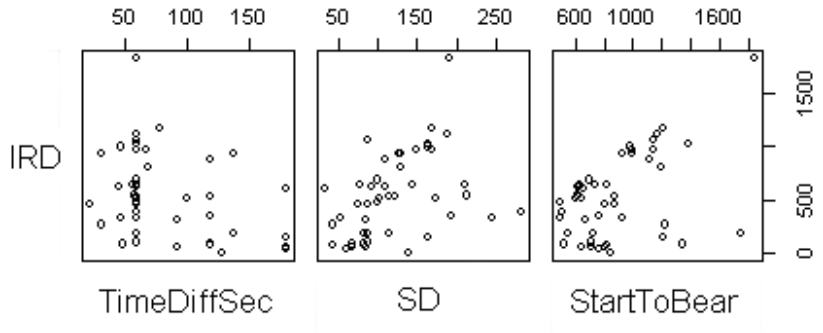

Figure 8: The initial reaction distance (IRD) of Scandinavian brown bears when approached by people on foot in south-central Sweden in 2006 and 2007, plotted against the variables found to have a significant effect on the IRD; the time difference (sec) between the last position of the bear inside the PARSA/below PARM and the first position outside the PARSA/above PARM (TimeDiffSec), the sighting distance (m) in the initial resting site (SD) and the distance (m) between the bear and the approachers at the start of the approach (StartToBear).

Table 3: Test statistics for the generalized linear model explaining the tolerance distance (log-transformed) of Scandinavian brown bears when approached by people on foot in south-central Sweden in 2006 and 2007 (n = 29). Test statistics are given for the variables at the time they were eliminated from the model. A backward elimination procedure was used to fit the model excluding the least significant variable with a P-value <0.05.

Explanatory variables	**β**	**SE**	**t**	**P**
Sighting distance	0.002	0.001	1.958	0.061
Sex	-0.269	0.154	-1.744	0.093
Time difference	-0.002	0.001	-1.923	0.066
Weather	-0.033	0.036	-0.903	0.375
Start To Bear	0.000	0.000	0.656	0.518
Season	0.064	0.122	0.524	0.606

For the bears that settled in a second resting site, the average linear distance moved was 812 ± 694 m (range 34 – 2668 m, n = 47), and the average total distance moved was 1040 ± 872 m (range 42 – 3296 m, n = 47). On average the bears moved at a maximum speed of 5.41 ± 4 km/h (range 0.5 – 14.5, n = 47) between the sites.

The first reaction occurred before the approachers had passed the bears' initial resting site in 58 (94%) of the incidents (n=62). In four (6%) incidents the first reaction occurred after the approachers had passed the initial resting site. I was able to determine whether the bear fled or stayed in the initial resting site in 58 incidents. Three types of responses were observed. The bears stayed in the initial resting site during seven (12%) of the approaches. Of the animals that left, the reaction occurred at two different points of time. During 44 (76%) of the approaches the bear left the PARSA before or as the approachers passed the initial resting site and during seven (12%) approaches the bear left after the approachers had passed.

If the bear left the initial resting site, they did not always run away from the approachers straight away. In some few cases they moved towards the approachers before they changed direction and moved away. Based on the positions using GIS, software I also noted that after the approachers had passed the initial resting site, the bears sometimes followed the tracks of the approachers for a while. We also detected this kind of behavior when in the field based on the VHF signal.

During the 89 approaches conducted on passive bears, we only saw bears 10 times (11%). The bears never showed any sign of aggressive behavior. A carcass was found at the initial resting site of the bear after six approaches. Most of the carcasses were moose (*Alces alces*) calves, but in one incident a roe deer (*Capreolus capreolus*) was found. The behavior of the bears that were seen also varied. Some of the bears were only seen as they turned around and ran away at high speed. Others started slowly, but increased their speed rapidly while running away and others turned around and moved away at a moderate speed. In some few incidents the bear did not run straight away, but stood up and watched the approachers before it moved away. We also experienced that the bears stopped after running for some distance and turned around to watch the approachers. Then they turned around again and moved away.

All of the fourteen approaches where the bear stayed at the initial resting site until the approachers had passed were conducted in the berry season. Hence I excluded season as a variable in the statistical analyses. The GLM showed that none of the variables examined had a significant effect on whether the bear stayed in the initial resting site or fled before or as the approachers passed (Table 4).

Table 4: Test statistics for the generalized linear model explaining whether the bear stayed in the initial resting site until the approachers had passed or fled before or as the approachers passed when Scandinavian brown bears were approached by people on foot in south-central Sweden in 2006 and 2007 (n = 58). Test statistics are given for the variables at the time they were eliminated from the model. A backward elimination procedure was used to fit the model excluding the least significant variable with a P-value <0.05.

Explanatory variables	**β**	**SE**	**Z**	**P**
Weather conditions	-0.242	0.137	-1.766	0.077
Sighting distance	0.003	0.006	0.556	0.579
Shortest distance	0.004	0.006	0.715	0.475
Sex	-0.047	1.293	-0.036	0.971

A two-sample t-test showed no significant difference between 2006 and the equivalent period in 2007 for the sighting distance at either the initial resting site (t = 1.57, df = 25, P = 0.130), or the second resting site (t = -1.18, df = 28, P = 0.248). When the bears settled at a second resting site the average sighting distance in the initial resting site (108 ± 45 m) and the average sighting distance in the second resting site (104 ± 44 m) were not significantly different (t = 0.47, n=47, P = 0.644) (Fig. 9).

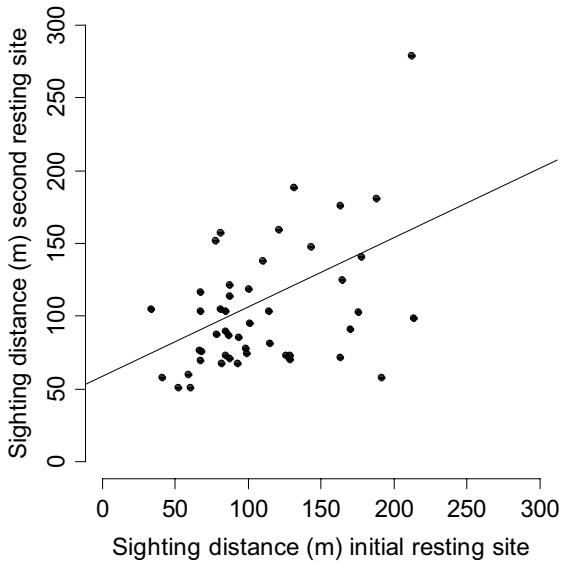

Figure 9: The sighting distance (m), indicating the density of the horizontal vegetation cover, at the initial and the second resting sites for brown bears that left the initial resting site and settled at a second resting site when approached by people on foot in south-central Sweden in 2006 and 2007.

The habitat analyses showed that while at a resting site, the bears did not necessarily lie still in a bed. Several signs of the bears' activity were found (Table 5). A bed was found at 87% of the resting sites and sign of foraging and marking behavior was commonly observed.

Table 5: Number of initial resting sites where signs of the bears' activities were detected during habitat analyses conducted after approaches on Scandinavian brown bears in south-central Sweden in 2006 and 2007.

Sign	**Number of initial resting sites where the sign was found**	**Percentage of total number of initial resting sites (n=88)**
Bed	78	89%
Scats	69	79%
Ground scratch	61	69%
Disturbed tree stubs	58	66%
Footprints	26	30%
Excavated anthills	8	9%
Carcass	6	7%
Tree scratch	3	3%
Turned stones	0	0%

Discussion

Ydenberg and Dill (1986) emphasized the importance of distinguishing between a prey animals *detection* of and *response* to a predator. A prey animal does not necessarily flee as soon as it detects a predator. The average TD (127 ± 132 m) in our study was significantly shorter than the average IRD (532 ± 394 m), but there was no correlation between the two. The difference indicates that the bears waited in the initial resting site, even though they had detected the approachers, and did not respond until the approachers came closer.

A study similar to ours was conducted by Sundell et al. (2006) in Finland. They recorded the *escape distance* of the bears, which is equivalent to the TD I have used. The average escape distance in their study was 212 ± 73 m. Their study was first and foremost a methodological study where one male bear was approached 12 times. The reaction distances are consequently not directly comparable. But their study also showed a large variance in both the reaction distance (range 37 to 624 m) and behavior (e.g. hiding, escaping and approaching the researchers) for the same individual bear when it was approached. Schleyer et al. (1984) studied the effect of nonmotorized recreational activities on grizzly bears in Yellowstone National Park, USA. They used radio telemetry to monitor the behavior of the bears prior to and after simulated recreational activity disturbances (day-use activities or establishment of a campsite). They reported an average *flush distance* of 370 m. Six out of seven tests resulted in immediate and rapid flight of the bear. In one incident the bear attacked one of the researchers before it ran off. One bear did not respond to the disturbance. The sample size in this study was low compared to our study. It is also important to emphasize that the study was conducted on grizzly bears, which are more aggressive than the Scandinavian brown bear (Swenson et al. 1996).

I found a significant positive relationship between the IRD and the sighting distance at the initial resting site of the bears, which suggested that the bears responded to our presence earlier when they were in more open vegetation. When approaching the bears, we made sure to pass the animal upwind with the direction of the wind approximately 90° to our route. The bears should have been able to smell us as we passed their resting site, but due to the direction of the wind their hearing and eyesight was probably more important for the bears' initial detection of the approachers. The density of the vegetation influences both the visibility and the audibility. If the sighting distance was long, the bears also would be able to hear the approachers earlier. I had expected to find a positive

relationship between the sighting distance and the TD as well. Denser vegetation creates better hiding for the bears. Schleyer et al. (1984) found that, if not already in cover, grizzly bears that were exposed to human disturbance moved to denser habitats before settling. McLellan and Shackleton (1989) showed that cover was an important factor reducing the magnitude of grizzly bears' responses (e.g. distance moved, speed when moving away) when exposed to human activities, such as people walking and moving vehicles. Hence I had expected that bears in denser habitats would stay longer than those in more open habitats. The relationship between the sighting distance and TD was positive, but not significant at a 5% significance level (Table 3). The sighting distance was the last factor to be excluded from the model in the screening procedure and it was close to significant when excluded ($P = 0.061$). I believe this indicates that there is a relationship between the sighting distance and the TD. Future analyses with larger amounts of data may provide a significant result at a 5% significance level.

There was a positive relationship between the IRD and the distance between the approachers and the bears at the start of the approach. I believe there are two plausible explanations for this relationship. When the starting distance was farther from the bears, the duration and length of the approach also increased. Consequently the bear could detect our presence earlier. McLellan and Shackleton (1989) showed that grizzly bears reacted more strongly to people on foot than to an approaching vehicle when the disturbance was > 150 meters away. A possible explanation for the relationship I found is that the bears did not react to the approachers in a car, but first after they left the car. The farther away the approachers left the car, the farther away the bears could detect the approachers. Average distance between the approachers and the bear at the start of the approach was 855 ± 292 m and the average IRD was 532 ±394 m. The IRD may have been underestimated in the approaches where the approachers left the car close to the location of the bear. The second possible explanation is of a methodological nature. The relationship could also be explained if the method used for detecting the reaction was too sensitive. 'Movement' caused by GPS error could then be interpreted as a reaction. The bears' movement was monitored from the time we started the approach. With a too sensitive method, the reaction would occur at a longer distance when the starting distance was large. When calculating the PARSA and PARM, I accounted for GPS error. Hence I do not believe this is a likely factor.

The IRD was negatively correlated to the time difference between the last position of the bear inside the PARSA/below PARM and the first position outside the PARSA/above PARM. I find this phenomenon hard to explain. If I had expected any relationship between the IRD and the time difference, it I would have been positive. The bears may have left the initial resting site later than the time of the last position received inside the PARSA/below PARM. The approachers would then have been closer to the bear when it actually responded and the reaction distance would have been overestimated. A negative relationship indicates that a larger time difference results in a shorter reaction distance. I do not have a logical explanation for this phenomenon, but it may be a result of the large variance in the data (Fig. 8).

The low number of significant results in the GLM analyses may also be due to the great statistical variance. Future analyses with larger amounts of data might provide significant results. On the other hand the large variance may have a biological explanation. Maybe there are no good predictors of the bears' behavior? It might be that the behavior of the Scandinavian brown bear when approached by people on foot is simply highly unpredictable. My results showed that even the variance in the reaction distances between approaches on the same individual was large. High variation on individual behavior in brown bears has been observed previously. Fagen and Fagen (1996) concluded that, like people, individual Alaskan brown bears' may even have distinct personalities. One of the factors they found that differed significantly among individuals was curiosity about people. Individualistic behavior has also been documented in other animal species (Fagen & Fagen 1996).

The performance of a GPS unit may be affected by number of and geometry of satellites, the collar antenna orientation, weather conditions, animal behavior (e.g. movement and foraging behavior) and the topography and vegetation in the animals habitat (Cargnelutti et al. 2007; D'eon & Delparte 2005; Frair et al. 2004; Gau et al. 2004). Fix-rates of less than 50% on free-ranging animals are not uncommon (D'eon & Delparte 2005). Sundell et al. (2006) suggested that the number of positions received from a bear decreases when the bear is at a resting site, due to the position of the collar when the bear is resting. This is supported by D'eon and Delparte (2005), who concluded that the collar position is extremely important for GPS collar performance. The approaches in our study were conducted during a time of the day when the bears were resting. The bears tend to select denser habitats when they are resting (Moe et al. 2007) and a higher percentage of canopy cover, mature stands, and less available sky normally limit the GPS units' performance (DeCesare et al. 2005;

Dussault et al. 1999; Hansen & Riggs 2008; Moe et al. 2007). In addition the approaches were conducted in an area dominated by coniferous forest, a vegetation type in which GPS performance normally is reduced (Cargnelutti et al. 2007). In a study conducted in our study area Moe et al. (2007) showed that almost 80% of the failed fixes they experienced occurred when the bears were passive. The reduced GPS collar performance resulted in fewer approaches with enough data to conduct analyses and it may have caused an overestimation of the reaction distances. The bears' actual time of reaction may have occurred later than the latest position we received. All the approaches were conducted in a habitat with overall dense vegetation. Hence I do not believe that the data are fix-rate biased. There was a large difference between the number of positions received in 2006 and in 2007. This is likely because the collars used in 2006 were equipped with GPS modules that shut down while transmitting locations with the GSM modem. Most of the bears used in the 2007 season wore collars where the GPS module recorded positions even if the GSM modem was transmitting data.

Only 11% of the bears were seen, even though the approachers knew the location of the bears and tracked any movement they made using the VHF signals transmitted from the bears' collar. This indicates that in most encounters between the Scandinavian brown bears and humans in the wild, the humans are not even aware of the presence of the bear. Three out of four bears fled before or as the approachers passed the initial resting site. None of the bears that stayed in the resting site were seen by the approachers. Evidently the bears prefer to avoid confrontations with humans. This behavior resembles the behavior of a prey avoiding a predator.

The bears never demonstrated any aggressive behavior. Swenson et al. (1999) identified some factors that may increase the Scandinavian brown bears aggression when encountering humans. In a decreasing order of importance the factors are: (i) a wounded bear, (ii) presence of cubs, (iii) proximity to a carcass, (iv) proximity to a den, and (v) the presence of a dog. In these situations the brown bears may be dangerous to people. Most of these situations were not included in our study. Only solitary unwounded bears were approached and the approachers did not bring a dog. No approaches were conducted in the denning season. The number of bears on a carcass was too small to include the factor in the statistical analyses. Nevertheless the six bears that were in the proximity of a carcass did not show any signs of aggressive behavior when approached. It is important to emphasize that the bears' behavior may very well be different in the situations known to increase the bears' aggression. The aim of our study was not to test the reaction of the bears in all these

situations. We wanted to gain some more knowledge about the behavior of the bears when encountered by hikers, berry pickers, or other people on foot in the forest. To be able to tell something about the reaction of the bears in the presumably more dangerous situations, it is important to have knowledge of the behavior of the bears when in a more normal situation. In that respect this study can serve as a baseline study for future research on human-bear interactions in various situations.

Management implications

The behavior of brown bears when approached by people on foot is extremely variable. The distance between the approachers and the bears at the time of the bears' reaction varied, even between approaches on the same individual. There was also a large variation in the distance the bears moved after the approach. Three of four bears fled before or as the approachers passed. Half of those that stayed moved away shortly after the approachers had passed. Some of the bears even approached the approachers before moving away. Neither of these types of behavior should be interpreted as an abnormal behavior of the Scandinavian brown bear. Due to the variation in time of and type of response it is on the other hand difficult to define a 'normal behavior' of the Scandinavian brown bear. Regardless of the type of reaction, the bears never behaved aggressively towards the approachers and only about one of ten bears were seen. The shy behavior of the bears resembles a prey animal's anti-predator behavior. I will not allege that a Scandinavian brown bear never is dangerous to people. People have been hurt and killed by the bears, with the latest incidents occurring in Sweden in 2007 and 2008. Care should be taken when encountering bears. In our study only single bears and mostly female bears were approached. Most of the situations known to increase the aggressiveness of the bears were not included. Bears in other situations may react differently and further research is necessary to fully understand the behavior of the Scandinavian brown bear when encountering humans in the wild. However the results I have presented indicate that, when approached by people on foot, the bears prefer to avoid a confrontation. Thus, they support previous studies stating that the Scandinavian brown bear is normally not an aggressive bear. My findings provide valuable knowledge to managers of the Scandinavian brown bear population. They show that when encountering people the Scandinavian brown bears may respond in several ways, but regardless of type of and time of response they do normally not respond aggressively.

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