To feed or to leave:

The effects of bait sites on the behaviour of brown bears towards humans

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Summary

Hunting of brown bears (*Ursus arctos*) using baits in Sweden was well established until 2000, but was banned in 2001. One of the main reasons it was banned was the fear that anthropogenic foods, in combination with human smell at bait sites, could result in food-conditioned and human-habituated bears. This in turn would increase the number of human-bear incidents. To evaluate if the use of bait sites could result in problem bears, 97 experimental approaches of individual brown bears were undertaken in Sweden from 2008 to 2011. These data were used to calculate the behavioural responses of bears towards approaching humans, such as flight initiation distance (FID) and specific time after stress exposure (STASE) using ArcGIS and MS Excel 2010. We validated visits of bears at bait sites in ArcGIS. Based on how often a given bear visited bait sites, we classified bears into three classes: bait avoider, bait indifferent and bait user. The behavioural responses of these classes during the experimental approaches were analysed with linear mixed effect models and general linear models in R 2.15.0. We found no difference in the wariness towards humans between bears that commonly used bait sites (bait users) compared to bears that used bait sites less commonly (bait indifferent), or did not use a bait site at all (bait avoiders). The FID of bears that had an experience with bait sites decreased the more often they had visited bait sites. Female bait users had a lower STASE than female bait avoiders and male bait users had a higher STASE than male bait avoiders. Our results suggest that bait users do not likely cause human-bear incidents in the forests more frequently compared to bait avoiders. Future focus on research of the behaviour of bait users, especially males, in the vicinity of human settlements is recommended.

Acknowledgements

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1. Introduction

1.1. Background and problem statement

Baits are described as an oral delivering of a variety of biological and chemical substitutes to selected carnivores and ungulates (Linhart et al., 1993). They are used as a lure in trapping, hunting, fishing, etc. (bait, 2009), and may also contain poisonous (bait, 2009), contraceptive or vaccination substances (Linhart et al., 1993). Baits are distributed mostly by hunters, and also by game wardens or forestry personnel (Linhart et al., 1993) to bait sites assigned for hunting purposes. The positions of these bait sites are usually predetermined (Linhart et al., 1993) and must be regulated on a large scale (Zedrosser et al., 2009). Unprocessed natural feed and salt licks at the bait sites are the main attractants for the target hunted animal (Poloczek, pers. comm.). Many animal species are hunted over baits, e.g. red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), foxes (*Vulpes* genus), white-tailed deer (*Odocoileus virginianus*) and some bear species (*Ursinae*).

In Europe, brown bears (*Ursus arctos*) are bait hunted in Estonia, Slovakia, Slovenia, Croatia and Russia (Sahlén, 2007). The use of bait sites to hunt brown bears was legal in Sweden until 2000 (Bishof et al., 2008), but was banned in 2001. The reason for this was the fear that the combination of anthropogenic food and human smell at bait sites could result in problem bears causing human-bear conflict (Zedrosser et al., 2009; Hopkins et al., 2010).

A bait site can represent the landscape of fear for a bear (Brown et al., 2001). Bear fear may be caused by humans, such as hunters, who act as predators for bears. According to Ben-David et al. (2004), bears develop a social hierarchical system at high-quality food sources, such as bait sites. This system allows some bears (e.g. younger bears, females with cubs) to utilize bait sites only during the day, while adult males, that are the most dominant, use bait sites during the night hours (Nevin and Gilbert, 2005).

Swenson et al. (1999) reviewed 114 encounters between bears and humans. Their results show that the Scandinavian brown bear is less aggressive than, for example, the North American brown bear. Swenson (1999) suggests that two main patterns may explain differences in aggressiveness among bear populations.

The first pattern may be the access to human-derived foods. The bears that learn to associate anthropogenic food with humans (or their smell, human activities, human-used areas, or food containers), are defined as food-conditioned bears (Herrero et al., 2005). Food conditioning is a form of positive conditioning when a bear gets a reward for a given response (behavioural act) to a given stimulus (McCullough, 1982). Food-conditioned bears are more likely involved in attacks on people than unconditioned bears (Herrero, 1970). Hunters leave foods at bait sites (e.g. meat, sweets, corn, etc.), that are not only attractive for bears, but also for other animals, such as foxes, wolverines, and ravens, to increase their chances of shooting a bear. Bears that have used such bait sites may therefore become food-conditioned, and thus may react differently towards humans than unconditioned bears. The food-conditioned bears may be less wary and more aggressive towards people than unconditioned bears. Bears close by or at bait sites may not be willing to leave the site in order to defend their food source. Or they can flee later, and therefore be more reluctant to flee than unconditioned bears.

The second pattern may be related to historic hunting pressure (Swenson, 1999; Zedrosser et al., 2011). Dood et al. (1986) suggested that bears in North America are less wary of people in areas where they are not hunted. Vaisfeld and Pazhetnov (1992) suggested that for bears in the European part of Russia, hunting pressure increases bears' wariness of people, unless bears actually reach human-derived food. Swenson (1999) speculated that bold brown bear individuals are the first ones to be selectively killed by hunters.

Terms such as conditioning and habituation are frequently used by researchers and others in bear management, but sometimes incorrectly interchangeably (Hopkins et al., 2010). A food-conditioned bear forms a simple association between people and anthropogenic stimuli such as food (Smith et al., 2005), contrary to habituated bears which have a neutral response to anthropogenic stimuli. The food-conditioned bears can once again become deconditioned (Herrero et al., 2005) by unconditioning stimuli (McCarthy and Seavoy, 1992), such as rubber bullets, firecrackers or dogs.

The process of bear habituation is happening, for example, in the USA national parks, where bear density is low and visitor density is very high. Under such animal and human density conditions, it is known that many food-conditioned bears can get habituated, and many habituated bears can get food-conditioned (Hopkins et al., 2010). Habituated bears have increased tolerance and decreased overt reaction distance (ORD) towards humans compared to non-habituated bears, and this can lead to more frequent interactions and potential conflicts with humans (Herrero et al., 2005). In Sweden people do not visit forests with such densities as the USA. Food-conditioned bears which defend their food could cause more potential human-bear conflicts.

No quantitative studies exist to evaluate if hunting with the use of bait sites affects the behaviour of bears towards humans. However, bait hunting has been widely discussed in Sweden since its ban, and nowadays especially hunting organizations pressure the authorities to re-allow bait hunting. The Scandinavian Brown Bear Research Project (SBBRP) is currently carrying out a research project to evaluate the effect of bait sites on brown bear behaviour. Knowledge about the behaviour of bears at bait sites is highly valuable information for wildlife managers, hunters and the general public. To investigate if bears that use bait sites can become food-conditioned and thus potentially problem bears in Sweden, we investigated their behaviour towards approaching humans.

1.2. Research objectives and research questions

This thesis is an experimental study at the level of the individual carnivore. The main goals are:

1. To evaluate if bears that use bait sites more frequently (bait users) are more willing to stay and less willing to leave a site while being approached by humans, compared to bears that do not use bait sites or use bait sites sporadically (bait avoiders).
2. To evaluate if bait users are less wary of humans than bait avoiders.
3. To evaluate if the increasing experience with the bait sites has an effect on wariness of bait users towards humans.

We studied the following research questions:

1. Do bait users have a lower willingness to leave a site while being approached by humans than bait avoiders?
2. Are bait users less wary of humans than bait avoiders?

3. Does the number of visits at the bait sites, as a measure of experience, have an effect on the wariness of bait users towards humans?

To answer these research questions, we formulated the following hypotheses and predictions:

1. Bait users flee less frequently and stay more frequently while being approached by humans than bait avoiders *(Swenson et al., 2000; Herrero et al., 2005; Zedrosser et al., 2009).*
    - The prediction for this hypothesis is: The ratio of bears that flee to bears that stay at the initial site will be higher by bait users compared to bait avoiders.
2. Bait users are less wary of humans than brown bears that did not use a bait site (bait avoiders) *(Swenson et al., 2000).*
    - The prediction for this hypothesis is: Bait users will have lower flight initiation distance (FID) than bait avoiders.
3. Brown bears that had at least one experience with using bait sites (bait-experienced bears) are less wary of humans with increasing number of visits at the bait sites *(Hopkins et al., 2010).*
    - The prediction for this hypothesis is: The FID of bait-experienced bears will decrease with increasing number of visits at the bait sites.

1.3. Readers' guide

The parts of the Chapter 3, Results, are organized in a way to answer all the hypotheses and predictions in the same order as they are listed in part 1.2. Further, this part shows additional results. Chapter 2 describes all the material and methods that were used to obtain the results.

The first four paragraphs of part 4.1., Discussion, imply conclusions of our hypotheses and of the additional results, discuss and reason them. Each paragraph discusses a hypothesis or additional results in the same order as they are enumerated in the parts of Chapter 3, Results.

The findings of this thesis are first summarized in the first paragraph of part 4.2., Conclusion. Then potential implications of these findings are summarized and topics for future research and wildlife management actions are recommended.

2. Material and methods

This chapter describes our study area (part 3.1.), data collection (part 3.2.) and data analysis (part 3.3.). In part 3.2., Data collection, information about the experimental bait sites (part 3.2.1.) can be found. Part 3.2.2., The bears, describes the bears that were approached and explains how the bears were classified as active or passive. Part 3.2.3., Approaches, first characterises the period, when bears were approached. It shows how approach data were distinguished into pre-berry or berry seasons. Then it focuses how approaches of bait users were arranged. Lastly, the methodology of conducting approaches is described in this chapter. The following part, Habitat measurements (part 3.2.4), provides information about how data for variables describing bear habitats were collected.

Data analysis, part 3.3., describes first how we validated a visitation of a bear at a bait site (part 3.3.1.). Part 3.3.2. deals with how bears were classified into three groups: bait avoiders, bait indifferent and bait users. Part 3.3.3. explains how upper control limit (UCL) and the response variable FID were calculated. Calculation of the response variable specific time after stress exposure (STASE) is explained in part

3.3.4. Finally, part 3.3.5 clarifies, how models analysing the response variables were selected.

2.1. Study area

The study area was located in Dalarna, Gävleborg and Jämtland counties (approximately 61°N, 14°E, Figure 1), in the southernmost area of the brown bear reproduction range in Sweden. The landscape is undulating with hills and ridges. Only less than 10% of the study area lay below the timberline (Dahle and Swenson, 2003). Lakes and bogs were common except for most of the hilly areas which were covered with forests. These boreal forests are heavily exploited by the timber industry, which has resulted in many clear-cuts and forests younger than 35 years. The most important tree species are Scots pine (*Pinus sylvestris*), and Norway spruce (*Picea abies*). Density of the bear population was estimated at ~30 individuals per km^2 (Solberg et al., 2006), and bears are managed by hunting. Most of human activity is concentrated in and around the settlements. A system of public forestry roads covering the study area is well developed. Human activity in the forested areas off the roads is mostly related to forestry, berry-picking and hunting.

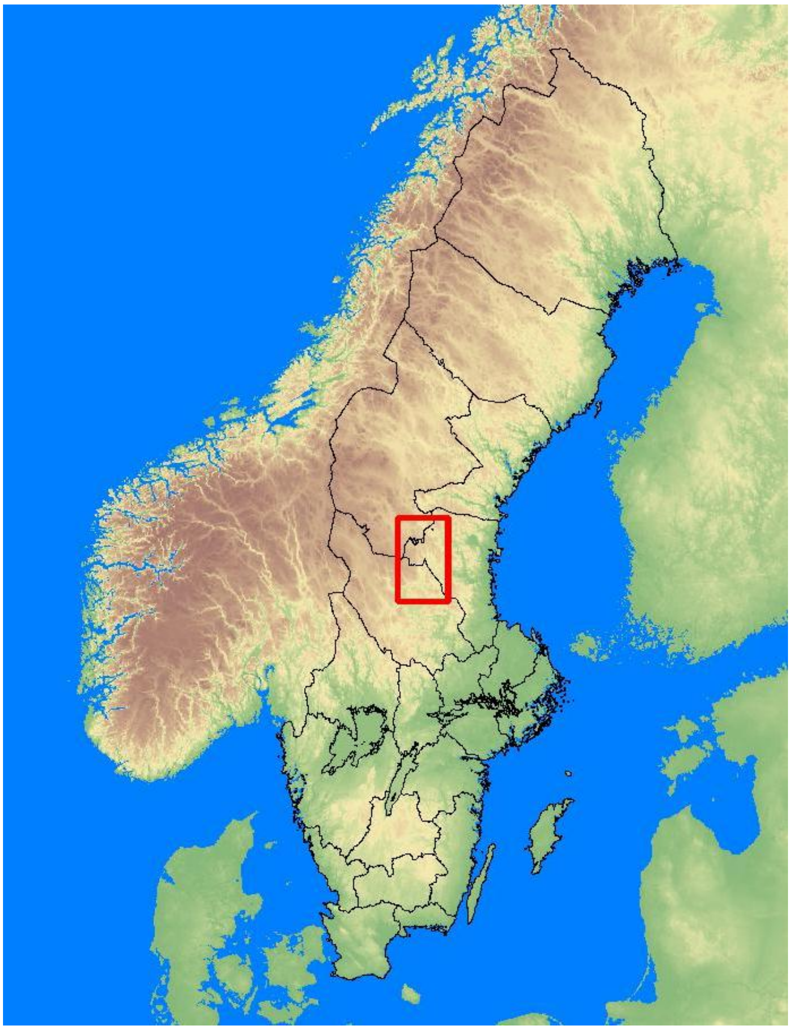

Figure 1: Location of the SBBRP study area in Sweden.

2.2. Data collection

2.2.1. Bait sites

Experimental bait sites (hereinafter referred to as bait sites) were established by the SBBRP in 2008. They were maintained until 2011. The positions of the bait sites were taken by researchers from the SBBRP with a hand-held Global Positioning System (GPS) unit Garmin GPSMAP 60 CSx (Garmin Ltd., USA). The approach data used here were collected by the SBBRP researchers from 2008 to 2011. Data from study years 2008, 2009, 2010, and 2011 were analysed in this thesis. The SBBRP maintained two permanent bait sites and several temporary bait sites each study year. The two permanent bait sites had the same locations. All the study years were open and maintained from the end of April/beginning of May until October/beginning of November (denning, Manchi and Swenson, 2005). Temporary bait sites were established from August 1 until bear denning each study year. Their locations changed every study year. Eight temporary bait sites were established in 2008 and 2009, and four temporary bait sites were established in 2010 and 2011. Their positions can be found in Figure 2.

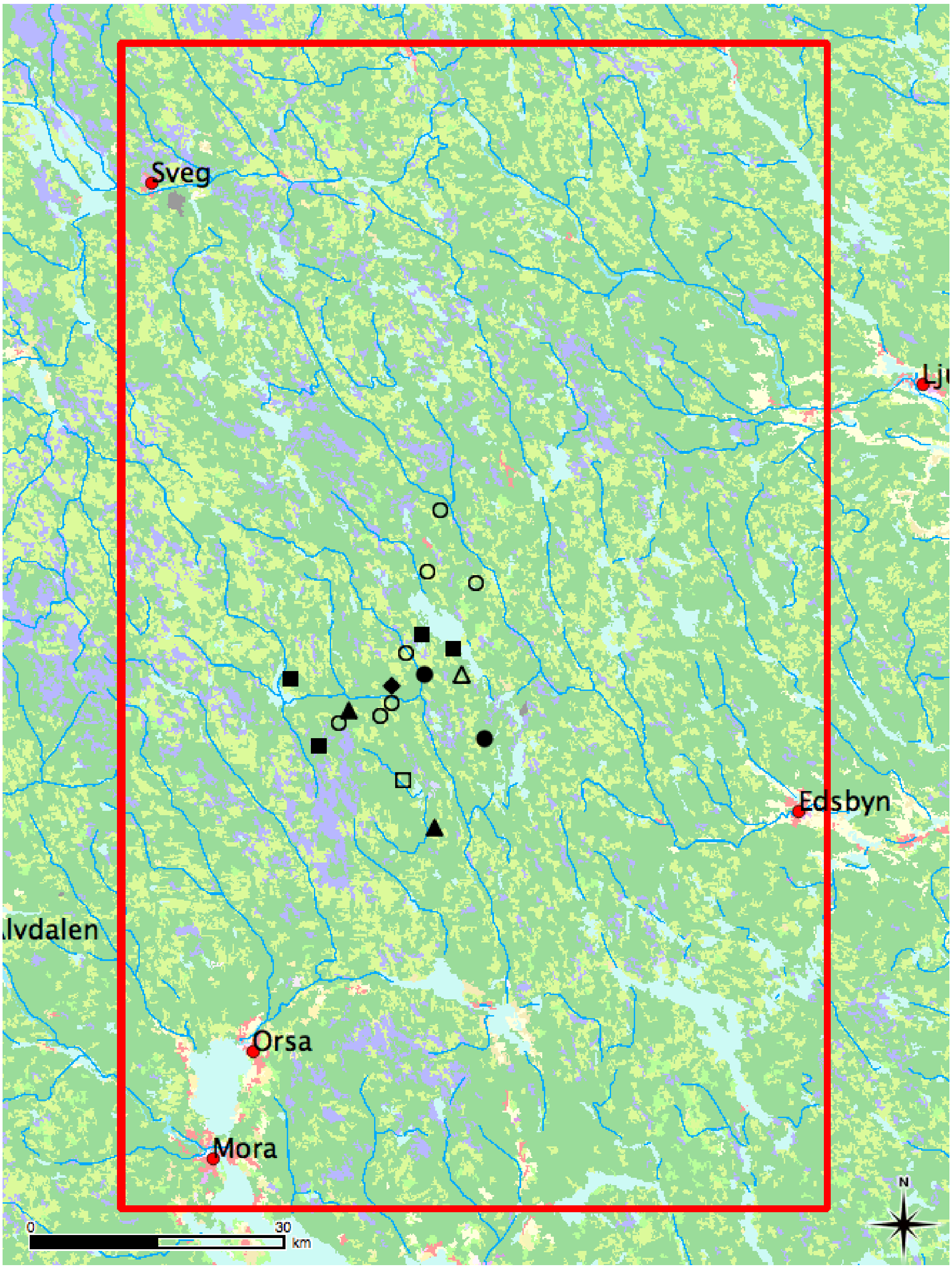

Figure 2: Positions of the experimental bait sites (n=18) in the study area. Positions of permanent bait sites are illustrated as filled circles. Positions of temporary bait sites from 2008 (n=7) are open circles and positions of temporary bait sites from 2009 (n=4) are filled squares. One temporary bait site had the same position in 2008, 2010 and 2011 (open square). Two temporary bait sites had the same position in 2009, 2010 and 2011 (filled triangle). One temporary bait site had the same position in 2009 and 2010 (open triangle) and one temporary bait site (filled rhombus) had the same position in 2009 and 2011.

2.2.2. The Bears

From 2008 to 2011, we successfully approached 21 females and 16 males, altogether 37 solitary bears, for one to seven times. The age of all the approached bears ranged from two to 20 years. A bear was approached maximally six times per year keeping the minimum period of 14 days between each approach (see Moen et al., 2012). Six bears, viz. three females and three males, were approached repeatedly in more than one year. From these, a female and a male were approached repeatedly throughout three years. The bears carried GPS Plus-3 or GPS Pro-4 neck collars (VECTRONIC Aerospace GmbH, Berlin, Germany) and abdominal implants IMP 400L (Telonics, USA).

According to the method of Moen et al. (2012), approached bears were divided into two groups: active and passive, according to their activity level during the control period. The bear was considered as passive if it stayed in the cluster with a diameter not bigger than 70m, where a daybed was often found. The active bears were moving in a more dispersed area than the cluster and usually foraging. Most of the bears stayed either active or passive during the control period. Nine bears were first passive and became active just before the end of the control period, therefore these bears were analysed as active. Fifteen bears were active during the control period and became passive before the approach started, and were therefore analysed as passive. Two bears changed their activity twice during the control period and were analysed in accordance with the last activity they displayed before the approach started.

2.2.3. Approaches

In the four study years, we conducted successfully 97 approaches according to the method of Moen et al. (2012). Sixty of these approaches were conducted in 2008, 23 approaches in 2009, three approaches in 2010 and 11 approaches in 2011. All the approaches were conducted from the beginning of June to October/beginning of November (denning). The GPS-radio collars could be scheduled to deliver the positions according to need. In the mating season (May until beginning of July, Steyaert, 2012), the relocation schedule of GPS-radio collars was one position every 10 minutes. While after the mating season the relocation schedule was kept to one position every 30 minutes as long as the bear was active. To monitor the movements of the approached bear more precisely, we rescheduled the GPS-radio collars before each approach to deliver one position every minute for three hours. The rescheduling was arranged via a web-based rescheduling service, usually not less than a week before the approach.

We divided the field season into two fruit-related seasons, pre-berry and berry (see Moen et al., 2012). The reason for this was that bears could alter their behaviour in the berry season, when abundant berries represent their main food source. The pre-berry season starts in the spring and finishes in early summer. As soon as we could observe fresh berries, the berry season started. In 2008, the approaches were conducted in both seasons. The end of the pre-berry season and the start of the berry season was marked by July 14. In 2009, 2010 and 2011 all the approaches were conducted in the berry season.

In 2011 we focused on approaching bait users. According to the regular temporal patterns observed in individual visits of the bait sites, we scheduled the expected date and time for the approaches of the bait users, thus increasing the chance of approaching the bear close to a bait site. In accordance with Moen et al. (2012), the approaches started and finished during the second hour of the one-minute positioning period from 10:00 to 14:00 GMT. In this period bears are, according to Moe et al. (2007), inactive and resting. Also most of the people came to the forests during this period. However, most of the bears did not visit bait sites in this period, as shown in Figure 3. Therefore, the approaches were planned at the beginning or in the end of a resting period. Figure 3 demonstrates the distribution of bear visits at the permanent bait sites during the day in 2011, based on validation of a visit (see 2.3.1. Validation) and according to the received GPS positions of bears.

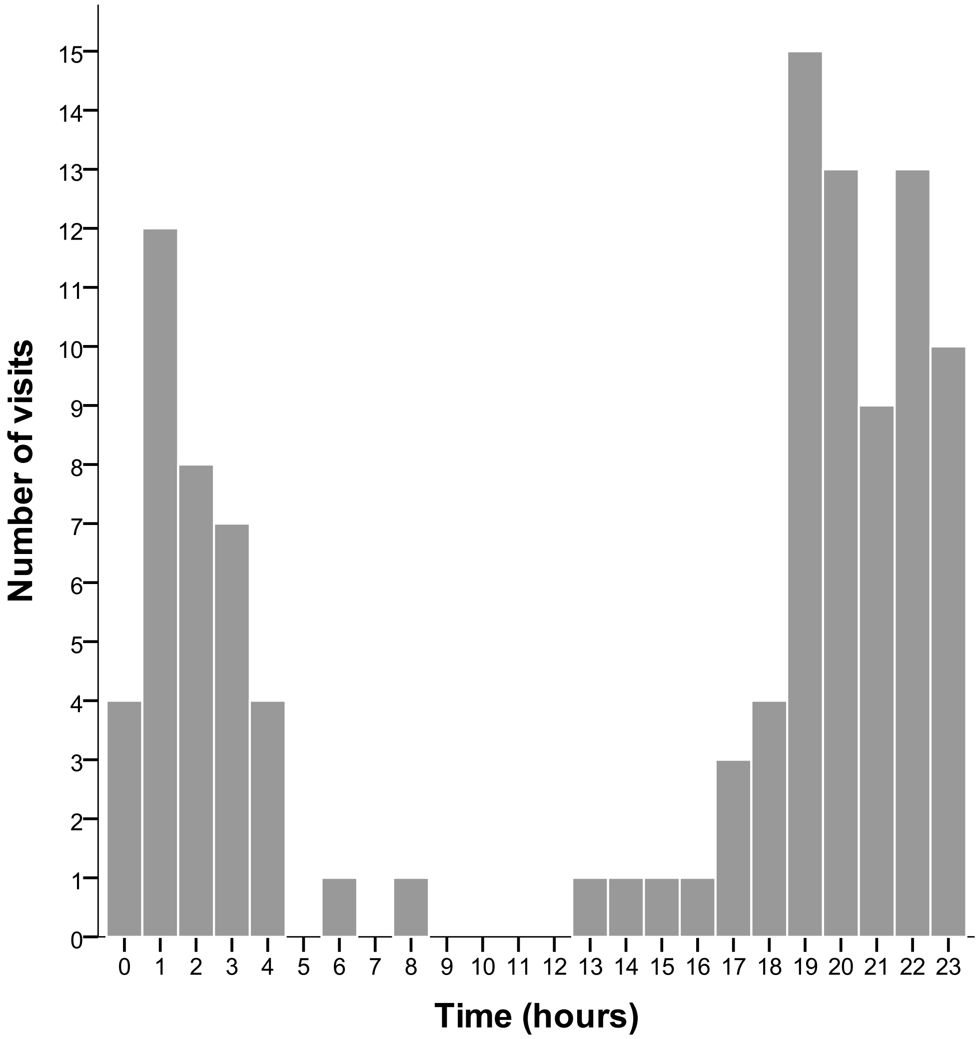

Figure 3: Distribution of bear visits (n=108) at the bait sites during day hours in 2011. Time is represented by hours. A visit of a bear at the bait site was validated (see 2.3.1. Validation) according to received GPS positions of bears.

The bear's positions were sent to a base tower via SMS, then stored in the computer database and retrieved by phone via SMS. The database and SMS information enabled us to locate the bear before the approach and subsequently to analyse the bear movements in ArcGIS 10. The approaches were conducted at different distances from human settlements. The closest approach was at an approximate distance of 400m from the settlement.

Observers used the triangulation method with the VHF signals from the radio collars or implants to allocate the bears in the control period. We received the VHF signals with a portable receiver, handheld yagi antenna and an omni-directional antenna. Wind strength was determined prior to each approach and while passing the initial site, according to the Beaufort Wind Scale. One to six observers conducted an approach. At least one of the observers carried a hand-held GPS receiver [Garmin GPSMAP 60 CSx (Garmin Ltd., USA)], recording the observer's position each 10m.

The observers started the approaches approximately 500m from the bear, moving at a normal hiking speed 3.0±1.4 km/h during the entire approach. The distance of 500m was chosen because some bears already reacted to observers at an approximate distance of 324m (see maximal FID in Moen et al., 2012). During the approach, the position of the approached bear was continuously monitored using the portable receiver and the omni-directional antenna. Two observers kept a conversation going during an approach. If the observer was alone, he/she talked to him/herself. If three observers conducted the approach, two of them kept a conversation with a normal voice, and the third observer stayed silent. When the observers were passing the bear, the wind direction was downwind to the bear. The observers then walked the next approximate 500m following the same direction as in the beginning of the approach. Thereafter, the observers followed a curve to head back to their starting point, monitoring the bear movements, assuring that the bear would be upwind to them and further than 500m from them. See Figure 4 and Moen et al. (2012) for a more detailed illustration and description of the approach.

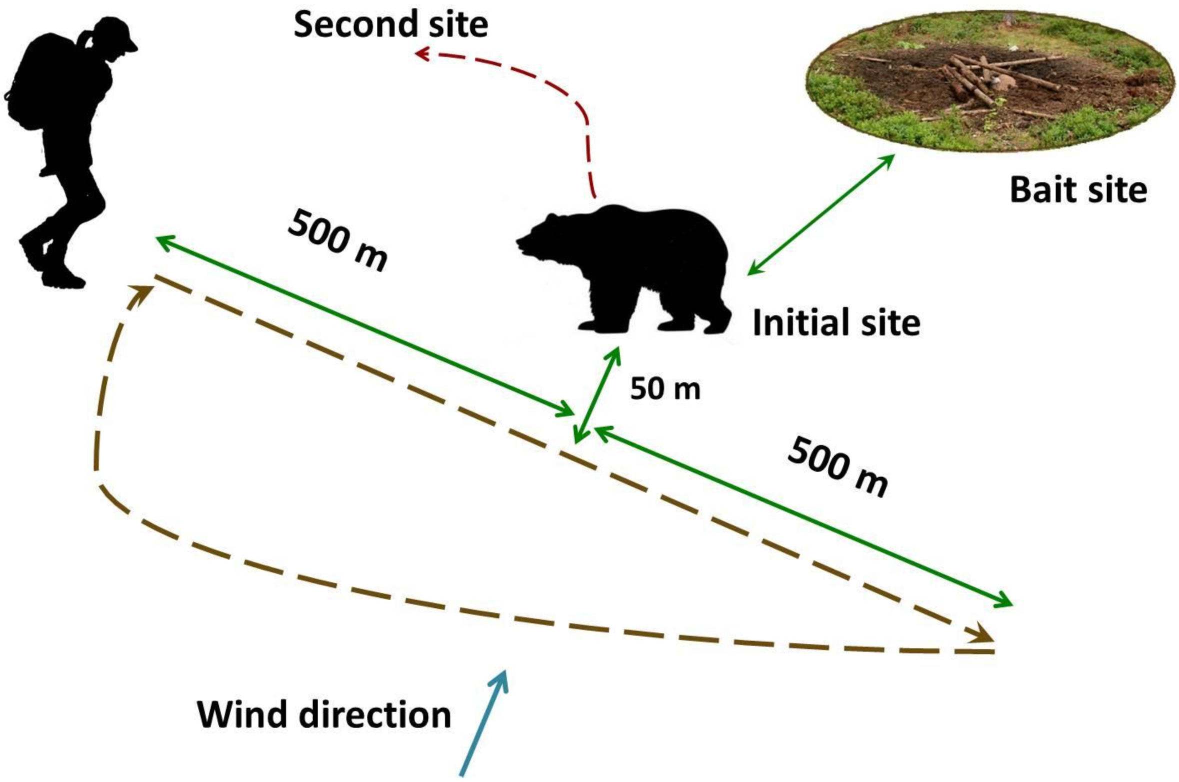

Figure 4: Illustration of the approach. The observer is at the starting point. The wind direction is perpendicular towards the observer's path.

2.2.4 Habitat measurements

We came to the initial site (see Chapter 6, Supplement and Moen et al., 2012) one to 41 days after the approach to measure habitat characteristics according to the Swedish Forest Inventory Scheme. We investigated the position of daybeds, and looked for signs of bear activity. We measured the horizontal cover as the sighting distance with a cylinder (60cm height and 30cm in diameter) according to the method of Ordiz et al. (2009). The cylinder is red and white, with the red colour on top. We placed the cylinder in the centre of the daybed and afterwards walked in four cardinal directions from the cylinder until we could not see it anymore. As a result, we obtained four distances in m. The average distance from these four distances was calculated as the sighting distance.

2.3. Data analysis

2.3.1. Validation

No studies exist yet about the exact accuracy of the positions delivered by the GPS radio-collars used here (GPS Plus-3 or GPS Pro-4 neck collars, VECTRONIC Aerospace GmbH, Berlin, Germany). The only information about the accuracy obtained from the collars, is the dilution of precision (DOP). DOP indicates the geometry of satellites determining the position (Wade and Sommer, 2006) and therefore, influences the data quality and accuracy. Lower DOP generally produces higher quality of data accuracy. This relation is however not direct, which means that the same DOP value does not always specify the same accuracy (Haberkorn, 2011). According to personal communication with D. Schulte, head engeneer at Vectronic Aerospace, accuracy of the GPS-radio collars was estimated between 10 and 15m in 2011. The data from 2008 to 2011 reflect variability of accuracy, because the quality of the collars has improved. This means that the number of incorrect positions has decreased, whereas the position accuracy has increased. The accuracy of the hand-held GPS unit Garmin GPSMAP 60 CSx, which was used to take the positions of the bait sites, is 10m (Garmin Ltd., USA) (GPSMAP 60CSx: Products: Garmin, 1996).

According to Herrero and Higgins (1999), Rajpurohit and Krausman (2000); and Hopkins et al. (2010), bears, which discover a location with a food source (i.e. a bait site), tend to visit this spot repeatedly. The study bears indicated similar behaviour.

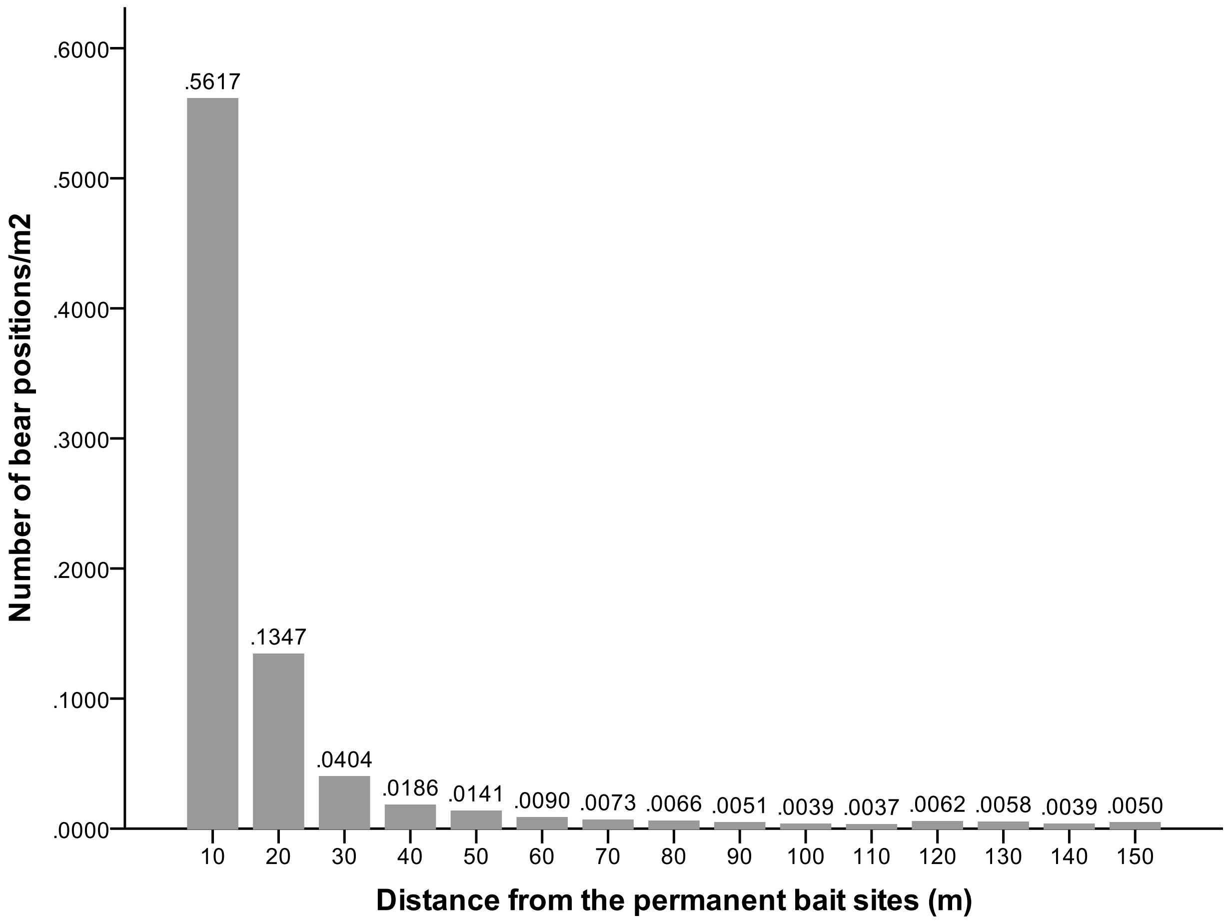

Figure 5: Density of bear positions (in number of positions/m^2) with increasing distance from the two permanent bait sites (0–150m) for the years 2008–2011. Notice, that the y-axis reaches the maximum at 0.6 positions/m^2.

To identify a visit, the error of accuracy of the collars and of the hand-held GPS unit were taken into account. The number of the bears' positions towards bait sites increased, following a non-normal distribution. Because the positions of the permanent bait sites stayed the same from 2008 to 2011 compared to the temporary bait sites, we chose the permanent bait sites to perform the validation. In ArcGIS, a multiple buffer around the permanent bait sites was created and divided by 10m-buffers up to 220m. In each 10m-buffer the number of positions and density of positions was calculated for all four years, from 2008 to 2011. Figure 5 shows the density of bear positions around the permanent bait sites in number of positions per m^2 in 10m-buffers up to 150m. To compare the distribution of density values around the two permanent bait sites, two random points were chosen by ArcGIS and the same multiple buffering was conducted as with the permanent bait sites. Figure 6 depicts the density of bear positions around the random points, in number of positions per m^2 in 10m-buffers up to 150m. The two-sample Kolmogorov-Smirnov test showed that the distributions of density values of bear positions around the permanent bait sites and around the random points differed significantly ($P<0.001$, $n=22$ density values). Hence, this showed that the permanent bait sites had different distribution of bear positions around them than the two randomly chosen points and bears did not visit them randomly.

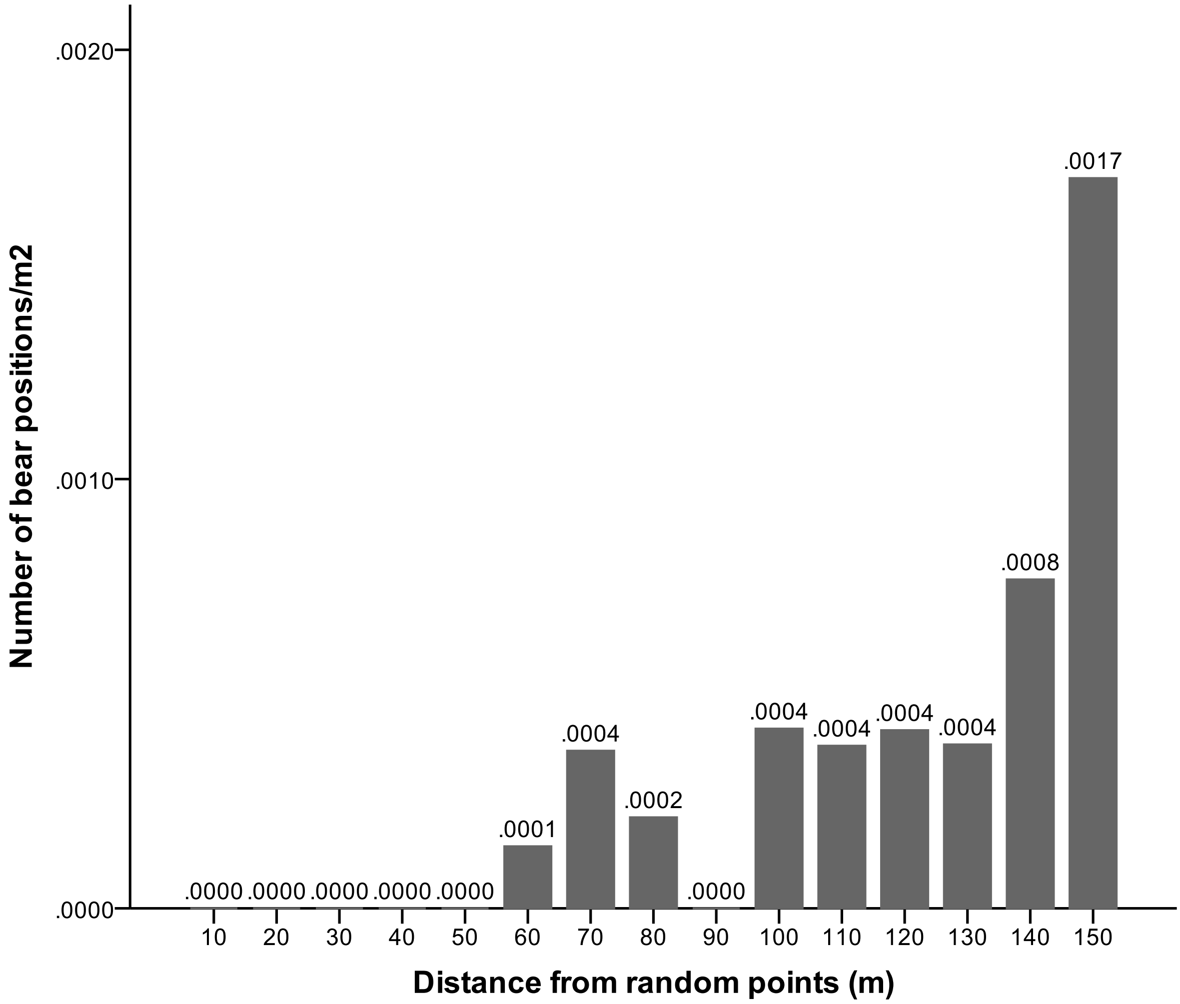

Figure 6: Density of bear positions (in number of positions/m^2) with increasing distance from two random points (0–150m) for the years 2008–2011. Notice, that the y axis reaches the maximum at 0.002 positions/m^2.

The density values beginning from the 10m-buffer of 70m to 220m followed normal distribution (Shapiro-Wilk test, P=0.968, n=16) without outliers. Ninety-five percent of the measurements are included in the confidence interval: mean±2 SD (Ott and Longnecker, 2010), and 95% CI (0.0012; 0.0077). All the density values of 10m-buffers from 70m to 220m belonged to this confidence interval. Therefore, we considered all the positions delivered from a bear GPS neck collar in a 60m round buffer zone around a bait site as a visit.

In this thesis, one GPS position from a neck collar in the validated 60m buffer zone determines a visit. One GPS position in this buffer zone indicates that the bear stayed in this zone 1-30 minutes. Because of a very well developed olfactory sense (Swenson et al., 2000) which primarily helps brown bears to orientate in the landscape (Rogers, 1992), we consider the probability of accidental visiting a bait site by a bear as minimal. Only one bear visited a bait site once in 2010 and once in 2011 delivering one GPS position per visit. All the other bears, which delivered only one position per visit, visited the bait sites more than once. Therefore, to minimize the probability of accidental encountering a bait site, only the bears which visited the bait sites three times or more were considered as bait users. Most of the bears visited a bait site and left. However, some bears visited the bait site, left and after a while returned again. To distinguish between one visit and two separate visits, we made criteria based on our observation of data. If the bear stayed at the bait site less than half an hour and came back before four subsequent hours, we considered this as one visit. If the bear stayed at a bait site longer than half an hour, went away and came back before one hour passed, this also was considered as one visit. All the other cases were considered as two separate visits.

2.3.2. Classification of the bears

Bears that did not visit a bait site before an approach were classified as bait avoiders. Bait indifferent bears visited bait sites once or twice. Bears that visited bait sites three times or more were classified as bait users (see also Chapter 6, Supplement).

Changes in bear behaviour occurred throughout the four study years. Some bears suddenly became bait users; some gradually became bait users, being bait indifferent at first. Some of the bait users stopped visiting the bait sites and therefore their classification needed to be revised. The bear which visited a bait site a minimum of three times before an approach was classified as a bait user from this time on. The majority of these bears were classified according to the same conditions as bait users in subsequent year(s). Two bears which were classified in previous year(s) as bait users, did not visit a bait site in the year of the approach. If the home ranges from such a bear overlapped fully with the 60m buffer zones around the bait sites, and at least three bear tracks per bear intersected the 60m buffer zone, we classified these bears as deconditioned, and thus bait avoiders. Conversely, if neither their home ranges nor a maximum of two tracks overlapped with the 60m buffer zone around a bait site, these bears stayed classified as bait users.

2.3.3. Upper control limit and flight initiation distance

According to Moen et al. (2012), bears that were scheduled for an approach, but were not approached, did not have different maximum moved distance in the control period compared to the following hour. We assumed that bears had the same behaviour in the following hour if they were not disturbed by observers. The speed between consecutive positions (m/min) was calculated. To normalize residuals, the speed values were transformed by (log (speed*100)). Statistical quality control (Montgomery, 2005) was used to calculate an UCL for passive and active bears. UCL signalizes a speed threshold. When a bear’s speed exceeds the UCL, a bear is disturbed and starts fleeing from the observers. Only speed data from bears that remained during the control period, either only passive or only active, were used for the UCL calculation. UCL of passive and active bears was 20.1m/min (1.20km/h) and 73.5m/min (4.41km/h), respectively.

To calculate the flight initiation distance (FID), both the bear's and the observer's positions needed to be determined. Calculating the UCL and locating the bear position, when the UCL was exceeded, was performed with MS Excel 2010 and controlled in ArcMap. The bear's position was connected to the observer's closest in time position using the Analysis tool Point distance in ArcMap.

The FID could be calculated only for bears that fled and delivered the one-minute positions before and when the flight started. Eighty bears fled from the initial site. The FID was calculated using the one-minute position data of 72 bears for two reasons. The first reason was that one-minute positions of six bears (five bait avoiders and one bait indifferent bear) were missing at the time before and at the start of the fleeing. The second reason was that two bait avoiders left the initial site after the observers passed them and were at a distance of 926m and 1127m from them.

2.3.4. Specific time after stress exposure

After being disturbed by observers, some bears fled, which was displayed by their exceeding the UCL for a period. According to Reeder and Kramer (2005) and Hopkins et al. (2010), flight is the behavioural stress response of bears. Bears expend their energy to respond to a stressor such as an observer's presence. Duration of the flight in minutes represented the level of energy expended and therefore was considered as a measure of stress. Time spent fleeing after stress exposure (STASE) was individual specific. STASE was measured in minutes and included the bear's positions exceeding the UCL. Sometimes bears stopped at a second site, rested, and then continued moving. If this rest took longer than 10 minutes, the following flight time to the STASE was not added. The STASE was only calculated for bears with a FID, and where the bear positions were not missing in the beginning or at the end of the STASE.

2.3.5. Selection of models

Generalized linear mixed models with a binomial response variable were used to determine the variables affecting whether or not a bear stayed or fled from the initial site with R 2.15.0. FID and STASE were analysed with R and linear mixed effect models. In all the models Bear ID and year were included as random effects. Backward elimination of the variables was applied according to the lowest Akaike's Information Criterion (AIC) in all the models.

All of the models were initially composed from these variables: (i) bait avoider/bait indifferent/bait user or number of visits at the bait sites before the approach, (ii) distance to the closest bait site, (iii) sex, (iv) age, (v) wind strength, (vi) season, (vii) activity, (viii) sighting distance, and (ix) number of observers. Plus the following interactions: (i) age*bait avoider/bait indifferent/bait user or age*number of visits at the bait sites before the approach, (ii) age* distance to the closest bait site, (iii) sex*bait avoider/bait indifferent/bait user or sex*number of visits at the bait sites before the approach, (iv) sex*distance to the closest bait site, (v) number of visits at the bait sites before the approach*number of observers or bait avoider/bait indifferent/bait user*number of observers, (vi) bait avoider/bait indifferent/bait user* sighting distance or number of visits at the bait sites before the approach*sighting distance, and (vii) sighting distance*distance to the closest bait site.

Besides the above-mentioned variables, linear mixed effect models analysing the FID of bait-experienced bears also included the variable (x) time spent from the last visit, and its interactions with (viii) sex and (ix) age. All the variables and interactions selected for the initial models can be found in Table 1.

Table 1: Selected variables and interactions for the initial models

Variable	Interaction	Dependent variable	Model
bait avoider/bait indifferent/bait user or number of visits at the bait sites before the approach	bait avoider/bait indifferent/bait user*age or number of visits at the bait sites before the approach*age	Staying or fleeing of bait-classified bears	generalized linear model, linear mixed effect models
distance to the closest bait site	age*distance to the closest bait site	FID of bait-classified bears	
sex	bait avoider/bait indifferent/bait user*sex or number of visits at the bait sites before the approach*sex	FID of bait-experienced bears	
age	sex*distance to the closest bait site	STASE of bait-classified bears	
wind strength	bait avoider/bait indifferent/bait user*number of observers or number of visits at the bait sites before the approach*number of observers		
season	bait avoider/bait indifferent/bait user*sighting distance or number of visits at the bait sites before the approach*sighting distance		
activity	distance to the closest bait site*sighting distance		

Variable	Interaction	Dependent variable	Model
sighting distance			
number of observers			
time spent from the last visit at a bait site	time spent from the last visit at a bait site*sex	FID of bait-experienced bears	linear mixed effect model
	time spent from the last visit at a bait site*age		

Normality of residuals and multi-collinearity were controlled in the linear mixed effect models. The residual normality condition was not satisfied in the linear mixed effect models analysing the response variables FID and STASE. After transforming the FID and STASE by log transformation to log(FID) and log(STASE), this condition was fulfilled.

3. Results

The structure of this chapter is following the order of the hypotheses. Part 3.1. summarizes the results of the first hypothesis, part 3.2. the results connected with the second hypothesis and part 3.3. the results of the third hypothesis. Part 3.4. shows the results from models analysing STASE.

3.1. Staying or fleeing of bait-classified bears

From all the 97 approaches, 80 bears fled and 17 stayed at the initial site. Of the bears that stayed at the initial site while being approached by observers, 16% were bait avoiders (n=75), 42% were bait indifferent bears (n=12) and 0% (n=10) were bait users (Figure 7).

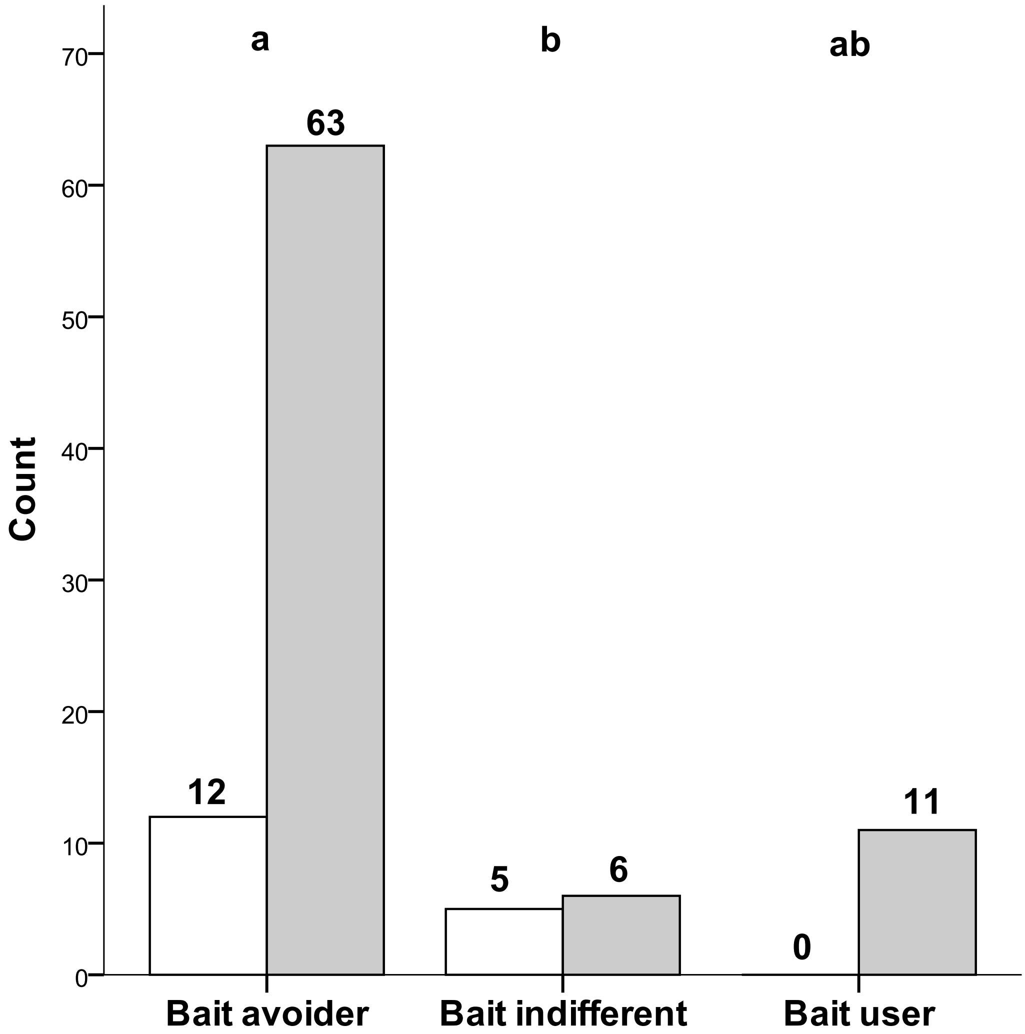

Figure 7: Ratio of frequencies of staying (white) and fleeing (gray) from the initial site of bait avoiders, bait indifferent bears, and bait users. The count of the stays or flights is above each bar of each group.

The results of the selected generalized linear mixed model (Table 2) showed that bait users did not stay significantly more frequently at the initial site compared to bait avoiders (z=0.008, P=0.994). The bait indifferent bears stayed significantly more frequently at the initial site than bait avoiders (z=-2.255, P=0.024, Table 2). Bears tended to stay more at the initial site during the berry season (z=-2.333, P=0.020, Table 2).

Table 2: Results from the generalised linear mixed model for staying or fleeing from the initial site

Explanatory variables	β	SE	t	P
Bait indifferent	-1.694	0.751	-2.255	0.024
Bait user	16.155	1987.747	0.008	0.994
Bait avoider	0	-	-	-
Season - Pre-berry	-1.519	0.651	-2.333	0.02
Season - Berry	0	-	-	-
Sighting distance	0.084	0.048	1.749	0.08

3.2. FID of bait-classified bears

The average values and standard deviation values were back transformed from explorative statistical analyses of log(FID) of bait classified bears. Bait avoiders had an average FID of 60±2m (back transformed from logFID, median 59m, minimum 13m, maximum 227m, n=56). The average FID of bait indifferent bears was 75±1m (median 67m, minimum 51m, maximum 141m, n=6). Bait users had an average FID of 54±2m (median 48.5m, minimum 28m, maximum 136m, n=10). Log(FID) was not significantly affected by any of the bait-classified group (F=0.147). Bait users did not have significantly lower log(FID) than bait avoiders (t=-1.61, P=0.113, Table 3). With increasing sighting distance log(FID) significantly increased (t=3.25, P=0.002, Table 3). Bears had a significantly lower log(FID) in pre-berry season (t=-2.85, P=0.006, Table 3).

Table 3: Results from the linear mixed effect model for log(FID) of bait-classified bears

Explanatory variables	β	SE	t	P
Bait indifferent	0.188	0.197	0.95	0.344
Bait user	-0.247	0.154	-1.61	0.113
Bait avoider	0	-	-	-
Season - Pre-berry	-0.477	0.167	-2.85	0.006
Season - Berry	0	-	-	-
Sighting distance	0.015	0.005	3.25	0.002

3.3. FID of bait-experienced bears

Twenty-four bears were classified as bait-experienced bears (see 6. Supplement). Twenty-two bears from these bait-experienced bears were bait indifferent bears (n=11) and bait users (n=11) and two bears were reclassified from bait users to bait avoiders (see part 2.3.2., Classification of the bears). Five bait indifferent bears stayed at the initial site. The one-minute position data of one bait indifferent bear were missing. Therefore, one-minute position data of 18 bait-experienced bears were used to calculate the FID.

Table 4: Results from the linear mixed effect model for log(FID) of bait experienced bears

Explanatory variables	β	SE	t	P
Sex - Male	-0.707	0.225	-3.14	0.008
Sex - Female	0	-	-	-
Number of visits before the approach	-0.018	8.218E-03	-2.182	0.048
Activity - Passive	-0.488	0.209	-2.333	0.036
Activity - Active	0	-	-	-
Distance from the bait sites	1.193E-05	1.060E-05	1.125	0.281

The average values and standard deviation values were back transformed from explorative statistical analyses of log(FID) of bait-experienced bears. The average FID of bait-experienced bears was 61±2m (median 60.5m, minimum 28m, maximum 141m, n=18). The selected model indicated that bait-experienced male bears had significantly lower log(FID) than bait-experienced female bears (t=-3.14, P=0.008, Table 4). Bait-experienced male bears had an average FID of 45±1m (median 48m, minimum 28m, maximum 66m, n=6) and bait-experienced female bears had an average FID of 70±2m (median 68.5m, minimum 35m, maximum 141m, n=12). Log(FID) decreased with increasing number of visits at the bait sites of bait-experienced bears (t=-2.182, P=0.048, Table 4, Figure 8). Passive bait-experienced bears had significantly lower log(FID) compared to active bait-experienced bears (t=-2.333, p=0.036, Table 4).

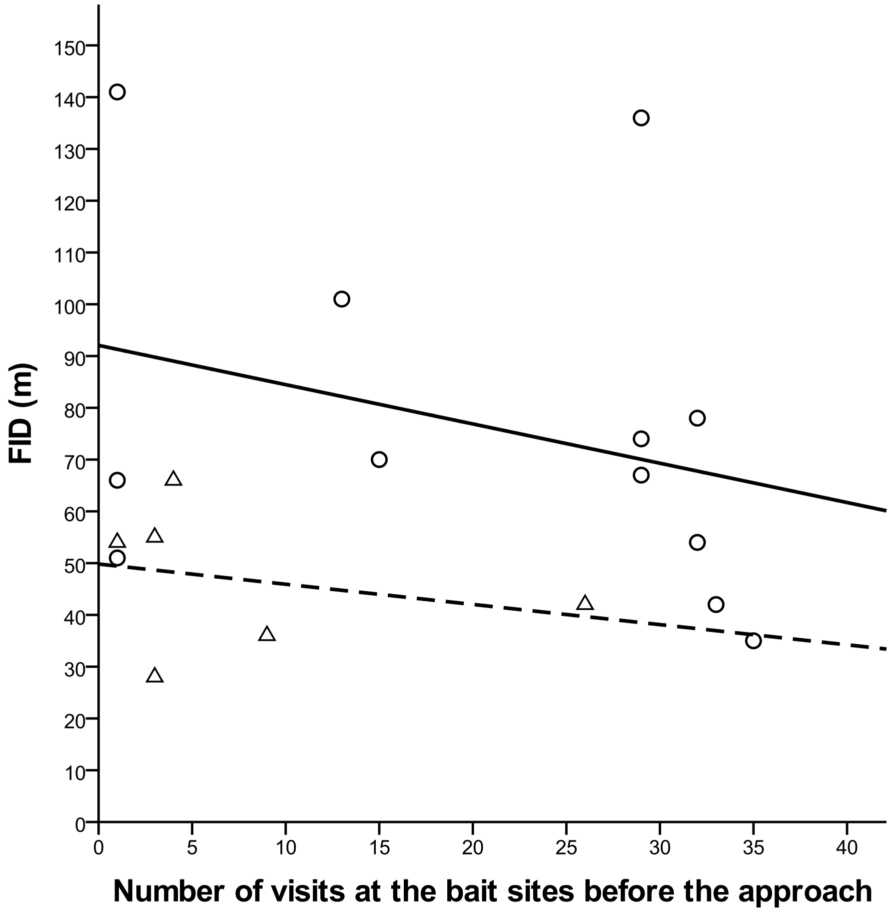

Figure 8: Effect of number of visits at the bait sites and sex on FID. Distribution of FID of bait-experienced male bears (triangles and broken line, n=6) and bait-experienced female bears (rings and full line, n=12) related to number of visits at the bait sites before the bear was approached.

3.4. Specific time after stress exposure of bait-classified bears

STASE was derived from the data of 69 out of 72 approaches with the previously calculated FID. One-minute positions of three approaches at the time around the end of STASE were missing and therefore STASE was not calculated for these approaches.

Table 5: Results from the linear mixed effect model for log(STASE) of bait-classified bears

Explanatory variables	β	SE	t	P
Bait indifferent	0.238	0.593	0.402	0.689
Bait user	-0.882	0.553	-1.595	0.116
Bait avoider	0	-	-	-
Sex - Male	-0.718	0.293	-2.451	0.017
Sex - Female	0	-	-	-
Number of observers	0.346	0.184	1.881	0.065
Sex - Male*Bait indifferent	-0.403	1.253	-0.322	0.749
Sex - Male*Bait user	2.016	0.735	2.743	0.008
Sex - Male*Bait avoider	0	-	-	-
Sex - Female*Bait indifferent	0	-	-	-
Sex - Female*Bait user	0	-	-	-
Sex - Female*Bait avoider	0	-	-	-

Log(STASE) did not differ significantly between all of the bait avoiders and all of the bait users in this model (Table 5). The average values and standard deviation values were back transformed from explorative statistical analyses of log(STASE) of bait classified bears. Bait avoiders had an average STASE of 12±3 minutes (median 12.5 minutes, minimum 1 minute, maximum 95 minutes). The average STASE of bait indifferent bears was 14±3 (median 11 minutes, minimum 4 minutes, maximum 45 minutes) and bait users had the average STASE of 10±4 minutes (median 10.5 minutes, minimum 2 minutes, maximum 89 minutes).

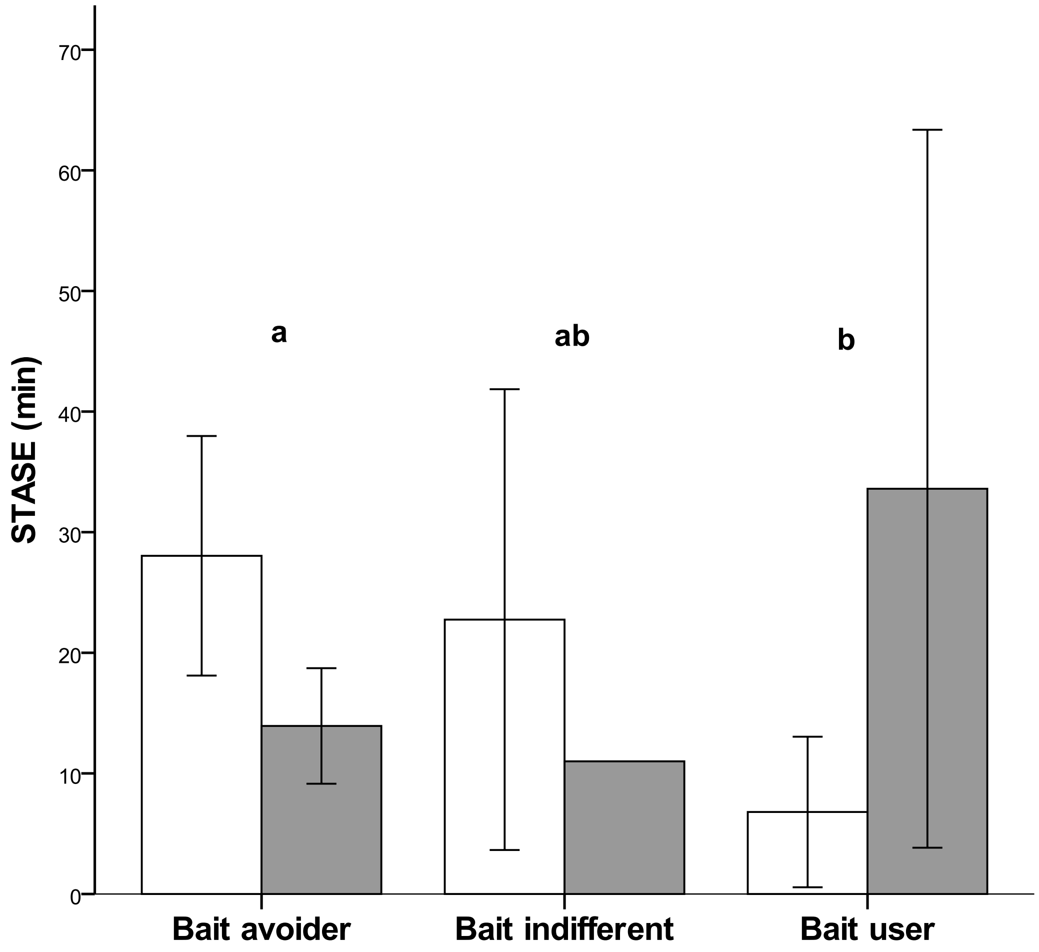

Figure 9: Interaction effect between bait-classified bears and sex on STASE. STASE was measured in minutes. The error bars represent standard errors. Female (white bars) bait users (n=5) had significantly lower STASE than female bait avoiders (n=24). Male (grey bars) bait users (n=5) had significantly higher STASE than male bait avoiders (n=30).

Interaction between sex and bait users had a significant effect on log(STASE) (t=2.743, P=0.008, Table 5). Figure 9 explains that male bait users had significantly higher stress response than male bait avoiders and female bait users had significantly lower STASE than female bait avoiders. Male bait users had the average STASE of 19±4 minutes (median 30 minutes, minimum 2 minutes, maximum 89 minutes, n=5) and male bait avoiders had the average STASE of 9±3 minutes (median 11 minutes, minimum 1 minute, maximum 63 minutes, n=30). The average

STASE of female bait users was 5±2 minutes (median 4 minutes, minimum 2 minutes, maximum 19 minutes, n=5) and the average STASE of female avoiders was 18±3 minutes (median 23 minutes, minimum 2 minutes, maximum 95 minutes, n=24). The STASE had an increasing tendency with increasing number of observers (t=1.881, P=0.065, Table 5, Figure 10).

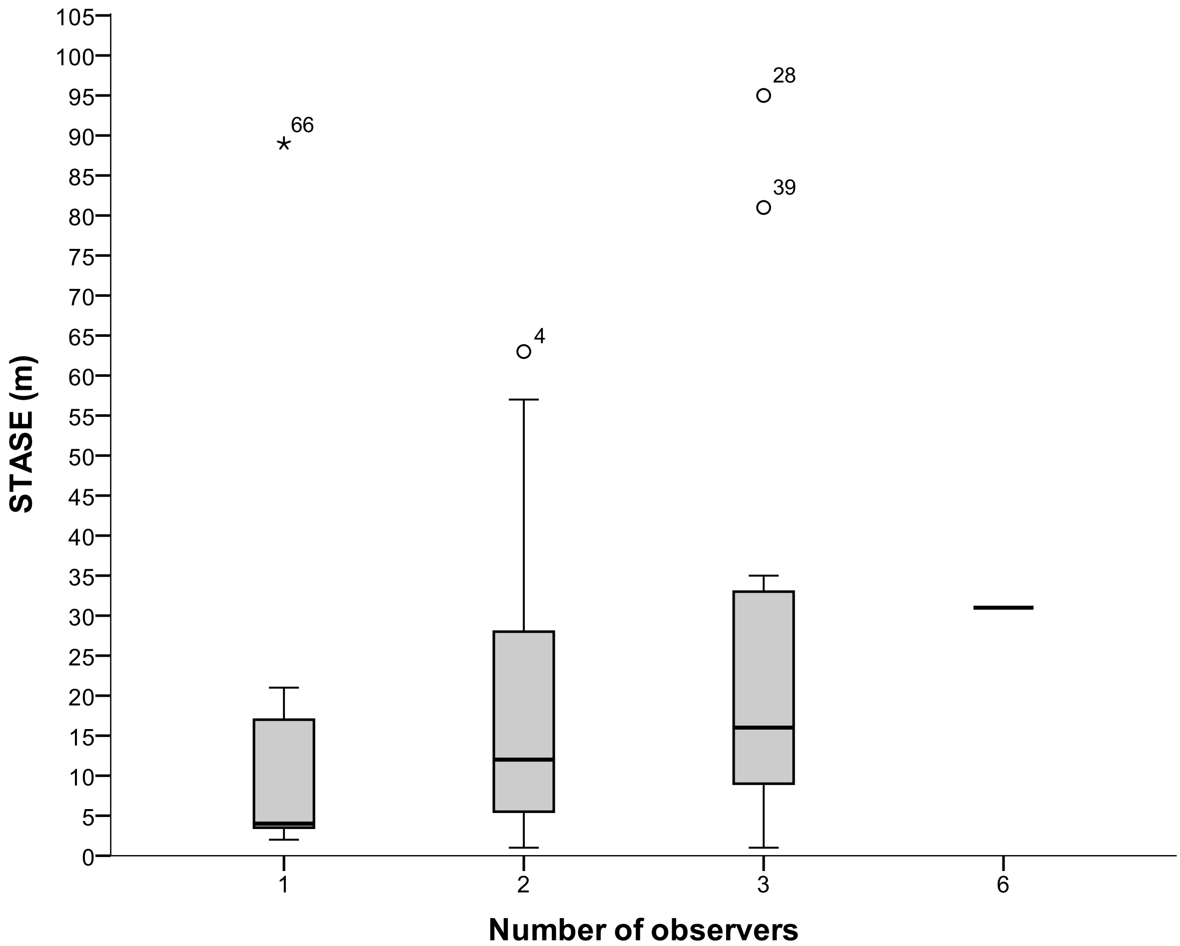

Figure 10: Effect of number of observers on STASE of bait-classified bears. STASE was measured in minutes. Box plots represent the non-normal distribution of STASE data for each number of observers that was analyzed. The increasing tendency of STASE was related to the increasing number of observers.

4. Discussion and conclusion

First, in part 4.1., Discussion, the results of the three hypotheses and predictions are discussed in the same order as they are enumerated in part 1.2. Afterwards, results from the analysis of STASE are presented. The next two paragraphs explain the uncertainty connected with the analysis of our geo-information data and its potential consequences and solutions. The next two paragraphs deal with the uncertainty and potential bottlenecks of our data from a general point of view. The rest of this part is devoted to comparing and discussing our results with existing studies.

Part 4.2., Conclusion, has three paragraphs. The results from this thesis are summarized in the first paragraph. The second paragraph shows potential implications of our results. Topics for future research and management actions are recommended in the last paragraph.

4.1. Discussion

Our results do not support the first hypothesis that bait users flee less frequently and stay more frequently at the initial site while being approached by humans. The ratio of flights to stays of bait users did not significantly differ from the ratio of flights to stays of bait avoiders. So the first prediction was rejected.

Further, the second hypothesis that bait users are less wary of humans than bait avoiders was also rejected. This is suggested because the difference in FID between bait users and bait avoiders was not significant, thus the second prediction was not supported. The variable bait avoider/bait indifferent/bait user did not explain the FID.

However, the third hypothesis that bait users are less aware of humans with increasing number of visits at the bait sites was not rejected. The third prediction stating that the increasing number of visits explained the decreasing FID of bait-experienced bears was supported. This result suggests that the number of visits at the bait sites can be considered as a measure of a bear's experience with bait sites.

The results explaining STASE showed that female bait users and male bait avoiders had significantly lower STASE than female bait avoiders and male bait users, respectively. Female bait users had significantly lower stress response towards approaching humans than female bait avoiders. Conversely, male bait users had significantly higher stress response towards observers than male bait avoiders.

Analysing GPS data from animal radio-collars brings 3 types of uncertainty. The first type is spatial inaccuracy in GPS locations acquired (Frair et al., 2004). To avoid this uncertainty, buffer zones of 60m around bait sites were created as Rettie and McLoughtin (1999) suggested (see part 2.3.1., Validation).

The second type of uncertainty is associated with the number of failed location attempts. With increasing number of these attempts, this uncertainty also increases (Frair et al., 2004). This type of uncertainty depends mainly on vegetation cover and GSM coverage around the bait sites. The bait sites were located in an area with a fair quality of GSM coverage, which minimized, but did not entirely eliminate, this uncertainty.

The third and final type of uncertainty is that which is caused by the movement patterns of bears (see, for example, Johnson et al., 2002). Bear positions were located once every 10 or 30 minutes. A bear could spend less than 30 minutes at a bait site and its position did not need to be necessarily located. Therefore, we considered only the bears that visited the bait sites three times or more as bait users.

This uncertainty still remains, and it is strongly recommended that a further study focusing on locating the GPS positions of collared bears at bait sites be undertaken.

Bait-experienced males had lower FID than bait-experienced females. The sample size of bait-experienced male bears, however, was small (n=6). Therefore, we only can suggest that bait-experienced males are less wary of humans than bait-experienced females. A bigger sample size of bait-experienced males is recommended in future studies concerning bears and bait sites.

Bears stayed more frequently at the initial site and had a lower log(FID) during the pre-berry season. However, none of the approaches on bait users was conducted during this season. Therefore, this thesis does not draw any conclusions about the behaviour of bait users in the pre-berry season. It is recommended that future studies be conducted in this regard.

Our hypotheses were drawn before the data were analyzed. Nothing was hypothesized about bait indifferent bears, because we developed this particular bait-classified group during the data analysis and after the data were gathered. This bait-classified group was created according to our subjective judgement of the data based on our personal experience. Existence of this group increased the certainty of correctness of the classification of bait users. Our hypotheses were oriented around explaining the effect of bait users on the dependent variables. Therefore, we paid less attention to the results of, or discussion about, bait indifferent bears.

Our results agree with some results of Moen et al. (2012). Bears stayed more frequently at the initial site during the pre-berry season and FID of bait-classified bears increased with increasing sighting distance. However, according to the results of Moen et al. (2012), older bears remained more frequently at the initial sites than younger bears. Older bears also had lower FID than younger bears. In our models age did not have a significant effect on the FID, or whether or not bears stayed or fled. Age may be a measure of experience, such as the variable bait avoider/bait indifferent/bait user. Bringing both variables into a model could cause a multicollinearity problem and subsequent exclusion of the Age variable from the final model.

Swenson et al. (2000) and Zedrosser (2009) suggested that anthropogenic food at the bait sites, associated with human presence, can cause problem bears. But Swenson et al. (2000) also added a comment saying that bait sites are established in the areas far from human settlements and that bears probably do not become food-conditioned and possibly human-habituated by using them. Our results agree with this suggestion.

Hopkins et al. (2010) stated that food-conditioned behaviour has various levels. Depending on the level, a food-conditioned bear is more or less tolerant to humans. This level of tolerance depends, according to Gunther et al. (2004), on the availability of anthropogenic and natural food sources. Bears that visit anthropogenic food sources more frequently become highly food-conditioned (Hopkins et al., 2010). These ideas, showing that bears became bolder with increasing number of visits at the bait sites, are supported by our results.

A human-habituated bear has little or no overt reaction to humans (Herrero et al., 2005). Swenson et al. (2000) and Zedrosser et al. (2009) suggested that a bear at a bait site might be not willing to leave the food source at the bait site while being approached by humans. At the majority of the initial sites, food sources and signs of foraging behaviour were found. However, all the bait users fled from the initial site while being approached by humans. The reason for this could be that no food source of a very high quality, such as a carcass or a bait site, was found at the initial site. Our results also suggest that bait users were not human-habituated.

Moen et al. (2012) investigating the FID response towards humans, did not find any difference between male and female bears. However the research of Moen et al. (2012) did not include the behaviour of brown bears associated with using bait sites. Herrero and Higgins (2003) reported that between 1960 and 1998, most human injuries were inflicted by female grizzly bears with cubs, followed by individual adult male grizzly and black bears. Herrero and Higgins (2003) included food-conditioned bears in their study. In this thesis we analysed data from individual bears, and our results support the results of Herrero and Higgins (2003), showing that male bait users were less wary of humans than female bait users.

Food-conditioning is a learned behavior (McCullough 1982; Herrero et al., 2005). A bear learns to get an anthropogenic food reward from a bait site. The number of bait indifferent bears and bait users was continually growing during the four study years. This shows that once a bear learned how to use the bait sites, it did not stop visiting them. Only one bear got deconditioned (see McCarthy and Seavoy, 1992; Herrero et al., 2005) during the four study years according to our bear classification method (see part 2.3.2., Classification of the bears).

Reeder and Kramer (2005) wrote in their review focusing on free-ranging mammals, that females generally have more robust stress responses compared to males. Our results further showed the same trend for bait avoiders.

No study investigating stress responses of bears towards humans was found. According to our results, females that are exposed to stress stimuli, such as those feeding at the bait sites, respond better to stress by spending less time fleeing from humans than females that were not exposed to stress stimuli. Males, however, reacted in an opposite way. Males that were exposed to stress stimuli spent more time fleeing from humans than males that were not exposed to such stimuli. A similar behavioral tendency in stress responses was observed in rats (see Westenbroek et al., 2005; Noschang et al., 2012).

Most of the authors (Herrero, 1970; Gunther, 1994; Swenson, 1999; Herrero and Higgins, 2003; Herrero et al., 2005) emphasize that suppressing availability of anthropogenic food as the key element in preventing development of food-conditioned bears and bear incidents. Hunting increases bear wariness of humans (Swenson, 1999) and may eliminate bolder (Swenson, 1999) and food-conditioned bears (Herrero and Higgins, 2003). But Swenson (1999) and Herrero et al. (2005) stated that bears lose wariness of humans if they have access to anthropogenic food even when the bear population is hunted. Swenson (1999; et al., 2000) further reasoned that the most important factor in preventing bear incidents is stricter maintenance of garbage located near people and their settlements. Our results showed similarities with the findings of Swenson (1999; et al., 2000) and Herrero and Higgins (2003), suggesting that bait sites in remote areas from human settlements do not present a risky food-conditioning food source, and the high hunting pressure in the study area keeps a bear population wary of humans.

4.2. Conclusion

Bait using bears did not show a lower willingness to leave the initial site than bait avoiding bears while being approached by humans. Bait users were not less wary of humans than bait avoiders. We observed that bears having increasing experience with bait sites lowered their wariness of humans. Furthermore, female bait users had a lower stress response toward humans than female bait avoiders, contrary to male bait users which had higher stress responses towards humans than male bait avoiders.

Our results suggest that bait users from the southernmost Swedish population do not cause bear incidents while being approached by humans in the forests more frequently than bait avoiders. If bait sites are established farther from human settlements, they represent an anthropogenic food source which apparently does not develop problem bears, as also suggested by Swenson (1999) and Swenson et al. (2000). According to the management status (see Hopkins et al., 2010), bears that had experiences with the bait sites showed a low level of food-conditioned and site-conditioned behaviour. This conclusion is supported by the fact that their stress response changed after learning how to use the bait sites.

From a management point of view, establishing bait sites far from human settlements, and keeping hunting pressure on, is recommended. In this way, bear incidents can be kept to a minimum in the study area.

Future research should focus on two points. Firstly, collecting and evaluating more data on bait users, especially male bait users, is needed. Secondly, evaluation of bait user movements in the vicinity of human settlements is recommended.

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6. Supplement

Review

To approach collared brown bears we used the method developed by Moen et al. (2012). This method has been approved and published as the first official method concerning humans approaching large carnivores. According to this method, several terms and variables used also in this thesis have been established:

- **Observer:** A person who conducts the approach.
- **Approach:** Approaching the bear by observers using the method from Moen et al. (2012).
- **Control period:** The period from the start of one-minute GPS positioning of the GPS-radio collars to the beginning of the approach
- **Passive/Active bear (discrete variable):** Bears can be recognized as active or passive according to the level of their activity in the control period.
- **Bed:** Resting or sleeping place of a bear.
- **Cluster:** Bear positions delivered and distributed in a diameter lower than 70m, where the approached bear stayed.
- **Initial site:** The cluster of GPS positions where the passive bear stayed before being approached by observers or the last GPS position from an active bear before the approach.
- **Sighting distance (continuous variable):** A measure of horizontal vegetation cover in meters measured at the initial site.
- **Age (discrete variable):** Age of a bear in years at the time of the approach.

- **Sex (discrete variable):** Sex of a bear approached by humans.
- **UCL (value):** Upper control limit is a value in meters/minute determining the speed limit of the bears. When bear's speed exceeds this UCL, this bear is fleeing from observers. See also part 2.3.3., Upper control limit.
- **FID (response, continuous variable):** Flight initiation distance is a distance in meters when a bear starts fleeing from approaching humans. FID is a first distance measured from the approached bear to approaching humans when the bear's speed exceeds an UCL.

Besides the variables used in the study of Moen et al. (2012), we specialized in terms and variables describing bears' behaviour connected with the usage of bait sites as further described here:

- **Visit:** A bear's visitation at a bait site determined further by conditions following from validation (see part 2.3.1. Validation).
- **Bait-classified bear**: A bear that was classified as bait user or bait indifferent bear or bait avoider.
- **Bait user/Bait indifferent/Bait avoider (discrete variable):** A bait user is a bear conditioned to the food at the bait sites. A bear which is bait indifferent, encountered the bait sites less than three times before being approached by observers. A bait avoider is a bear which did not visit bait sites before being approached by observers. For further details see part 2.3.2., Classification of the bears.
- **Number of visits of bait sites (continuous variable):** Number of visits of bait sites before a bear is approached by humans.

- **Distance to the closest bait site (continuous variable):** Distance from a bear to the closest bait site in meters in the last minute of a control period before being approached by humans.
- **Time spent from the last visit (continuous variable)::** Time in days from the last visit at a bait site to the end of the control period of a bear before being approached by humans.
- **STASE (response, continuous variable):** Specific time after stress exposure (Reeder and Kramer, 2005; Westenbroek et al., 2005). Time in minutes when speed of the approached bear exceeds UCL. The first position of the approached bear used for calculation of STASE is the position of FID. The bear has to have lower speed than the UCL in at least two positions after the last position used for calculation of the STASE.