University of South-Eastern Norway

Faculty of Technology, Natural Sciences and Maritime Sciences

Master's Thesis

Ecology and environmental management

Spring 2024

Benedikte Elvine Rosenkilde & Sandra Berge Lian

The Bear Minimum: Brown bears “bearly” react to secondary research activities

University of South-Eastern Norway
Faculty of Faculty of Technology, Natural Sciences and Maritime Sciences
Department of Natural Sciences and Environmental Health
PO Box 235
NO-3603 Kongsberg, Norway
http://www.usn.no

This thesis
is worth 60 study points
Cover illustration by Sandra Berge Lian

Foreword

In a world where human disturbances on wildlife are constantly increasing, understanding their consequences is crucial. Our thesis aims to fill a gap in knowledge about how Brown Bears in Sweden react to disturbances, contributing to a better understanding of the species. Working on this topic has been both interesting and formative and has sparked an interest in bear behavior.

We would like to thank our supervisor, Professor Andreas Zedrosser, for his invaluable guidance. His insights and experience have been essential to our work. We also wish to express our sincere gratitude to Ashlee Mikkelsen and Rick Heeres, our co-supervisors, for their support with both coding, statistical analysis and writing. We would also like to thank the Scandinavian Brown Bear Research Project for providing us with the data needed for our thesis.

Lastly, we want to thank each other. Here's to “bearly” surviving the wild journey of thesis writing and coming out stronger (and more knowledgeable) on the other side!

Midt-Telemark/15.05.2024

Benedikte Elvine Rosenkilde & Sandra Berge Lian

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Summary

Anthropogenic disturbances can alter wildlife movement, potentially causing changes in behavior, increased stress, reduced fitness, and, in severe cases, death. This study focuses on how non-intrusive field research activities, hereafter referred to as "secondary research activities", affect brown bear movement behavior. To identify potential disturbance events, we used GPS data from 42 brown bears (22 females and 20 males) and coordinates from 53 den sites used during the previous hibernation period. We established a 300 meter buffer around den visit locations and a 600 meter buffer around bears, identifying 9 events where bears and researchers were within these buffers. To ensure accuracy in monitoring researcher-bear interactions, we excluded hours between 23:00 and 08:00 when researchers were not in the field. We calculated the daily Net Squared Displacement (NSD) for a three-day period surrounding each disturbance event (the day before, during and after) to analyze possible changes in movement distance as a response to secondary research activities. We did not find clear differences in movement distances by bears in close proximity to researchers, though we did find individual differences. To achieve a more comprehensive understanding of how brown bears respond to secondary research activities, future studies should consider larger sample sizes or a longer study period in combination with integration of physiological data. Taking individual variability into account is essential for developing ethical research practices that aim to reduce the impact on wildlife while performing field research.

1 Introduction

Human activity disrupts wildlife and its habitats and can lead to alter animal behavior (Ritzel & Gallo, 2020; Lewis et al., 2021; Pinto et al., 2024). Disturbances can take many forms, including habitat fragmentation due to urbanization or agriculture, as well as direct disturbances from recreational activities and hunting (Dominoni et al., 2020; Osuri et al., 2020). Wild animals constitute only 4% of the world's mammal biomass and continue to face shrinking habitats (Bar-On et al., 2018). The ripple effects of human disturbances extend to behavioral adaptations among various animal species (Tucker et al., 2018). For instance, many mammal and bird species adjust their circadian activity patterns and increase nocturnality to avoid human activity (Gaynor et al., 2018). A comprehensive study involving 803 individuals across 57 species observed a decrease in movement rate, by one-half to one-third, in areas with significant human presence (Doherty et al., 2021). A study on brown bears (*Ursus arctos*) in Sweden found that during the moose hunting season, hunters induced a landscape of fear for bears, which led to bears avoiding areas with a high occurrence of moose hunting as well as areas near roads even though they were not the targeted species (Brown et al., 2023). A study also found that bears in the same area decrease their foraging activity during the annual bear hunt (Hertel et al., 2016b). Such changes in foraging behavior can lead to lower energy intake, which in turn can lead to poorer body condition (Ciuti et al., 2012).

Anthropogenic disturbance can also include activities thought to benefit wildlife, such as research activities where the goal is to understand more about a species' ecology, management and conservation (Kilpatrick et al., 2020). Wildlife studies often consist of an extensive number of research activities, including behavioral observations, handling of animals for tagging or medical examination, as well as data collection in the field (Arnemo & Evans, 2017). Once captured, researchers can equip animals with GPS-tagging equipment and collect tissue, blood or various other types of samples (Taberlet et al., 1999; Marks, 2010; de Carvalho Ferreira et al., 2014). However, capture and handling can lead to elevated stress hormones in the captured individual (Harcourt et al., 2010), and potential changes in behavior that may last for months post-capture and disrupt important life-history events, such as reproduction. For instance, female Svalbard reindeer (*Rangifer tarandus platyrhynchus*) that were captured multiple times were less likely to be observed with calves compared to females that were captured once or not at all (Trondrud et al., 2022). Changes in behavior from capture and handling have also been documented in large carnivores. In Alaska, polar bears (*U. maritimus*) change behavior and activity for up to five days post-capture (Rode et al., 2014). Both brown and black bears (*U. americanus*) captured multiple times (2-10) tend to have poorer body condition than those captured only once (Cattet et al., 2008).

In contrast to capture, tagging, and other direct researcher-animal interactions, the possible effects on animals from other research activities have received less attention (Kilpatrick et al., 2020). Here, we use the term “secondary research activities” (SRA) to describe the activities of researchers in a study area without intentional, direct contact with the study species. SRA encompass all activities that require researchers to be physically present in a study area. These are activities including, but not limited to, tracking of individuals, collection of fecal samples, visits at resting or den sites and vegetation surveys. It is important to recognize that the absence of a direct contact or an intentional interaction with wildlife does not necessarily mean that animals are unaware of the researchers’ presence or unaffected by their activities. Animals have evolved sophisticated systems to detect potential threats through a variety of sensory cues, such as visual, auditory, and chemical signals (Caro, 2005, p.181). Alarm calls from other species can be used as an indicator of potential danger (Fallow et al., 2010). These abilities enable animals to recognize and respond to threats, a capacity that can be either innate or acquired through experience. For instance, species like elk (*Cervus elaphus*), caribou (*Rangifer tarandus),* moose (*Alces alces*), and bison (*Bison bison*) exhibit various types of reactions to the sounds of different predators, influenced by their previous encounters with these predators (Berger, 2007). Given that animals can perceive humans as potential predators (Suraci et al., 2019), it becomes evident that even subtle cues associated with SRA, such as human scent or sound, can potentially trigger anti-predator responses in wildlife, including the study species. Therefore, it is essential as well as research-ethically appropriate to consider the implications of SRA and strive to minimize their potential negative effect on the studied species.

The Scandinavian Brown Bear Research Project (SBBRP) started in 1984 and approximately 1000 individuals have been captured as part of the research (e.g., Bjärvall & Sandegren, 1987; Bjärvall et al., 1990, Brown et al., 2023). However, the research project has also carried out extensive SRA in the field, ranging from the collection of various samples, visits of kill sites or resting locations, to vegetation surveys (e.g., Frank et al., 2015; Hertel et al., 2016a; Hertel et al., 2018). While these activities are essential for studying bear behavior and ecology, they also raise concerns about the potential occurrence of unintentional disturbances. Our thesis is a pilot study on how research affects a study species, and the main goal is to evaluate the potential effects of SRA on the movement behavior of brown bears. We use locations from GPS-collared brown bears and sites of interest (abandoned winter den sites) visited by researchers in the field to understand if and how such activities affect the movement rate of bears. We predict that 1) 50% of abandoned den site visits by researchers result in the unintentional disturbance of a GPS collared bear. To our knowledge there is no data available in the scientific literature on how often such unintentional disturbances happen during field research activities. Therefore, we use a "best guess" estimate. If a GPS-collared bear is disturbed unintentionally, we predict 2) an increase in net squared displacement (NSD) compared to days without disturbance from secondary research activities.

2 Methods

2.1 Study area and study species

The study area is located in south-central Sweden (approximately 61° N, 15° E), in Gävleborg and Dalarna counties (Thiel et al., 2022; Thorsen et al., 2022) (Figure 1). The landscape consists of bogs and lakes, some agricultural land and boreal forest. The forest is intensively managed and consists mostly of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) (Thorsen et al., 2022). While the area is characterized by a low human population density, the autumn months see a surge in human activities, including berry picking, mushroom gathering and hunting (Thiel et al., 2022). Notably, bear hunting is permitted from 21 August to 15 October and around 10% of the total population is culled annually (Bischof et al., 2019). Sweden has one of the most productive brown bear populations in the world (Steyaert et al., 2012), and the average population density of brown bears in the study area is 29.3 bears/1000 km², however, local densities can likely reach up to 60 bears/1000 km² (Støen et al., 2006; Zedrosser et al., 2006)

We focused our analysis on data of the movement behaviors of 42 GPS collared bears during May-August in 2011. The SBBRP captures and tags bears with GPS collars shortly after den emergence from the middle of April until the beginning of May. All captures and handling are carried out following a predefined biomedical protocol (Arnemo & Evans, 2017). Bears are located via helicopter and sedated using remote drug delivery. During these captures researchers may attach tracking devices such as GPS collars or VHF transmitters (Arnemo & Evans, 2017). Measurements of various physiological parameters such as body temperature, respiratory rate, heart rate or blood sampling are also done (Evans et al., 2012). The project operates under strict guidelines approved by the Swedish Ethical Committee on Animal Research (Arnemo & Evans, 2017). The period with SRA of the SBBRP usually begins at the end of May and lasts until the start of the bear hunting season. These activities include den surveys, fecal sampling and berry monitoring (Bellemain et al., 2005; Sahlén & Swenson, 2011; Stenset et al., 2016.)

Brown bears are solitary, non-territorial carnivores and generally most active during the crepuscular periods (Ordiz et al., 2014; Hansen et al., 2021). Seasonal home range sizes vary depending on food availability, sex, population density and reproductive status (Dahle & Swenson, 2003b; Steyaert et al., 2012). The mating season lasts from spring to early summer (Steyaert et al., 2012). Males and solitary females have relatively large home-ranges during the mating season, while females with cubs-of-the-year decrease their home-range size during mating season (Dahle & Swenson, 2003a). The median annual home range sizes for bears in our study area is 1055 km^2 for males, 217 km^2 for single females, and 124 km^2 for females with cubs-of-the-year.

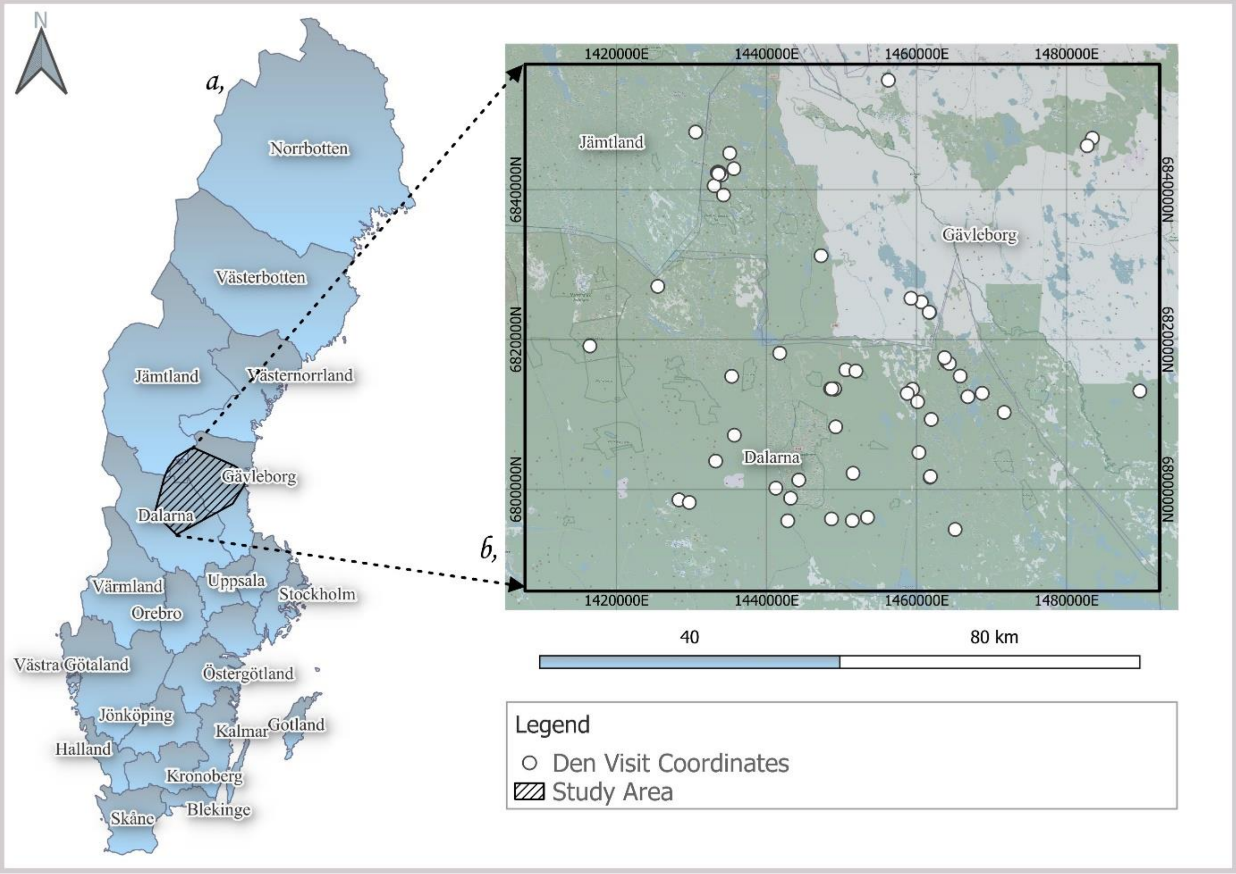

Figure 1): a) Map of study area and b) coordinates for research visits to abandoned brown bear winter den locations (white dots) in the study are in south-central Sweden, May-August 2011.

2.2 Data preparation and methods

2.2.1 GPS data of bears and secondary research activities

Relocation data of GPS-collared bears were provided by the SBBRP. The GPS collars are programmed to record locations at hourly intervals and obtained on average 22 locations per day in our dataset. For this analysis, we used data from 26 May to 20 August 2011, as it encompasses the majority of the active period of brown bears and includes both the mating season and hyperphagia (Steyaert et al., 2012, Hertel et al. 2016b). We excluded the bear hunting season from our analyses to ensure that our findings accurately reflect the natural behavior of bears during crucial phases of their annual lifecycle (Hertel et al., 2018, Brown et al., 2023).

The SRA used in this study were 53 visits to abandoned winter den sites by researchers over a period of 23 days between May 26 to August 20, 2011. The SBBRP aims to visit and register the winter den of every GPS-collared bear in the study area (Friebe & Hammer, 2023). Those visits usually last for about one hour and during this time various data on the den and its surrounding habitat is collected (e.g., Shiratsuru et al., 2020).

2.2.2 Definition of disturbance by SRA and Net Squared Displacement

Previous studies on bear responses to human encounters in Sweden have documented flight initiation distances ranging from 13 to 324 meter (Moen et al., 2012). To estimate the potential disturbance of SRA on bears, we created a buffer with a radius of 300 meter around den locations with the st_buffer function in the sf package (Pebesma, 2018). It is important to note that the potential disturbance by SRA only reflect the presence of researchers at a den site but does not include the routes researchers walked to and from their vehicles.

The mean hourly movement distance of GPS-collared bears in our dataset was 343.25 ± 65.6 meter (SD), which aligns with mean hourly movement distance of bears in Sweden documented by Hertel et al. (2021). To obtain conservative estimates of potential disturbances by SRA, we created a buffer with a radius of 600 meter around every location of a GPS-collared bear before, during, and after a den visit by researchers. Because visits to abandoned winter dens as part of SRA are carried out exclusively during the daytime, we excluded hours between 23:00 and 08:00. We defined a potential disturbance of a bear by SRA as the intersection or overlap of bear buffer and SRA buffers. We used the st_intersection function from the sf package (Pebesma, 2018) to identify such potential disturbances.

We used Net Squared Displacement (NSD) as a measure to evaluate if and how the movement rate of a bear was affected by an SRA disturbance (Bastille-Rousseau et al., 2016; Morelle et al., 2017). NSD is defined as the total distance travelled from an animal's initial location to all subsequent locations (de Angelis et al., 2021; Thompson et al., 2024), i.e., NSD is a measure of an animal's daily movement rate and distance. For each disturbance detected in our data set, we calculated the NSD of the bears for a three-day window. This included the day preceding the disturbance (Day -1), the day of the disturbance (Day 0), and the day following the disturbance (Day +1). This approach facilitated a detailed examination of movement patterns before, during, and after disturbance by a SRA.

2.3 Data analysis

To determine the proportion of times researchers unintentionally disturbed GPS-collared bears, we performed an exact binomial test. We considered the number of successes as when the researchers and bears were within our set total buffer (900 meter). The number of trials were 53 (all den visits).

We used the NSD of Day -1 to represent normal bear behavior in the absence of research disturbance as baseline for all comparisons. We compared this baseline to the NSD of Day 0 and Day 1 to identify any significant deviations in NSD, indicating altered movement behavior. We performed two separate Kruskal-Wallis rank sum tests with a predetermined level of significance at $\alpha = 0.05$ to evaluate differences in NSD between these three days. All the data handling and analyses were executed in R 4.3.0 (R Development Core Team, 2023).

3 Results

3.1 Rate of disturbance by SRA

During our study period, 42 GPS-collared bears were present in the study area. Out of 53 den site visits by researchers, we identified overlaps with bears on 9 occasions (Figure 2), indicating a 17% disturbance rate from SRA. This rate is significantly lower than the predicted 50%, with an exact binomial test confirming the substantial difference (p-value < 0.001). These 9 events were further analyzed to assess how such disturbances affect bear movement behavior.

3.2 Effects of disturbance by SRA

On average, bears moved 8273 ± 6535 meter (SD) on Day -1, with distances ranging from a minimum of 380 meter to a maximum of 18977 meter (Figure 2). On Day 0, the average movement distance for all the bears was 13937 ± 11350 meter), with individual movements varying between 1460 and 37619 meter (Figure 2). On Day +1, the bears moved on average 10815 ± 8278 meter, with movement distances spanning from 3400 to 25157 meter.

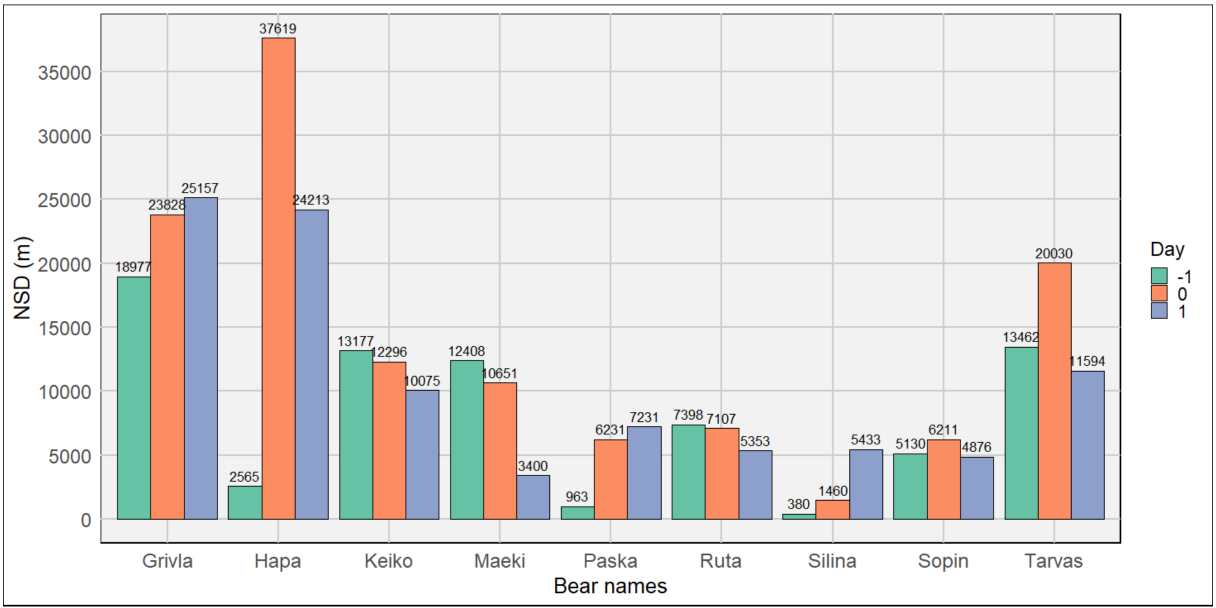

Figure 2: Net Square Displacement (NSD) for bears affected by disturbance from secondary research activities in Sweden, May-August 2011. Each bear is represented on the x-axis with their unique name, and the y-axis indicates the NSD in meters. The bars are color-coded to represent different days: Day -1 (red) shows the day before the disturbance, Day 0 (green) indicating the day of the disturbance, and Day +1 (blue) the day after the disturbance. Numerical values atop each bar show the exact NSD measures for each bear and day.

We found no significant differences in NSD between Day -1 and Day 0 (Kruskal-Wallis test, $\chi^2 = 0.860$, df = 1, p = 0.354) (Figure 3). Furthermore, we found no significant differences in NSD between Day 0 and Day +1 (Kruskal-Wallis test, $\chi^2 = 0.236$, df = 1, p = 0.627) (Figure 3).

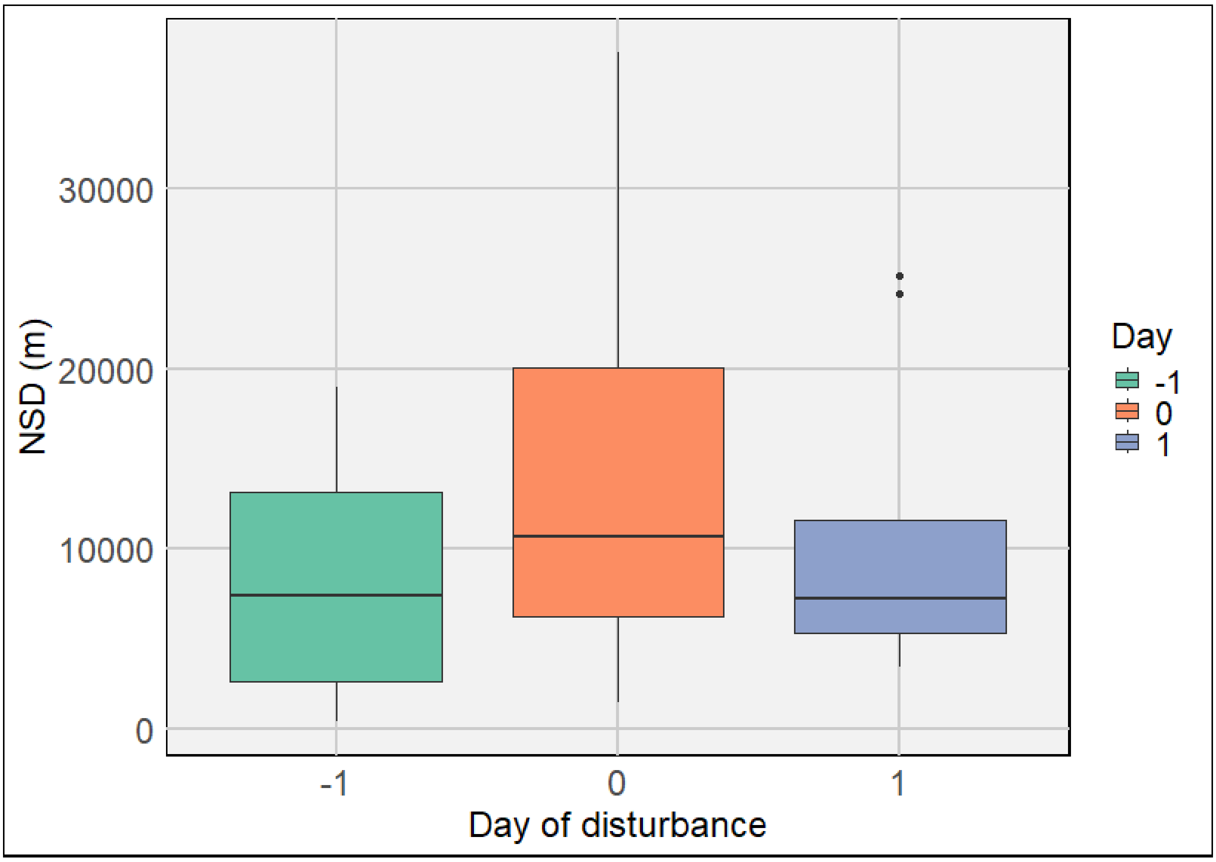

Figure 3: Boxplot of Net Square Displacement (NSD) for bears affected by disturbance from secondary research activities in Sweden, May-August 2011. The x-axis represents time in days, with Day -1 indicating the day before the disturbance, Day 0 the day of the disturbance, and Day 1 the day after the disturbance. The y-axis shows NSD in meters.

4 Discussion

We found that the disturbance rate by SRA was 17% and significantly lower than predicted (50%; no support prediction 1). We further found no increase in NSD in relation to SRA (no support prediction 2).

Our results suggest that the disturbance rate from SRA, in our study defined as researchers visiting abandoned winter den sites during May to August, was approximately 17%. This disturbance rate is significantly lower compared to our initial prediction that 50% of the den visitations would lead to unintentional disturbance of bears. This initial prediction was speculative, because as to our knowledge, no data exists on how often bears are unintentionally disturbed by SRA. Our research focused only on the consequences of den visitations. However, a multitude of other SRA have been carried out in our study area since the start of the project in 1985, including VHF telemetry (e.g., Dahle & Swenson, 2003b), various food studies (e.g., Swenson et al., 1999; Stenseth et al., 2016; Hertel et al., 2018), predation studies (Swenson et al., 2007; Rauset et al., 2012) and habitat selection (e.g., Moe et al., 2007; Elfström et al., 2008). Since the start of the project in 1985, there have been field seasons were up to 10 field workers working on different aspects of bear ecology were active in the field at the same time at different locations (A. Zedrosser, personal communication, 24.04.2024). Our results of the effect of one particular SRA therefore represent a highly conservative estimate of the unintentional disturbance of research effects on a study species. In addition, our estimate only takes into consideration GPS-collared bears. During many years, the SBBRP estimated to have about 50% of the adult males and 80% of the adult female radio-collared in the study area (Bellemain et al., 2006; Solberg et al., 2006; Zedrosser et al., 2006; Zedrosser et al., 2013). This means that there were also a substantial number of unmarked bears in the study area, and the effects of SRA on these individuals remains unknown. It is therefore possible that the disturbance rate of SRA on brown bears found in this study is a gross underestimate. Future research should consider the whole effect of multiple disturbances to fully understand their implications on brown bear movement behavior.

Bears are no strangers to human activity on the landscape level; conservation of brown bears and all other large carnivores must by definition occur in a human-dominated landscape (Chapron et al., 2014). Bears adapt to the general presence of humans on the landscape by increasing their nocturnality (Ordiz et al., 2013). During the daytime, bears tend to rest in day beds that are well hidden and far from humans (Ordiz et al., 2011; Ordiz et al., 2017). Therefore, it is reasonable to assume that bears avoided some disturbances by SRA due to their crepuscular activity patterns, as they actively avoid human presence during the time the researchers are performing den site visits (Ordiz et al., 2011; Ordiz et al., 2017). It is also possible that bears detected approaching researchers earlier than what we accounted for in our methods, for example by scent or by hearing. Researchers travel as close to the den as possible by car to have the shortest possible walking distance to a den site (A. Zedrosser, personal communication, 24.04.2024), and bears could therefore have noticed the cars and left the area before the researchers got close to the den site. Even though we used a 300 meter buffer around the den location, the researchers walked through the forest and could have been detected by the bears before entering the 300 meter buffer.

For the bears that qualified as 'disturbed' by den site visits, the Kruskal-Wallis test showed no significant effect on NSD across all 9 individuals. We also have to acknowledge that 9 events of disturbance represent a rather low sample size. In addition, how close the bears and researchers where within the overlap could affect the potential reaction, which we did not analyze. Nonetheless, it is possible that the presence of the researchers did indeed disturb some of the bears. Therefore, it could be beneficial to reconsider our analytical methods in future research on this topic. However, individual differences in NSD are also evident (see Figure 2). For example, "Hapa" (Bear ID W0703), who showed an increase in NSD from 2565 meters (Day -1) to 37619 meters on the day of disturbance (Day 0), with a subsequent decrease to 24213 meters (Day +1). Other bears like "Maeki" (BearID W1005) had a decrease in NSD, from 12490 meters (Day -1) to 10651 meters (Day 0) and 3400 meters (Day 1). These individual variations underscore the variability in bear responses and highlight that while some bears exhibit increased movement potentially as a flight response, others may decrease their activity, possibly as a form of hiding or minimizing energy expenditure during stressful periods (Ordiz et al., 2019).

We cannot fully conclude that changes in NSD are due to disturbances by SRA or if other factors or disturbances affected bears during the time of SRA. Another study of bear reactions to human encounters by le Grand et al. (2019) has observed that while adult bears may run faster when directly approached by humans, they do not necessarily cover greater distances. This might suggest that bears could be detecting researchers and reacting by moving quickly away from the immediate area of disturbance without engaging in prolonged movement. The lack of significant change in NSD can perhaps be attributed to how the SRA in our study was conducted, compared to other studies on bears reaction to humans. During the SRA, the researchers did not know where the bears in the study area was, and they had no intention of encountering them. This differs from other studies (e.g. Moen et al., 2012; Sahlen et al., 2015; le Grand et al., 2019) and where the researchers deliberately walked towards the bears to study their reaction and flight initiation distance.

To enhance future research on brown bear movement with NSD, we believe that including the speed at which the bears are moving could provide more information about how the bears respond to human disturbance from SRA. Integrating physiological data, such as heart rate and temperature monitoring, could add value by providing a more comprehensive view of bears' internal or physiological responses to SRA (Støen et al., 2015; le Grand et al., 2019). At the same time, this would include additional disturbance to the bears. Considering the amount of SRA being conducted in our study area, it is important to understand the total effect of all these activities. Our research provides valuable insights into the effects of SRA on movement behavior on brown bears in Sweden. These insights contribute to the discussion on the ethics of wildlife research, underscoring the need for a balance between scientific inquiry and the welfare of the studied species.

In conclusion, this study assessed the impact of secondary research activities on the movement behavior of brown bears in south-central Sweden, using GPS data from GPS-collared brown bears and coordinates from winter den visits by researchers during the summer of 2011. Contrary to our first prediction that 50% of the den site visits would result in the unintentional disturbance of a GPS collared bear, only 9 instances (±17 %) where found when bears' movements intersected with research activities. Our second prediction tested whether bears increased their movement after a disturbance. We found no significant changes in movement distances post-research activities. However, individual variations in bear responses were observed; for instance, bear “Hapa” (Bear ID W0703) increased NSD during the day of disturbance, whereas bear “Maeki” (BearID W1005) decreased. These differences underline the complexity of how animals react to human disturbances and the potential for SRA to influence individual movement behavior. These insights contribute to the discussion on the ethics of wildlife research.

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