IMMEDIATE AND DELAYED BEHAVIOR OF SCANDINAVIAN FEMALE BROWN BEARS WHEN ENCOUNTERED BY HUMANS ON FOOT

UMIDDELBAR OG FORSINKET ADFERD HOS SKANDINAVISKE BRUNBJØRNBINNER VED MØTER MED MENNESKER TIL FOTS

BJØRN ERIK PEDERSEN

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
DEPARTMENT OF ECOLOGY AND NATURAL RESOURCE MANAGEMENT

MASTER THESIS 30 CREDITS 2007

Abstract

The population of brown bears (*Ursus arctos*) in Scandinavia has increased during the last 80 years, from almost extinction to about 2400-3000 individuals today. During the same period the extent of areas with little human influence has declined, and the conflicts between human activities and brown bears have increased. To better understand the effect of nonmotorized recreational activities on Scandinavian brown bears, we conducted 25 trials where we simulated hiking in the vicinity of 10 GPS-collared Scandinavian female brown bears during the summer of 2006 in south-central Sweden. The resting bears' initial reaction distance, the distance between the persons and the bear when the bears showed a first reaction of the approaching persons' presence, was 267±213 m (SD). The resting bears left its initial resting site during 14 of these 19 trials and the tolerance distance, the distance between the approaching persons and the bear when the bear left its initial resting site was 39±18 m. The bears that left its initial resting site moved a mean linear distance of 716±1267 m to a second site where they rested again. The vertical cover at the initial resting site had no impact on the behavior of the resting bears and the vertical cover did not differ between the initial resting site and the second resting site following the movement.

Most of the female brown bears were passive for a longer time during the evening after the trial than normal. The bears also reduced their daily movement pattern during the resting periods for up to 48 hours after the trial. Both results suggest a human-induced hiding behavior by the bears. The knowledge from our study, together with future similar studies, can together give managers a useful tool in landuse planning of human activities, and increase the public's knowledge about bear behavior, including how to behave in areas with brown bears.

Key words: Brown bear, *Ursus Arctos*, Scandinavia, GPS, human-bear encounters, disturbance.

Sammendrag

Etter en nær utryddelse av brunbjørnen (*Ursus arctos*) i Skandinavia for 80 år siden, har populasjonen av brunbjørn økt til rundt 2400-3000 individer. I løpet av samme periode har arealene av utmark med lite menneskelig påvirkning blitt redusert, noe som medfører økte konflikter mellom brunbjørnen og menneskelig aktivitet. Sommeren 2006 ble det i Sverige gjennomførte 25 forsøk med simulerte turgåing i nærheten av 10 GPS-merkede binner. De hvilende binnene viste første reaksjon på personenes nærvær når de var 267±213 m (standardavvik) unna. 14 av de 19 binnene flyttet seg fra sitt opprinnelige hvilested når personene var 39±18 m unna. Binnene som forlot hvilestedet, forflyttet seg til et nytt hvilested 716±1267 m i luftavstand fra det opprinnelige hvilestedet. Binnenes vertikale skjul på opprinnelige hvilestedet hadde liten eller ingen betydning på binnenes adferd og de viste ingen tegn til å oppsøke hvilesteder med tettere vegetasjon etter forflyttningen.

De fleste binnene var passive i en lengre periode utover kvelden etter forsøket enn hva de normalt er. Binnene reduserte også sitt daglige bevegelsesmønster under hvileperiodene i opp mot 2 døgn etter forsøkene. Begge resultatene tyder på en adferd der binnene trykket som følge av menneskelig forstyrrelse. Kunnskapen fra dette studiet, sammen med fremtidige liknende studier, kan bli et verdifullt verktøy i arealforvaltningen og kan øke allmennhetens kunnskaper om bjørnens oppførsel mot mennesker, inkludert hvordan man selv skal oppføre seg i områder med bjørn.

1. Introduction

During the 1900's the area with little human influence has declined dramatically in Scandinavia, due to human development. Human development and activities can have large negative impacts on brown bears (*Ursus arctos*). Direct mortality due to collisions by vehicles or trains (Huber et al., 1998; Kaczensky et al., 2003), increased bear mortality as a result of more bear-human interactions (Mace et al., 1996**;** Gibeau and Herrero, 1998), habitat fragmentation due to semi permeable barriers, such as highways and railways (Proctor et al., 2002; Kaczensky et al., 2003), direct short-term loss of habitat due to intensive forestry (Nielsen et al., 2004), or indirect habitat loss due to displacement or avoidance of areas close to human development, such as infrastructure and settlements (McLellan and Shackelton, 1988; Gibeau et al., 2002; Mueller et al., 2004; Waller and Servheen, 2005; Nellemann et al., 2007) are some major concerns when considering impacts of human development on bears. Brown bears avoid humans by altering their spatial and temporal use of areas with high human recreation activities (Naves et al., 2001; Smith, 2002; DeBruyn et al., 2004; Rode et al., 2006). Smith (2002) reported that brown bears at a sockeye salmon (*Oncorhynchus nerka*) river in Alaska spent less time on the river, less time resting and more time moving about in the areas with high human use. He also reported that human-bear interactions usually were a result of humans entering areas of concentrated bear activity and not bears entering areas with high human use. A study of the immediate reaction of grizzly bears (also *U. arctos*) to different human activities in British Columbia revealed that the bears reacted more strongly to people on foot in vicinity of a vehicle than to fixed-wing aircraft (McLellan and Shackleton, 1989).

There were about 4000-5000 brown bears on the Scandinavian Peninsula around 1850; with Norway having the densest population (Swenson et al., 1995). After years with intensive overexploitation in both Norway and Sweden, the number of brown bears declined rapidly until about 1930, when the brown bear population was virtually extinct in Norway and only about 130 individuals were left in Sweden (Swenson et al., 1995). The population began to increase in Sweden after stringent protection during the 1900's. Today the number of brown bears in Norway is still very low, but there are 2350 to 2900 individuals in Sweden (Kindberg and Swenson, 2006).

The increasing brown bear population in Scandinavia results in more bears close to inhabited areas and leads to increasing conflicts with humans. Although many studies have shown that brown bears tend to avoid humans, it is also well documented that brown bears have hurt and killed people (Herrero, 1985; Chestin, 1993; Swenson et al., 1999) and for the first time in more than 100 years a hunter was killed by a bear in Sweden in 2004. However, the Scandinavian brown bear does not appear to be very aggressive towards people. Chestin (1993) reported that brown bears were more aggressive towards humans in central and eastern Russia than in European Russia, and the bears in North America and Siberia appear to be more aggressive than the Scandinavian brown bear (Swenson et al. 1996). Swenson et al. (1999) analyzed the outcome of 114 encounters between brown bears and bear research personnel in Scandinavia. None of the encounters resulted in direct attacks, but bluff charges occurred in 4% of the encounters. Based on the outcome of the 114 encounters and a literature review of bear attacks from the past (1750-1962), Swenson et al. (1999) concluded that the Scandinavian brown bear is only truly dangerous if it is wounded. Swenson et al. (1999) also speculated that the relative high proportion of wounded bears, caused by less effective hunting techniques, was an important factor contributing to the seemingly higher loss of humans to bears in the past. Although the statistics show that the Scandinavian brown bear is not very aggressive, it is still the most dangerous large carnivore in Scandinavia (Røskaft et al., 2003). A survey among the Norwegian public revealed that Norwegians are more afraid of bears than the other three large, but less dangerous carnivores: wolves (*Canis lupus*), lynx (*Lynx lynx*) and wolverine (*Gulo gulo*), and the fear of bears is greater in rural areas outside the bears' range than in areas with bears (Røskaft et al., 2003).

Many studies have examined human-bear interactions, but few studies have been conducted on how bears behave when encountering humans on foot. Schleyer et al. (1984) and Haroldson and Mattson (1985) studied the effects of camping and hiking on grizzly bears in Yellowstone National Park and Sundell et al. (2006) recently introduced new method using Global Positioning System (GPS) and Global System for Mobile Communications (GSM) to study the behavior of brown bears when encountered by humans, but all three studies are based on few encounters. Studies of how lynx and wolf behave when encountering humans on foot have been conducted in Norway (Sunde et al., 1998; Wam 2003), but more knowledge of how Scandinavian brown bears react and behave in the vicinity of hikers is important to minimize the increasing conflicts between humans and bears. To address this need for knowledge, we conducted a standardized experimental disturbance treatment to determine how GPS-collared female brown bears behave when approached by humans on foot. The treatment simulated an encounter between bears and humans that can, and does occur when people (e.g. hikers, hunters, berry pickers, forest workers) intentionally or unintentionally approach bears in the forest. The knowledge from this study can be used to inform the public about how to behave in areas with bears, and be used in landuse planning to decrease the human impacts on brown bears.

2. Study area

The study was conducted in Dalarna and Gävleborg counties in south-central Sweden (61°N, 15°E). The area is gently undulating with scattered hills, and elevations ranging from about 200 to 700 m. No part of the study area is above the timberline. The area belongs to the northern boreal forest region, and is dominated by coniferous forest, intersected by lakes, rivers and large bogs. Forestry is intensive in the region, and large clear cuts and tree monocultures are important components in the landscape. There is an extensive road system in the area, mostly consisting of gravelled logging and public roads, but also paved public roads. Human settlements are limited to a few scattered villages and cabins. GPS data of the bears in the study area show that the bears come into the vicinity of human development and activities several times each year, and most likely also encounter humans on foot once in a while.

The forest is dominated by Scots pine (*Pinus sylvestris*), with a large portion of Norway spruce (*Pica abies*) and lodgepole pine (*Pinus contorta*). Deciduous tree species, like birch (*Betula pubescens*), silver birch (*B. pendula*), aspen (*Populus tremula*), European mountain ash (*Sorbus aucuparia*), and gray alder (*Alnus incana*) are also common. The field vegetation includes 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*) are widespread and are abundant in most years.

The study area is located in the southernmost reproductive core area of the Scandinavian brown bear population (Fig. 1). Using a combination of a mark-recapture technique and fecal DNA sampling the density of bears was estimated to be 30 bears per 1000 km^2 in the center of the area (Bellemain et al., 2005; Solberg et al., 2006). The area is open for bear hunting, and the bear hunting season lasts from 21 August to 15 October.

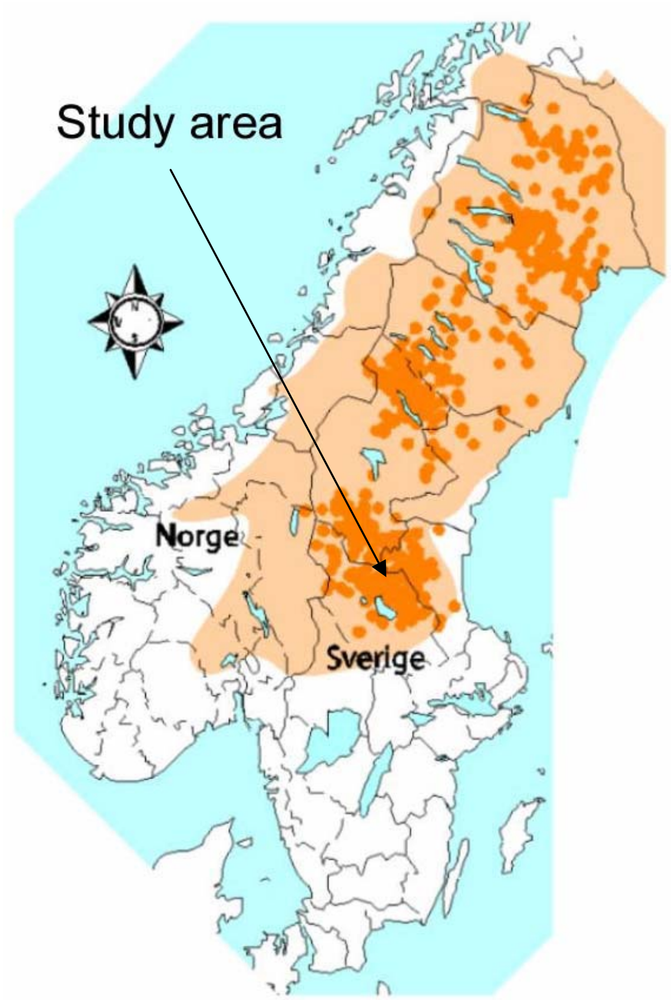

Figure 1: The distribution of brown bears (*Ursus arctos*) in Scandinavia in 2006 (darker area), and the locations of female brown bears shot in Sweden between 1981 and 2006 (dots) representing the core areas of the brown bear population in Scandinavia. This study was conducted in the southernmost core area.

3. Methods

3.1. The bears

The brown bears were immobilized in late April-mid June by darting them with a mixture of tiletamine/zolazepam and medetomidine from a helicopter (Arnemo et al., 2006). All bears were sexually mature, with ages ranging from 3 to 14 years. All bears were solitary, except for one which was accompanied by her two yearlings. The age of bears not followed from birth was determined by counting the annuli on a cross-section of one of the premolar roots (Jonkel, 1993; Matson et al., 1993). The brown bears were all equipped with GPS Plus-3 or GPS Pro-4 neck collars and GSM lateral modems (VECTRONIC Aerospace GmbH, Berlin, Germany). All bears, except one, carried an implanted radiotransmitter in their body cavity (Arnemo et al., 2006; *Biomedical Protocols for Free-ranging Brown Bears, Gray Wolves, Wolverines and Lynx*; available at http://www.rovviltportalen.no/attachment.ap?id=1535; last accessed 22 May 2007). The methods used to capture and marking the bears were more thorough described by Dahle et al. (2006).

3.2. The trials

The approaches, hereafter called the trials, were conducted between the 29 of June and the 15 of August 2006, before (29 June – 19 July) and during (20 July – 15 August) the berry season. The berry season started the day we first noted berries in bear scats. All trials were conducted between 13:00 and 16:00, which is at the time of day when the bear usually have their day rest (Moe et al., 2007).

The locations of the bears were stored in the GPS collar and were automatically transmitted to a base station, in packages of seven stored GPS locations, by the GSM modem, as soon as the seventh location was stored in the collar. The collars could also receive short message commands, which were used to reprogram the GPS schedule before the trials. The collars were programmed to obtain locations every minute between 13:00 and 16:00 during the trials, yielding a theoretical maximum of 180 locations during each trial. The GPS collars were programmed to obtain locations in intervals of 30 minutes during the rest of the time. The GPS collars also had a Very High Frequency (VHF) transmitter, and standard telemetry methods and the received GPS-collar locations were used to locate the bears prior to the trials.

One or two persons, hereafter called the approachers, approached the bears on foot at a speed of 1.5 – 2.6 km/h, simulating hikers. The approachers started walking 17 to 120 min after the GPS collar started obtaining locations at one-minute intervals and started walking 0.5 – 1 km from the bear in all but three trials. In those three trials the approachers started at about 300 m from the bear on a trafficked road. The approachers did not walk straight towards the bear, but chose a route passing at about 50 m from it. The route was always upwind of the bear, with the wind direction at about a 90° angle to the route. The approachers talked to each other during the trials, and when only one person approached the bear, he simulated a normal conversation. The approachers monitored the implanted radiotransmitter during the trials to adjust the directions of the route, when it was necessary due to varying accuracy of the initial bear location obtained prior to the trial. Radio telemetry was also used to monitor the behavior of the bear during the trials. The time of sudden shifts in signal strength or direction, indicating changes in the bear's behavior, was recorded. The approachers continued walking about 500 m after passing the bear, and walked back to the starting point upwind and a minimum of 500 m from the bear (Fig. 2).

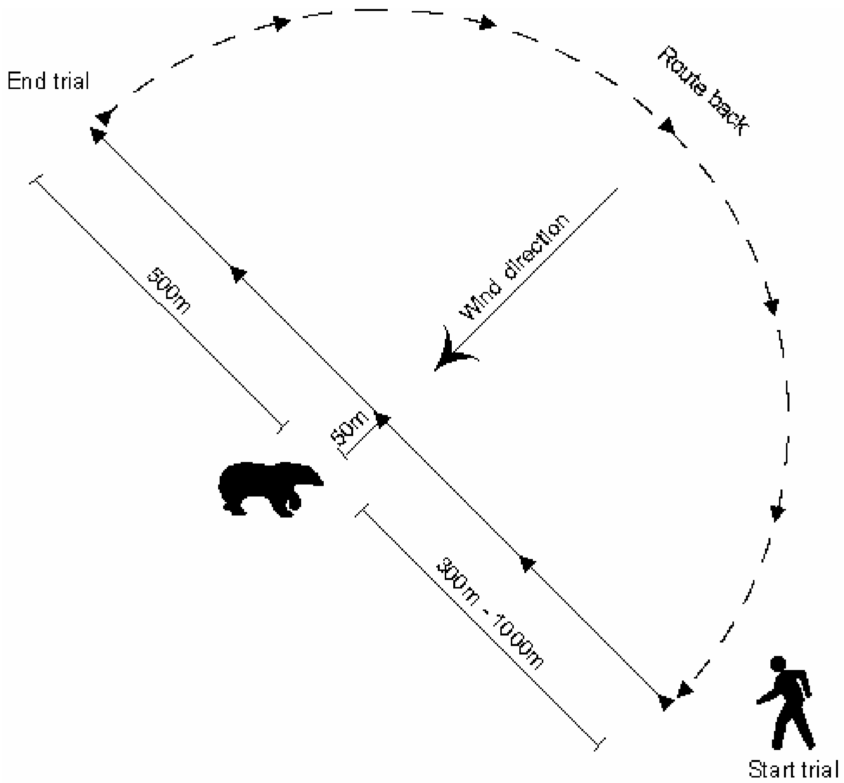

Figure 2: The setting of the trials where female brown bears were approach by humans on foot to test their immediate and delayed behavior to humans, in south-central Sweden 2006.

The route of the persons who approached the bears was recorded by a handheld GPS receiver (MAGELLAN SporTrack Color [Thales, Santa Clara, California, USA]). The tracklog on the GPS was programmed to obtain a location every 10 meters along the route.

3.3. Habitat characteristics

Two to four days after the trials, we searched the area within a radius of 30 m from the midpoint of the cluster of GPS-collar locations or the last bear location prior to the trial to document the bear's behavior prior to the trial and to register habitat characteristics. The bear was considered to have been active prior to the trial if no beds (the place where the bear has rested) were found at the location, or if the VHF signals prior to the trial indicated an active bear. Otherwise, the bear was defined as a resting bear. A bears' resting site often consists of several beds and describes the area used by the bear while resting. We also investigated the second resting site, if the bears moved to a second resting site after the trial.

We used an umbrella to estimate the vertical cover at the bear location. The umbrella was placed on its side in the bed closest to the middle of the investigated area. We estimated the visible area of the umbrella from a distance of 10 m, 70 cm above ground and from four directions (north, south, east and west). The umbrella was 95 cm in diameter and was divided into 8 equal sectors. Each sector was given a value depending of how much of the sector was visible (0 = 0-25% visibility, 0.5 = 25-75% visibility and 1 = 75-100% visibility). The visibility score for all directions was summed, giving a maximum total value of 24 with full visibility, indicating zero vertical cover in all directions.

3.4. Analysis

I divided the behavior of the bears following the trials into immediate behavior and delayed behavior. The immediate behavior describes the behavior of the bears during the three-hour period (13:00-16:00) when the GPS collar obtained locations at one-minute intervals. I have only analyzed the immediate behavior of bears during trials where the bear was resting prior to the trial, because there were few trials with active bears. However the delayed behavior includes all the trials, and describes the behavior of the bears after the three-hour period.

3.4.1. Immediate behavior

I compared the area used and average rate of movement by the bears prior to and after the start of the trials, to determine if the encounter changed the behavior of the bears. The period prior to the trial was from the time the GPS collar started obtaining positions at one-minute intervals to the start of the trial, and was considered to be normal bear behavior. The period prior to each trial varied from 17 to 87 min (mean 39±10 m (SD), N=19).

The normal area used by the resting bears was defined as the average size of the resting site area used by the bears prior to the trials. Due to variable numbers of locations from each GPS collar and the low number of trials, I used a pooled estimate of the normal area used by all the resting bears. I calculated the diameter of the circle bounding all of the bear locations collected during the period prior to each trial (mean 25.8 m, 95% CI 12.4–39.2 m, N = 17). This upper 95% confidence interval (39.2 m) was set as the limit of the bears' normal resting site area (NRSA) for all the bears prior to the trials. I placed the center of the NRSA in the bed closest to the center of the cluster of GPS-collar locations collected prior to each trial.

The normal rate of movement (NRM) of the resting bears was, analogous to the NRSA, calculated as the average movement rate between successive GPS-collar locations collected during the period prior to the trials. The time intervals between successive GPS-collar locations varied greatly (0.37–22.8 min), with a major peak less than 5 min and a minor peak above 5 min. I assumed that the GPS module was shut down during the time intervals above 5 min, due to the transmitting of GPS-collar locations by the GSM modem. Hence, I did not calculate the movement rate during time intervals above 5 min. I also rejecting the 5% shortest and the 5% longest intervals of the remaining time intervals shorter than 5 min to avoid extreme values of the movment rate. The remaining 76 time intervals varied between 0.75 and 3 min, and was used to calculate the NRM. There was no correlation between movement rate and temperature ($F = 2.098$, $df = 1$, $p = 0.152$) and I did not test the movement rate against individual or precipitation, because of too few samples for each bear and only three of the trials were conduced while it was raining. Hence, I used a pooled estimate of the NRM used by the resting bears. The average movement rate of the bears before the trials was 0.30 km/h (95% CI (0.23–0.37 km/h), N = 76). The upper 95% confidence interval (0.37 km/h) was set as the limit of the bears' NRM while resting. I defined encounter-induced reaction to have occurred if the bears increased its area of use or rate of movement beyond the limits of the NRSA and NRM, respectively.

Five different immediate behavior patterns were measured during each trial:

- ***Initial reaction distance (IRD)***: The distance between the approacher(s) and the bear, when the bear first showed a response to being approached. The initial reaction distance (IRD) was measured from the approacher(s) to the bear location; 1) where the bear started the movement out of the NRSA or, 2) where the bear's rate of movement started to increase above the NRM (0.37 km/h) or, 3) the time the approacher(s) saw that the bear reacted to the approach, or at the time a distinct increase in the VHF signals was recorded (indicating that the bear changed its position).

Tolerance distance (TD): The distance between the approacher(s) and the bear, when the bear left its initial resting site (resting site prior to the trial). The tolerance distance (TD) was measured from the approacher(s) to the bear location; 1) where the bear moved out of the NRSA and did not return until the trial ended or, 2) where the bear's rate of movement increased and stayed above the NRM (0.37 km/h) during the movement out of the NRSA and the bear did not return until the trial ended or, 3) where the approacher(s) saw the bear leave the area, or where the VHF signals indicated that the bear left the NRSA.

- ***Linear distance moved***: The linear distance that the bear moved between its initial and second resting site following a trial.
- ***Total distance moved***: The actual distance the bear moved between its initial and second resting site following the trial. (Based on the sum of distances between each GPS-collar locations collected during the bear movement.)
- ***Maximum rate of movement***: The maximum speed the bear attained between two successive GPS-collar locations during the movement between the initial and second resting site.

I plotted the locations of the bear and the approachers in ArcMap™ 9.1 [Environmental System Research Institute 1999]. I assumed that the rate of movement and direction moved by the approachers was constant between two GPS locations and interpolated their location at the time when the initial reaction and tolerance was recorded. I then measured the IRD and TD from the location of the bear at time of initial reaction and tolerance to the interpolated location of the approachers.

3.4.2. Delayed behavior

I compared the area used (the diameter of the circle bounding the GPS-collar locations) by each individual bear while at the second resting site with the area used by the same individual during the same time of day on days without trials (normal behavior), to determine if the bears were altering their late-day activity after the trials. I only compared the second resting sites after the trials when I knew at which time (within a half-hour) the bear left this resting site. For bears that stayed after the trial, I compared the area used by the individual bear between 16:30 and 18:30 after the trial with days without trials during the same time period. The area used by the bear was compared within the same season (before and during the berry season).

I also compared the average half-hour movement pattern of all the bears during a 72-hour period after the trials, with their average movement pattern at days without trials (normal daily movement pattern). The normal daily movement pattern was calculated as the daily average half-hour movement of all the encountered bears during the whole study period, except for the 72-hour period after the trials.

3.4.3. Statistical analysis

I used the One-Sample Kolmogorov-Smirnov Test with Lilliefors significance correction to test if data were normally distributed. If not, the data were log-transformed. I used a paired-samples t-test to test the normal rate of movement against temperature, to determine whether the IRD distance was longer than the TD, and whether vertical cover differed between the initial resting site and the second resting site. All these analyses were run in SPSS® 13.0 [SPSS Inc., Chicago, Illinois, USA]. Linear mixed model for TD, including the random effect of the individual bear and IRD as fixed effect, was fitted using the glmmPQL function in R 2.4.1 (the MASS library) (R Development Core Team 2007). I also used linear mixed models, including the individual as a random effect, to test the effect of vertical cover on IRD and TD. I tried a logistics mixed model (using the glmmPQL function) to determine the probability of movement from the initial resting site, including the individual as a random effect and vertical cover and the distance at which the initial resting site was passed as fixed effects, but the model did not converge. I therefore tested the probability of movement with logistics regression, using cover and the distance at which the initial resting site was passed as fixed effects, but without the random effect. I chose a level of $p \leq 0.05$ for statistical significance and a 95% confidence interval, where confidence interval was used.

4. Results

We approached 10 GPS-collared female brown bears a total of 25 times. Each of the 10 bears was approached one to four times and there were 13 to 23 days between approaches of the same bear.

4.1. GPS-collar location success

The location success of the GPS collars between 13:00 and 16:00 while positioning at minute intervals was, 23.1±9.7% (mean±SD), giving a mean time between successive locations of 4.33 min. The location success prior to the trials was 19.9±14.7% and after the start of the trials was 24.7±11.8%, giving mean times between successive locations of 5.02 min and 4.15 min, respectively. The location success between 13:00 and 16:00 on days without trials, while positioning at half-hour intervals, was 31.6±15.4%. The overall location success of the GPS collars while positioning at half-hour intervals, was 54.0±26.2%. After removing two cases of serious collar malfunction, the location success between 13:00 and 16:00 on days without trials and the overall location success rate was improved to 38.6±5.1% and 66.2±6.2%, respectively.

4.2. Immediate behavior

I was able to determine the immediate behavior of 8 different resting bears during 19 trials. This behavior varied greatly. The bear left the initial resting site during 14 of these 19 trials. One bear that left returned to the initial resting site after the trial. Another bear moved only a short distance and hid at a new location, where she was passed at 50 m, before she continued to a second resting site. Another bear crossed our trail during the movement and followed the approachers' tracks for about 15 m, before she continued to a second resting site. One bear moved 47 min after the approacher had passed her. Because she did not move during the trial, I have counted her as a bear that did not move in the further analysis. The results showed that she might have smelled the approachers' tracks, and left immediately afterwards. She then moved a total distance of 2230 m, with a maximum rate of movement of 10.7 km/h, to a second resting site.

The distances at which the approacher(s) passed the center of the initial resting sites varied from 8 to 98 m (mean 39±22 m, N=19). In the trials where the bear left the initial resting site, the sites were passed at distances between 8 and 59 m (mean 31±14 m, N=14). In the five trials where the bear stayed at the initial resting site, the sites were passed at distances of between 32 and 98 m (mean 61±25 m, N=5). The shortest distance between the bear and the approacher(s) during the trials varied from 10 to 98 m (mean 45±22 m, N=18).

4.2.1. Initial reaction distance and tolerance distance

I was able to register an initial reaction by the bear during 16 of the 19 trials, which gave an IRD of 267±213 m (range 17-803 m, N=16). Using only the GPS-based criteria for initial reaction (criteria 1 and 2), the mean IRD was 339±197 m (range 50-803 m, N = 12). During 6 trials we could register initial reaction by shifts in the VHF signals, and during one trial we visually observed that the bear reacted. Using only this criterion (criterion 3), the mean IRD was 48±17 m (range 17-67 m, N = 7). We registered a reaction with both the GPS-collar and the VHF-transmitter during three trials, and the IRD registered with the GPS was farther than the IRD registered with the VHF during all these trials. The differences were 177 m, 470 m and 762 m. I was able to measure the TD during 13 of the 14 trials where the bear left the initial resting site. The TD was 39±18 m (range 10-67 m, N=13). The IRD was on average 223±250 m (range 0-777 m, N = 12) and significantly longer than the TD ($t = 0.3082$, $df = 11$, $p = 0.010$) (Fig. 3). There was no correlation between IRD and the corresponding TD ($\beta = -0.0062$, $df = 4$, $t = -0.28$, $p = 0.79$).

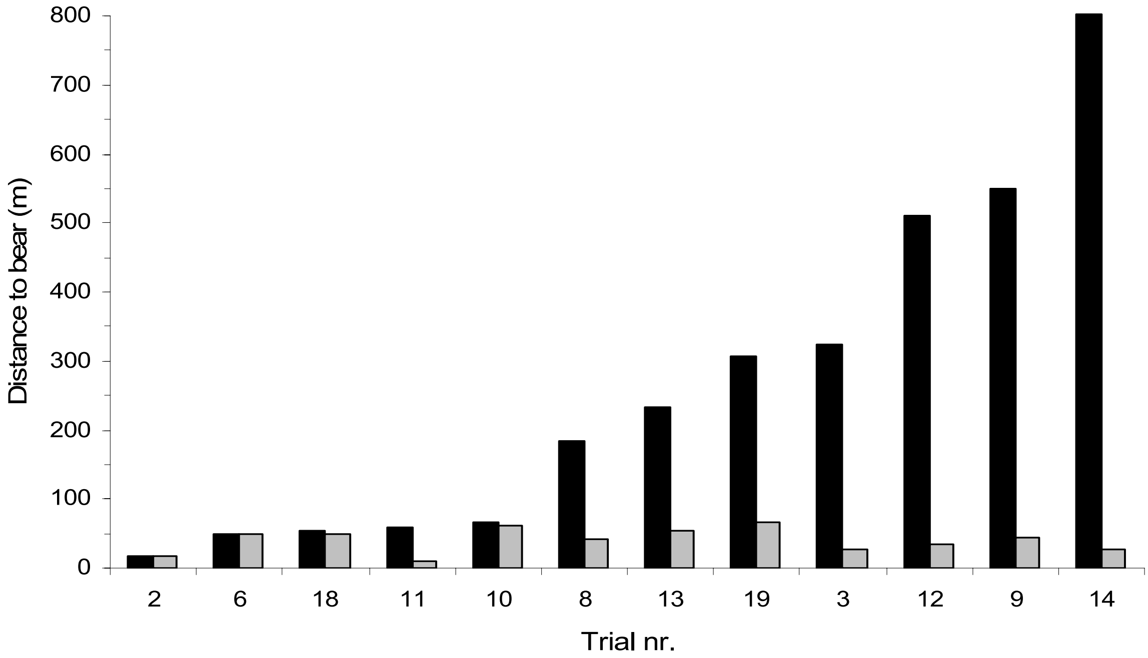

Figure 3: Comparison of the initial reaction distance (black bars) and the tolerance distance (gray bars) of resting female brown bears during 12 out of 19 trials where resting female brown bears were approached by humans on foot, in south-central Sweden 2006.

4.2.2. Linear distance moved, total distance moved and rate of movement while leaving

Only one of 14 bears moved back to its initial resting site after the trial, 53 minutes after the encounter; the other bears moved to a second resting site. The linear distance moved between the initial and the second resting site was 716±1267 m (range 47-4373 m, N = 11). The mean total distance moved was 1267±1835 m (range 47-4776 m, N=6), and was on average 17.5±16.5% longer than the linear distance moved. The maximum rate of movement while leaving averaged 5.6±4.7 km/h (1.4-12.9 km/h, N=6). The bear that moved the farthest distance (4776 m) following the trial had two yearlings. This trial was also the only trial among the resting bears where we saw that the bear left the area. GPS collar data from another female bear showed that she accompanied the bear with the two yearlings during this movement. They moved together for about 3 km, and crossed three roads and three rivers before they stopped at a second resting site.

4.2.3 The importance of vertical cover

There was no correlation between the vertical cover at the initial resting site and the IRD (β = 6.69, df = 7, t = 0.63, p = 0.55) or the TD (β = -0.37, df = 5, t = -0.40, p = 0.70). The probability of a bear moving from the initial resting site was not correlated with the vertical cover at the bed site (β = 0.52, df = 16, z = 1.27, p = 0.20), but there was a trend towards the probability that movement was negatively correlated with the distance at which the approacher(s) passed this resting site (β = -0.13, df = 16, z = -1.69, p = 0.09). The vertical cover at the second resting site was on average 4.4±28.3% lower than on the initial resting site, but this difference was not significant (t = 0.49, df = 9, p = 0.64, Fig. 4).

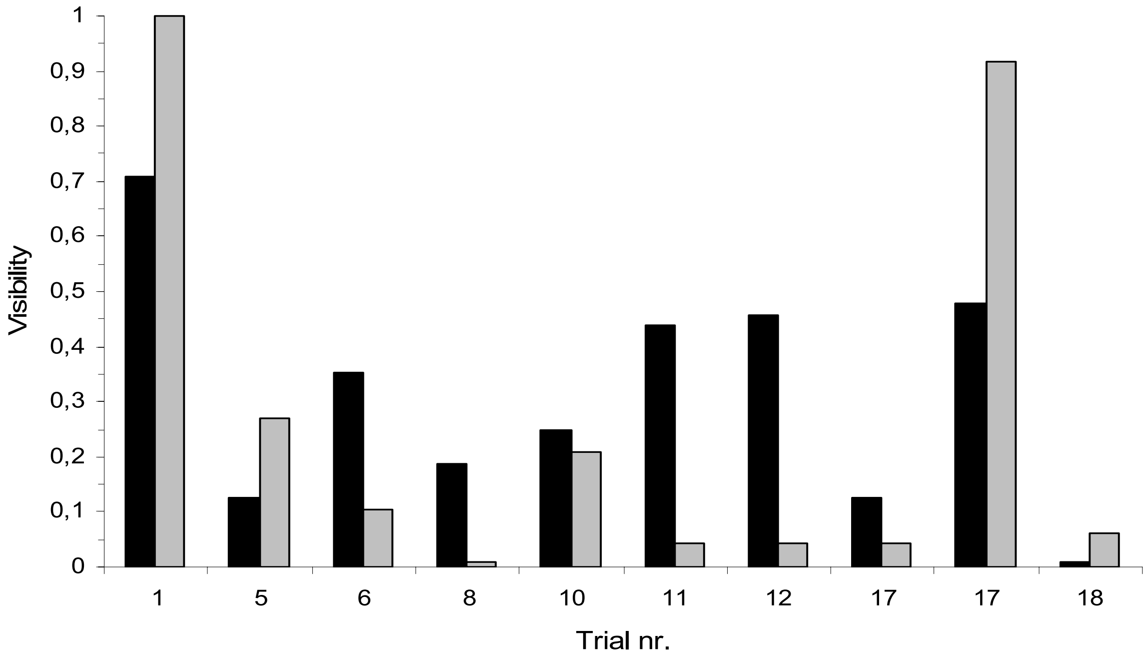

Figure 4: Visibility at the initial (black bars) and the second resting site (gray bars), after 10 out of 19 approaching trials where resting female brown bears were approached by humans on foot, in south-central Sweden 2006. The visibility score 1 indicates zero vertical cover at the resting site.

4.3. Delayed behavior

The bear moved after 19 of the total 25 trials. In 10 of these 19 trials, the GPS-collar data indicated the time when the bear left the second resting site (or during one trial left the initial resting site for the second time). The bears used a significantly smaller area while at the second resting site than during the same time period on days without trials in 9 of these 10 trials (Fig. 5). Where the bears stayed after the trial, the GPS-collar data indicated that, in 3 of the 6 trials, the bear used a significantly smaller area between 16:30 and 18:30 on the day of the trial than during the same time period on days without trials (Fig. 5). In the remaining 3 trials where the bears stayed, GPS-collar data between 16:30 and 18:00 were missing.

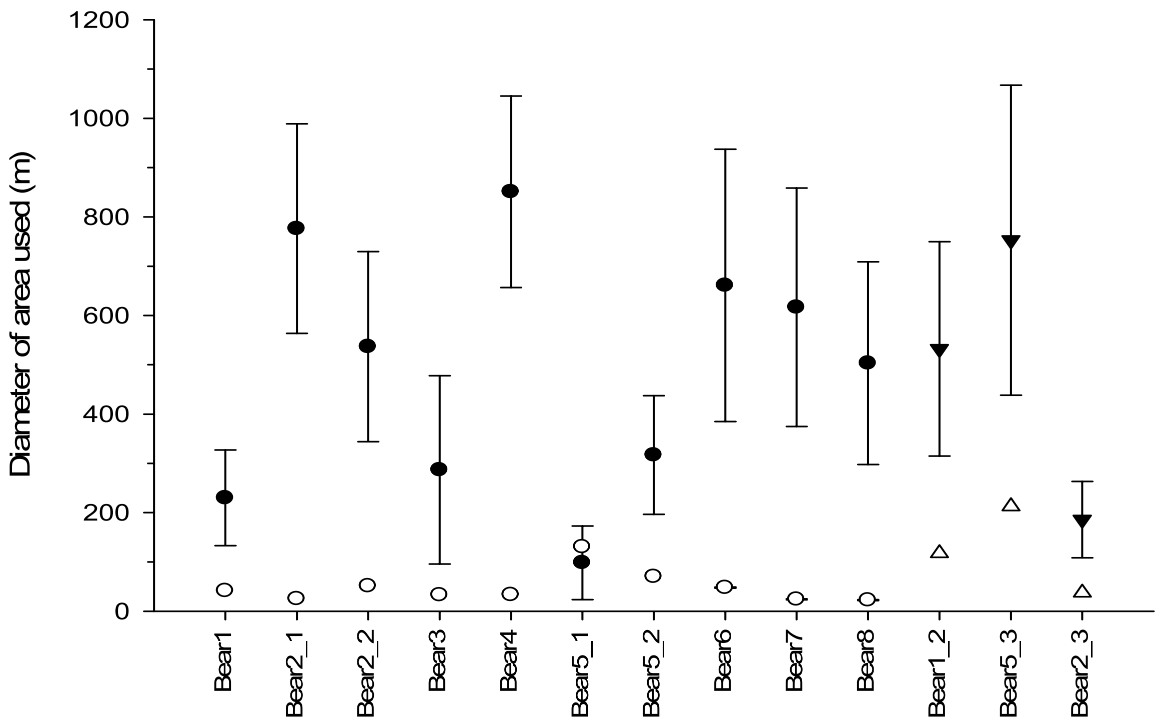

Figure 5: Comparison of the diameter of the area used by female brown bears while at the second resting site after being approached by humans on foot (○), compared with their normal (undisturbed) area use during the same time period (●). The figure also shows the area used by female brown bears that stayed after being approached by humans on foot between 16:30 and 18:30 the day of the trial (∆), compared with their normal area use during the same time period (▼). South-central Sweden 2006.

The movement patterns of the bears following the trials showed that the bears had significantly shorter movements during 6 of 9 half-hour periods between 16:30 and 21:00 following the trials, compared with their normal movements on days without trials (Fig. 6). In addition these bears also had shorter movements during 12 of 19 half-hour periods between 06:30 and 16:00 the morning following the trials (Fig. 6). The movement was also, to a lesser degree, shorter the second day after the encounter, but was only significant during 2 half-hour periods (Fig. 6). I did not observe any difference between the movement pattern the third day after the encounter and normal daily movement patterns.

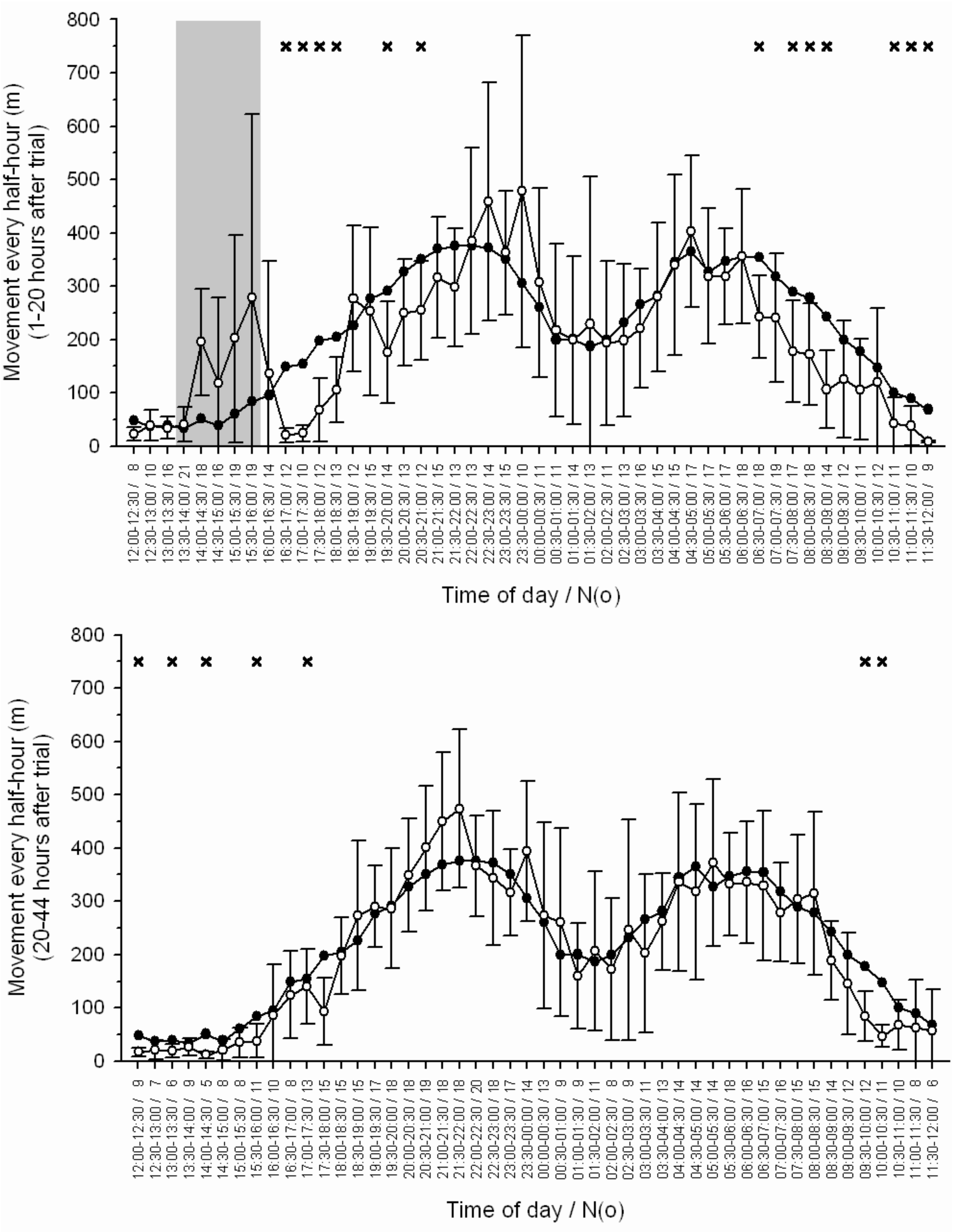

Figure 6: Daily movement pattern (with 95% confidence interval) of female brown bears 1 to 20 hours, and 20 to 44 hours after being approached by humans on foot (○), compared with their normal daily movement pattern (●). The observations illustrated are based on 25 trials where 10 different female brown bears were approached by humans on foot in south-central Sweden 2006. The darker section shows the period during the trials and the **x** shows the half-hour periods where the movements differed significantly from normal. The 95% CI limits on normal daily movement pattern were not shown because they were narrow, N(●) = 94-273).

5. Discussion

5.1. Methodology

GPS technology has improved our ability to monitor movements of free-ranging species, but problems include missing data due to failed location attempts and spatial inaccuracy in the acquired animal location. Missing data and spatial inaccuracy are reported to depend on vegetation, topography, satellite constellation and animal behavior (Moen et al., 1996; Moen et al., 1997; Bowman et al., 2000; Frair et al., 2004; D'Eon et al., 2002; Cain et al., 2005; DeCesare et al., 2005; D'Eon & Delparte, 2005).

The overall location success for my study (54.0±26.2%), while positioning in half-hour intervals, was compatible with other studies using GPS receivers on bears (Belant and Follmann, 2002; Gau et al., 2004; Rauset, 2006). The location success between 13:00 and 16:00 (31.6±15.4%) was much lower than the overall location success, which is probably due to decreased location success when the bears were passive, also reported by Moe et al. (2007). The behavior-induced GPS-data loss was probably caused by three factors; the collar position (D'Eon & Delparte, 2005), the obstruction of the signal transmission by the resting bear's body, and the bear's habitat selection when inactive. The location success during the trials (23.1±9.7%), with one-minute fix intervals, was much lower than the location success with half-hour fix intervals during the same time of the day. This does not correspond with a recent literature review of GPS collar performance (Cain et al., 2005) and a recent study on wolves (Mills et al., 2006), which reported that the fix interval used was inversely related to the location success. The opposite result in my study may partly be due to shorter fix intervals than reported in those two studies, but is most likely due to the use of GPS-GSM collars where the GPS module was shut down while transmitting locations with the GSM modem. This may also explain why the location success during the trial of my study was much lower compared with the study of Sundell et al. (2006), which reported a location success of 81.2% with fix intervals at 25-600 seconds, and that 93.6% of these locations was successfully transmitted by the GSM modem. The GPS collars used in Sundell et al.'s study (2006) were programmed to take locations continuously at full power all the time, and was not shut down while transmitting locations. The difference in location success may also partly be due to differences in GPS coverage, which was reported as good in Sundell et al.'s study (2006), whereas it varied greatly from no coverage to good coverage in my study area.

Missing data may have a profound effect on habitat studies (Dessault et al., 1999), but I believe it was of less concern in my study. The low location success reduced the accuracy and increased the variance of my estimates, but the estimates were not biased systematically. The use of VHF tracking during the trials was useful, and increased the accuracy during the trials where no GPS-collar locations were received when the bear left the initial resting site.

GPS location error from a true location is reported to be approximately ≤ 30 m 95% of the time (D'Eon et al., 2002; Cain et al., 2005; D'Eon & Delparte, 2005). Spatial inaccuracy in GPS locations may have biased the estimates of the bears' behavior during a given trial, but the bias of the pooled estimates would be less, because location error is equal in all directions (Moen et al., 1996). The normal behavior (NRSA and NRM), which I used as threshold for encounter-induced behavior, included both location error and real movements by the bears, and thus takes into consideration the potential spatial inaccuracy of the GPS.

5.2. Immediate behavior to approaches

The estimated IRD based on the GPS criteria (339±197 m) was much longer than the estimated IRD based on the on the VHF and visual criteria (48±17 m). It is likely that the IRD based on the VHF and visual criteria were biased low. Visually detection is only possible at close distances in dense forest and the VHF monitoring during the trial was most likely not suited to detect the changing of the bear's activity at large distances, due to the small antenna and monitoring while walking.

The generally short TD (39±18 m) among the 14 bears that left the initial bed site shows that the bears tolerated people that appeared unpredictably in their vicinity quite well. The IRD was on average 223±250 m farther than the TD, but there was no correlation between the IRD and TD. The difference between the IRD and TD could indicate that the bear awaited the situation having full control, but considered it not yet critical. It may also indicate that the bear needed time to determine that it was approached by a human. Sundell et al. (2006), who conducted 12 approaching experiments with one male brown bear in Finland, found that the bear's escape distance (equal to my TD) varied from 37 to 624 m, averaged 212 m. A study of human encounters of two male and three female grizzly bears in open and forested areas in Yellowstone National Park showed varying results. In 5 occasions the grizzly bears moved away when the approach team was 180-600 m away, two times the bear approached the team before moving away at close distance and one approach resulted in the mauling of a person before the male bear left (Schleyer et al., 1984).

The linear distances between the initial bed site and second resting site varied between 47 and 4373 m, with average at 716±1267 m. The average distance moved for the grizzly bears following the approach in the study of Schleyer et al. (1984) was 2.98km, which is much longer than the result from my study.

My result differs from both Sundell et al.'s (2006) study and Schleyer et al.'s (1984) study, but one has to consider the small sample size of these two studies and that the methology differed. Schleyer et al. (1984) studied grizzly bears, which appear to be more aggressive than the Scandinavian brown bear (Swenson et al. 1996). Schleyer et al. (1984) also studied both male and female bears and Sundell et al. (2006) studied only male bears and approached one bear several times. It may also have been differences in forest density and human activity in the study areas, which also may explain the different results of the bear behavior. McLellan and Shackelton (1989), found that grizzly bears reacted more strongly (farther TD and farther distance moved after a human encounter) to people in open areas and in areas with low human activity.

I did not observe any correlation between vertical cover at the initial resting site and IRD, or TD, or the probability of moving from the initial bed site. The bears that left the initial resting site had no preferences of denser vertical cover at the second resting site. Their behavior varied among the trials; some of the bears used a distinctly denser second resting site, suggesting that they were hiding, whereas other bears used more open second resting sites. As mentioned above, McLellan and Shackelton (1989) reported that the grizzlies had a greater TD in open areas. Wam (2003) found that the gray wolves in Scandinavia used a denser habitat after being approached by humans than prior to the approach. The fact that the vertical cover had no impact on the behavior of the bears in my study may be because we approached bears in areas with an overall very dense vegetation. I measured the vertical cover by dividing the visibility into three unequally sized categories, which may have biased my results and must be considered.

5.3. Delayed behavior to approaches

The difference between the size of the area used by the bears at the resting site following a trial and the area normally used clearly showed that most of the female brown bears were passive for a longer time during the evening after the trial than normal. This was also the case among the bears that stayed after the trial, which used a smaller area than normal between 16:30 and 18:30, although the sample size was small. The female brown bears also reduced their daily movement patterns during the resting periods for up to almost 48 hours after the trials. Both the decreased area used by the female brown bears the evening after the trial and the altered movement patterns suggest a human-induced hiding behavior by the bears. Other studies also have reported that brown bears altered their activity pattern when they were exposed to human recreational activities, but the disturbance lasted for longer periods and was not single encounters (Smith, 2002; Rode et al., 2006). Schleyer et al. (1984) found some degree of altered behavior among the grizzly bears after single encounters with humans, in contrast to Haroldson and Mattson (1985), who reported that the response was limited or not evidenced.

5.4. Visual bear-human encounters during the fieldwork

We saw three bears during the fieldwork. One of the bears was a noncollared bear that was encountered while approaching a trial bear. The noncollared bear issued a “blow” vocalization, signalizing that the approacher was not welcome. Vocalizing is a good indication of the presence of cubs (Swenson et al. 1999) and there was a female bear with cubs in that area. The two other bears were trial bears. One of them was the female bear with two yearlings and was encountered at a distance of 17 m. They ran away quickly, as mentioned earlier. The last one was seen foraging on berries at a distance of between 40 and 50 m. The bear stood up watching, before it moved away. It is important to point out that we most likely had a greater chance of encountering bears than hikers, because we knew where the bears were and because we were walking in favorable bear habitats. Hikers will usually walk around the densest habitats, which are often used by bears during their day rest. The berry season will most likely be the period when bears are easiest to observe in the field, because they then often use more open habitats while foraging on berries than resting and are more active throughout the day (Moe et al., 2007).

6. Conclusion

The results from my study show that nonmotorized human recreational activities affect the behavior of Scandinavian female brown bears. They avoid humans and alter their daily activity patterns for up to 48 hours after encountering humans. My study, together with future similar studies of brown bears, can give managers a useful tool in landuse planning of human activities. The knowledge from the studies can also contribute to increase the public's knowledge about bear behavior, and how to behave in areas with brown bears.

7. Acknowledgments.

This Master thesis was funded by the Norwegian County Governors in Finnmark, Nord-Trøndelag, Hedmark and Oppland, the research programme ''Adaptive management of fish and wildlife populations'' and the funders of the Scandinavian Brown Bear Research Project. It has been a great privilege to conduct my Master thesis within the Scandinavian Brown Bear Research Project. I would like to thank supervisors Ole-Gunnar Støen and Jon Swenson, and field supervisor Sven Brunberg. I really appreciate their inspiring and helpfully support during my work. Thank you Jonas Kindberg for technical support during the field work and digital maps. Thank you Geir Rune Rauset, Veronica Sahlén and Jodie Martin for assistance in the field and companionship during the field season 2006.

8. Literature cited

Arnemo, J.M, Ahlqvist, P., Anderse, R., Bertnsen, F., Ericsson, G., Odden, J., Brunberg, S., Segerström, P., Swenson, J.E., 2006. Risk of capture-related mortality in large free-ranging mammals: experiences from Scandinavia. Wildlife Biology 12, 109–110.

Belant, J.L., Follmann, E.H., 2002. Sampling considerations for American black and brown bear home range and habitat use. Ursus 13, 299-315.

Bellemain, E., Swenson, J.E., Tallmon, O., Brunberg, S., Taberlet, P., 2005. Estimating population size of elusive animals with DNA from hunter-collected feces: four methods for brown bears. Conservation Biology 19, 150-61.

Bowman, J.L., Kochanny, C.O., Demarais, S., Leopold, B.D., 2000. Evaluation of a GPS collar for white-tailed deer. Wildlife Society Bulletin 1, 141-145.

Cain, J.W., Krausman, P.R., Jansen, B.D., Morgart, J.R., 2005. Influence of topography and GPS fix interval on GPS collar performance. Wildlife Society Bulletin 33, 926-934.

Chestin, I.E., 1993. Brown bear – human conflicts in Russia. Unpublished report to U.S. Fish and Wildlife Service.

Dahle, B., Støen, O.G., Swenson, J.E., 2006. Factors influencing home-range size in subadult brown bears. Journal of Mammalogy 87, 859-865.

DeBruyn, T.D., Smith, T.S., Proffitt, K., Partridge, S., Drummer, T.D., 2004. Brown bear response to elevated viewing structures at Brooks River, Alaska. Wildlife Society Bulletin 32, 1132-1140.

DeCesare, N.J., Squires, J.R., Kolbe, J.A., 2005. Effect of forest canopy on GPS-based movement data. Wildlife Society Bulletin 33, 935-941.

D'Eon, R.G., Delparte, D., 2005. Effects of radio-collar position and orientation on GPS radio-collar performance, and the implications of PDOP in data screening. Journal of Applied Ecology 42, 383-388.

D'Eon, R.G., Serrouya, R., Smith, G., Kochanny, C.O., 2002. GPS radiotelemetry error and bias in mountainous terrain. Wildlife Society Bulletin 30, 430-439.

Dussault, C., Courtois, R., Ouellet, J.P., Huot, J., 1999. Evaluation of GPS telemetry collar performance for habitat studies in the boreal forest. Wildlife Society Bulletin 27, 965-972.

Frair, J.L., Nielsen, S.E., Merrill, E.H., Lele, S.R., Boyce, M.S., Munro, R.H.M., Stenhouse, G.B., Beyer, H.L., 2004. Removing GPS collar bias in habitat selection studies. Journal of Applied Ecology 41, 201-212.

Gau, R.J., Mulders, R., Ciarniello, L.M., Heard, D.C., Chetkiewicz, C.B., Boyce, M., Munroe, R., Stenhouse, G., Chruszcz, B., Gibeau, M.L., Milakovic, B., Parker, K.L., 2004. Uncontrolled field performance of Televilt GPS-simplexTM collars on grizzly bears in western and northern Canada. Wildlife Society Bulletin 32, 693-701.

Gibeau, M.L., Clevenger, A.P., Herrero, S., Wierzchowski. J., 2002. Grizzly bear response to human development and activities in the Bow River watershed, Alberta, Canada. Biological Conservation 103, 227-236.

Gibeau, M.L., Herrero, S., 1998. Roads, rails, and grizzly bears in the Bow River Valley, Alberta. In: Evink, G.L. (Ed), Proceedings of the International Conference on Ecology and Transportation, Florida Dept. of Transportation, Tallahassee, Florida, USA, pp 104-108.

Haroldson, M., Mattson, D., 1985. Response of grizzly bears to beackcountry human use in Yellowstone National Park. Unpublished study, Interagency Grizzly Bear Study Team, Montana State University, Boezman, Montana.

Herrero, S., 1985. Bear attacks, their causes and avoidance. Winchester Press, Piscataway, New Jersey.

Huber, D., Kusak, J., Frkovic, A., 1998. Traffic kills of brown bears in Gorski Kotar, Croatia. Ursus 10, 167-171.

Jonkel, J.J., 1993. A Manual for Handling Bears for Managers and Researchers. United Fish and Wildlife Service, Missoula, Montana, USA.

Kaczensky, P., Knauer, F., Krze, B., Jonozovic, M., Adamic, M., Grossow, H., 2003. The impact of high speed, high volume traffic axes on brown bears in Slovenia. - Biological Conservation 111**,** 191-204.

Kindberg, J., Swenson, J., 2006. Populationsberäkning av björnstammen I Sverige 2005 – Skandinaviska Björnprojektet. Estimate of the bear population Sweden 2005 - The Scandinavian Brown Bear Research Project. Report nr. 2006-2 to Swedish Environmental Protection Agency, Stockholm, Sweden. (In Swedish)

Mace, R.D., Waller, J.S., Manley, T.L., Lyon, L.J., Zuuring, H., 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33, 1395-1404.

Matson, G.M., van Daele, L., Goodwin, E., Aumiller, A., Reynolds, H.V., Hristienko, H., 1993. A laboratory manual for cementum age determination of Alaskan brown bear first premolar teeth. Matson's Laboratory, Milltown, Montana, USA.

McLellan, B.N., Shackleton, D.M., 1989. Immediate reactions of grizzly bears to human activities. Wildlife Society Bulletin 17, 269-274.

McLellan, B.N., Shackleton, D.M., 1988. Grizzly bears and resource extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25, 451-460.

Mills, K.J., Patterson, B.R., Murray, D.L., 2006. Effects of Variable Sampling Frequencies on GPS Transmitter Efficiency and Estimated Wolf Home Range Size and Movement Distance. Wildlife Society Bulletin 32, 693-701.

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

Moen, R., Pastor, J., Cohen, Y., 1997. Accuracy of GPS telemetry collar locations with differential correction. Journal of Wildlife Management 61, 530-539.

Moen, R., Pastor, J., Cohen, Y., Schwartz, C.C., 1996. Effects of moose movement and habitat use on GPS collar performance. Journal of Wildlife Management 60, 659-668.

Mueller, C., Herrero, S., Gibeau, M.L., 2004. Distribution of subadult grizzly bears in relation to human development in the Bow River Watershed, Alberta. Ursus 15, 35-47.

Naves, J., Fernández-Gil, A., Delibes, M., 2001. Effects of recreation activities on a brown bear family group in Spain. Ursus 12, 135-140.

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

Nielsen, S.E., Boyce, M.S., Stenhouse, G.B., 2004. Grizzly bears and forestry I. Selection of clearcuts by grizzly bears in west-central Alberta, Canada. Forest Ecology and Management 199, 51-65.

Proctor, M.F., McLellan, B.N., Strobeck C., 2002. Population Fragmentation of Grizzly Bears in Southeastern British Columbia, Canada. Ursus 13, 153-160.

Rauset, G.R., 2006. *Estimating individual kill rates on moose calves by brown bears based on GPS technology and GIS cluster analysis.* Thesis, Norwegian University of Life Sciences, Ås.

Rode,. K.D., Farley, S.D., Robbins, C.T., 2006. Behavioral responses of brown bears mediate nutritional effects of experimentally introduced tourism. Biological Conservation 133, 70-80.

Røskaft, E., Bjerke, T., Kaltenborn, B., Linnell, J.D.C., Andersen, R., 2003. Patterns of self-reported fear towards large carnivores among the Norwegian public. Evolution and Human Behavior 24 (3), 184-198.

Schleyer, B.O., Jonkel, J.J, Rhoades, K.G., Dunbar, D.M., 1984. The effects of nonmotorized recreation on grizzly bear behavior and habitat use. Unpublished study, Interagency Grizzly Bear Study Team, Montana State University, Boezman, Montana.

Smith, T.S., 2002. Effects of human activity on brown bear use of the Kulik River, Alaska. Ursus 13, 257-267.

Solberg, K.H., Bellemain, E., Drageset, O-M., Taberlet, P., Swenson, J.E. 2006. An evaluation of field and non-invasive genetic methods to estimate brown bear (*Ursus arctos*) population size. Biological Conservation 128, 158-168.

Sunde P., Stener S.Ø., Kvam, T., 1998. Tolerance to humans of resting lynxes *Lynx lynx* in a hunted population. Wildlife Biology 4, 177-183.

Sundell, J., Kojola, I., Hanski, I., 2006. A new GPS-GSM-Based Method to Study Behavior of Brown Bears. Wildlife Society Bulletin 34, 446-450.

Swenson J.E., Sandgren F., Söderberg A., Heim M., Sørensen O.J., Bjärvall A., Franzén R., Wikan S., Wabakken P., 1999. Interactions between brown bears and humans in Scandinavia. Biosphere Conservation 2 (1), 1-9.

Swenson, J.E., Sandegren, F., Heim, M., Brunberg, S., Sørensen, O.J., Söderberg, A., Bjärvall, A., Franzén, R., Wikan, S., Wabakken, P., Overskaug, K., 1996. Is the Scandinavian brown bear dangerous? Oppdragsmelding 404, Norwegian Institute for Nature Research, Trondheim, Norway. (In Norwegian with English summary).

Swenson J.E., Wabakken P., Sandgren F., Bjärvall A., Franzén R., Söderberg A., 1995. The near extinction and recovery of brown bears in Scandinavia in relation to the bear management policies of Norway and Sweden. Wildlife Biology 1, 11-25.

Waller, J.S., Servheen, C., 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69, 985-1000.

Wam, H.K., 2003. *Wolf behaviour towards people - the outcome of 125 monitored encounters*. Thesis, Norwegian University of Life Sciences, Ås.