IMPACTS OF POWER LINES ON BROWN BEAR MOVEMENT IN CENTRAL SWEDEN

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Diplôme : Master en bioingénieur : gestion des forêts et des espaces naturels, à finalité spécialisée

Année académique : 2016-2017

URI/URL : http://hdl.handle.net/2268.2/3098

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The cover picture was taken by the author, above the forests North of Mora, Sweden, on April 28th, 2017.

La photo de couverture a été prise par l'auteur, au-dessus des forêts au nord de Mora, en Suède, le 28 avril 2017.

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Acknowledgements

I would like to thank my supervisors Philippe Lejeune and Sam Steyaert for overseeing my work during this project, as well as the other members of the jury for the defence: Marc Dufrêne, Alain Licoppe, and the president of the committee, Jacques Hebert. I would also like to thank Anne Hertel and Richard Bischof from the Norwegian University of Life Sciences as well as Stephanie Bonnet, Anais Gorel, Nicolas Latte, Jérome Perin and Samuel Quevauvillers from Gembloux Agro-Bio Tech (Liège University) for helping me with the data treatment and statistics.

I would also like to thank the researchers from the Scandinavian Brown Bear Research Project, for their careful work with capturing and collaring bears, collecting and managing the GPS data, and providing access to the long-term data base used in this report.

I would like to express my gratitude to the European Commission for the Erasmus+ program and the Department of Forest Resources Management at Gembloux Agro-Bio Tech for providing mobility funds during my project.

Finally, I would like to thank my family for supporting me both financially and emotionally through years of university, the students at Gembloux Agro-Bio Tech for carrying on the greatest sense of community, as well as the Belgian people, as a contributor to a system that allows access to higher education for everyone.

Bastien Desmecht

Abstract

A. English

For decades climate change and renewable energy have been at the centre of media attention, as well as in private and public sectors. Sweden took on ambitious commitments to reduce the national emission of CO_2, including promoting the switch to renewable energies, among which wind energy occupies an important place. However, its production requires building wind parks that are often placed in wildlife habitat for reasons mainly based on wind properties. Wind parks construction implies building the necessary infrastructure (roads and power lines) to support and maintain it and to transport the produced electricity. How these power lines and associated roads affect wildlife movement and behaviour remain important questions in wildlife management and conservation.

Recent advances in GPS telemetry and remote sensing technologies provide researchers with abundant data that can be used to investigate detailed questions about wildlife behaviour. Using these technologies, this report aims to determine whether brown bears (*Ursus arctos*) are affected by power lines in their general habitat selection behaviour in the intensively managed boreal forests of central Sweden. It also intends to determine whether bears adjust their movements in the immediate vicinity of those structures. Finally, it aims to determine whether the bear's movement responses towards power lines are ambiguous with respect to reproductive status and season.

Maxent modelling showed relatively little influence of power lines on bear habitat selection, albeit that power lines explained a greater part of variation in habitat selection for specific reproductive classes and seasons. Movement analysis demonstrated that power lines had little influence on bears' speed, with again more or less specific reactions regarding reproductive classes and seasons. Subadults, however, appeared to decrease their movement rates during the berry season. Movement analysis also demonstrated that bears' speed is influenced by roads up to 275 metres from the feature.

Management strategies may include, besides minimizing the development of power lines in bear habitat, making transmission lines unsuitable as travel routes to reduce the impacts of human development and to restore the edge areas between the corridor and the forest.

B. French

Depuis des décennies le changement climatique et les énergies renouvelables sont au cœur de l'attention des médias et des secteurs public et privé. La Suède a pris des engagements ambitieux pour réduire sa production de CO_2, notamment en encourageant le passage aux énergies renouvelables avec parmi elles, l'énergie éolienne. Sa production requiert toutefois la construction de parcs éoliens, souvent situés dans des zones réculées après étude de la faisabilité de l'implantation et de modélisation des vents. La mise en place de ces infrastructures nécessite également l'extension du réseau routier ainsi que de celui de transmission électrique, ce qui perturbe le milieu avec une potentielle dégradation de l'habitat pour les espèces sauvages. Les effets de ces lignes électriques et du réseau routier associé sur les mouvements et le comportement de la faune restent d'importantes questions en gestion des ressources naturelles et de conservation de la faune sauvage.

Les développements technologiques en télémétrie GPS et en télédétection donnent accès aux chercheurs à de riches données qui leur permettent d'investiguer en détail des questions sur le comportement des animaux sauvages. En utilisant ces technologies, ce rapport a pour objectif de déterminer si l'Ours brun (*Ursus arctos*) est influencé par les lignes de transmission électrique dans son comportement de sélection d'habitat dans les forêts intensément exploitées du centre de la Suède. Il cherche également à déterminer si les ours modifient leurs déplacements à proximité des lignes électriques. Dernièrement, ce rapport cherche à déterminer si la modification du déplacement des ours près de cette structure est en relation avec le statut reproducteur et la saison.

La modélisation de la sélection d'habitat Maxent a montré le peu d'importance relative des lignes électriques sur la sélection d'habitat par l'ours, bien que ces infrastructures expliquaient une plus grande part de la variation pour certains statuts reproducteurs et pour certaines saisons. L'analyse des déplacements a démontré le faible impact des lignes électriques sur la vitesse de l'ours, avec là encore des variations en fonction du le sexe, du statut reproducteur et de la saison. Cependant, les individus subadultes ont semblé diminuer la vitesse de déplacement durant la saison de fructification des baies. L'analyse des déplacements a également révélé que ceux-ci sont influencé par les routes dans un rayon allant jusqu'à 275 mètres.

Les stratégies de conservation pourraient inclure, outre la limitation du développement du réseau électrique dans l'habitat de l'Ours brun, un entretien des corridors de lignes à haute tension pour les rendre inadaptées comme chemin d'accès afin de réduire les impacts du développement humain et instaurer des lisières entre le corridor et la forêt.

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1. Introduction

1.1. Climate change, wind turbines and power lines

Global warming is now a certainty and the fact that these changes in weather patterns are in large part caused by human activities is commonly accepted by both the scientific community and the general public (Lorenzoni & Pidgeon 2006). The main anthropogenic factor responsible for climate change is the increase in greenhouse gas (GHG) concentration in the atmosphere (Huntley et al. 2006). The most important and well-known of these GHGs the carbon dioxide (CO_2), released by the combustion of fossil fuels, deforestation and agricultural activities (Stocker et al. 2001). The increasing demand for energy is thus a serious threat to the climate and renewable energy is part of the solution (Dincer 2000). Renewable energy, as opposed to conventional energy such as coal, gas, oil and nuclear, is energy that is collected from renewable resources that are replenished in a human timescale (Stead & Stead 2009). Sources of renewable energy include: solar radiation, wind, tides, geothermal heat and several activities that impact landscapes are associated with producing renewable energy as, for example, infrastructures for transportation, water and air heating and cooling (REN21 2010).

In 2006, the Swedish Government announced their aim for sustainable development, more specifically their goal to free the nation's economy of fossil fuel use by 2050 (REN21 2014). The principal policy instrument for energy efficiency is taxation on energy and CO_2 emissions (Swedish Energy Agency 2015). And whereas energy consumption in Sweden has remained rather stable over the last decade (with electricity carrying roughly 33% of it), renewable energies are providing for a growing part of it (Meyer, 2007). Wind energy produced by wind turbines is one such example, and the unprecedented rate and scale of development of wind farms raises questions about impacts on wildlife (Drewitt & Langston 2006).

Considering the huge investments at stake, wind parks are located on the most favourable spots in the landscape. The main criteria for choosing a wind park site are the wind resources (as wind speed and thus energy production increases with altitude, and the presence of obstacles creating turbulence), the available space, and whether the potential site is in a noise-sensitive neighbourhood or could damage visually-sensitive viewpoints (Latinopoulos & Kechagia 2015). For these reasons the rolling landscape of central Sweden, largely dominated by production forests provides plenty of suitable locations for the construction of wind parks. Forests owners are compensated for the expropriation of forest land, but with such large areas at stake it is primordial to assess the impacts of power lines on wildlife (Kuvlesky et al. 2007) and possibly set up countervailing measures. These new wind farms are typically connected to the existing power grid by electric power lines, thus modifying the landscape around the site up to several dozen kilometres along the linear structure.

Sweden is expanding and strengthening its old national grid to secure the electricity supply and enable the expansion of renewable electricity production to honour their mandate for the common European electricity market (Brodin et al. 2015). The Swedish national power-line grid extends to about 192,000 kilometres of overhead lines and the area covered by forest strips under the lines or otherwise affected by them is estimated to add up to several hundreds of thousands hectares (Svenska kraftnät 2017). More than the array of turbines, it is the associated infrastructure required to support it, such as roads and transmission lines, that can represent a potential threat to wildlife, because such infrastructures can result in extensive habitat fragmentation (Bevanger 1998) and can provide avenues for invasion by exotic species (Kuvlesky et al. 2007).

Studies on the impact of wind energy production and power lines on wildlife are mostly focussing on flying vertebrates and seabed fauna and flora at offshore wind farms (Bevanger 1998; Bergström et al. 2014). The main concerns are disturbance during construction, electromagnetic fields that could disturb birds and bats as well as the obstacle it represents for flying fauna locally causing higher injury and mortality frequencies for the species (Bevanger 1998).

The impacts of power lines on terrestrial fauna are less well-known compared to those of roads and railways. Power lines are not dangerous to pass under and their existence does not automatically facilitate human use (Nellemann et al. 2001). This aspect is important as the anthropogenic disturbance of bears has led to avoidance of areas close to disturbance and led to a displacement of home ranges (Nellemann et al. 2007). Considering that vegetation, including disturbance-tolerant forbs and berry producing shrubs, may be enhanced along the power line corridors, brown bears could select this habitat (Eldegard et al. 2015).

However, transmission lines may have negative effects on wildlife habitat use and movement (Kuvlesky et al. 2007) as they cause habitat loss and disruption of landscape connectivity (Richardson et al. 2017). These linear features create a barrier effect for small terrestrial animals such as micromammals, amphibians, reptiles and insects. The barrier effect is attributable to the substantial structural and microclimatic habitat differences within the corridor and to interspecific competition with the better-adapted species of open areas (Miriam & Helene 1997). The effects of power lines on reindeer migration are thought to be negative, with a strong avoidance of areas beneath and close to the features (Reimers et al. 2007). Indeed, large predators such as wolves and brown bears often avoid areas of high human activity, which can create a predation free area to which prey species may be attracted (Hebblewhite et al. 2005, Berger 2007, Nellemann et al. 2007, Martin et al.2010). However, a study conducted in north-eastern Alberta demonstrated that caribou that are close to linear corridors are at a higher risk of depredation by wolves (James & Stuart-Smith 2000).

There are relatively few studies on the impacts of electric power lines on wildlife in Sweden and it is therefore hard to draw a general conclusion on the consequences of power line construction. This report aims to determine how electric power lines and the clearcuts under overhead corridors affect bears' movements and whether the reactions (i.e. avoidance, selection or neither) depends on the season and the bears' reproductive status.

1.2. Brown bear in Scandinavia

As the number and distribution of brown bears are increasing in several areas of northern and eastern Europe (Swenson 2000) new challenges are brought to new areas. Because the species depredates on livestock and game, thus competing with farmers hunters, and they cause fear to other users of forests because bears can be dangerous to people (Swenson et al. 1998). The bear population in Sweden has been increasing (Kindberg et al. 2011) and therefore it becomes more and more important to ensure continuous research to assess their population dynamics, their ecological role, and how they affect humans and land use (Swenson 2000). For those reasons, the brown bear has been the subject of a long-term study (since 1984) in two study areas in Sweden: near the Northern edge of the species' range in the county of Norrbotten and near the Southern edge of its range in the counties of Dalarna and Gävleborg (Swenson 2003).

The expansion of human activities is responsible for habitat loss and fragmentation, major causes of animal population declines in many parts of the world (Fahrig 1997). Among these activities, forest production with its dense network of exploitation roads occupies a preponderant place. In addition, the current replacement and extension of the transmission system for electricity is a growing cause for potential habitat fragmentation (Bevanger 1998). Moreover, like many other large carnivores, brown bears are generally threatened by human-caused mortality (Steyaert et al. 2016). For example in Sweden, about 90% of all bear mortality is caused by people (Bischof et al. 2009). Consequently, brown bears avoid human activities throughout their range (Nellemann et al. 2007; Ciarniello et al. 2007).

Since a power line is not a physical obstacle in itself for bears, such as it can be for flying animals and since there is no proof that bears are affected by electromagnetic fields, I hypothesized that power lines could be considered as a network of linear clearcuts ranging from 30 up to 60 metres wide, associated with potential human disturbance, as wildlife may associate power lines with traffic, hunters and berry pickers (Nellemann et al. 2001). Therefore, as this report focuses more on movement patterns than on habitat selection, the parallel was made with roads, which are linear features that are used in a predictable or unpredictable way by humans, and that are largely avoided by bears (Bischof et al 2017). Other research has shown an increase in speed of bear movement near roads (Kite et al. 2016), suggesting increased fear and higher movement rates to quickly cross them. Hence, the brown bear could avoid transmission line corridors to minimize exposure and risks of encounter with humans.

In contrast, the maintenance of corridors under power lines, much like clearcuts, immediately increases the direct sunlight incidence under and near the features. This higher exposition to sunlight increases productivity on early clearcuts for both bilberry and lingonberry (Ordiz et al. 2011) leading to high local berry abundance (Kardell and Eriksson, 2011). In Sweden, brown bears forage almost exclusively on bilberries (*Vaccinium myrtillus*), lingonberries (*Vaccinium vitisidaea*), and crowberries (*Empetrum spp.*) from mid-July until den entry (Hertel et al. 2016). Considering that berries comprise approximately 44% of the annual digestible energy intake and 68 % of the autumn digestible energy intake (Dahle et al. 1998; Persson et al. 2001; Stenset et al. 2016), they represent a very attractive resource for brown bears. Moreover, clearcuts appear to increase the occurrence of the carpenter ant (*Camponotus herculeanus*), a relatively important summer food item for the brown bear on Swedish managed forests (Frank et al. 2015). Therefore, transmission line corridors could be attractive for the brown bear and they could select for them.

Furthermore, numerous studies pointed out that brown bear behaviour is highly dependent on their reproductive status and time of the year. For example, mating behaviour (Swenson 2006), subadult dispersal (Støen et al. 2006) and male despotic behaviour (Steyaert et al. 2016) are important drivers of spatiotemporal behaviour differences between the reproductive classes. The brown bear is a species known to perform sexually selected infanticide (SSI); hence mothers with cubs are usually extra cautious and avoid encounters with their conspecifics as they represent a serious threat to their offspring (Swenson 2006). During mating season, SSI and male despotic behaviour explains differential habitat selection between adult males, subadults and females with dependent offspring (Steyaert et al. 2013). Recent studies indicate that they can use humans as shield (Steyaert et al. 2016), but in this report it is expected that the exposure to conspecifics is a greater loss than the potential protection provided by the human-built feature. Younger bears can occur near human settlements because they are naïve in terms of lacking experience of people (Kaczensky et al. 2006). Hence, subadults could use the linear clearcuts alongside electric power lines as highways for dispersal, which occurs during mating season – from early May until mid-July (Støen et al. 2006), without avoiding them because of their artificial nature. Fear ecology theory predicts that animals respond to predation risk by adjusting their spatiotemporal behaviour to avoid the risk source, and therefore trade resources (typically food) for safety (Brown et al. 1999). This implies that all bear groups should avoid areas of human presence, especially during the hunting season, which coincides with hyperphagia (Steyaert et al. 2016).

Considering all these status and season specific behaviours, the relation among bear movement patterns and their reproductive status, as well as the time of the year, deserves special attention.

1.3. Objectives and hypotheses

A. Hypotheses

Firstly, considering that power lines are anthropogenic disturbances throughout the matrix of bear habitat, and that similar disturbances such as roads are generally avoided by Scandinavian brown bears (Bischof et al. 2016), I predict that bears are affected by power lines in their general habitat selection behaviour (H1).

Secondly, for the reasons mentioned above, I hypothesize that bears will adjust their movements in the immediate vicinity of those structures (H2). Provided that bears typically increase their movements near human structures such as roads (Kite et al. 2016), I predict that brown bears will increase movement rates (i.e. speed) near power lines.

Finally, provided that brown bear movement and behaviour is highly dependent on sex, reproductive status, and season (Støen et al. 2006; Swenson 2006; Steyaert et al. 2016), I predict that bears' movement responses towards power lines are ambiguous with respect to sex, reproductive status and season. Hence, I predict that speed will decrease during the berry season for all bears as they forage, that speed will increase during the hunting season as exposure is a risk and that mating season will show most differences in speed among reproductive status.

B. Project structure

The three hypotheses were tested using the three following methods, respectively (see 2. Materials & methods for more details).

First, I analysed habitat selection modelling using the Maximum Entropy software (Maxent) to see if brown bears are affected by power lines for habitat selection.

Second, I analysed the movement patterns of the bears in vicinity of roads (to test the application of the method) and power lines. I produced graphs showing the evolution of speed and variability of speed in relation to the proximity of the linear feature.

Third, I used multivariate linear regression (lme4 software) to observe the importance of human features and environmental variables on bears' speed. Then I produced the movement pattern graphs for each class.

2. Materials & Methods

2.1. Description of the study area

The study area is situated in central Sweden in the counties of Dalarna, Gävleborg, Jämtland and Värmland. Human population density there is among the lowest in the European brown bear range, with humans concentrated in villages in the Northern and Southern parts of the study area, whilst isolated houses are scattered throughout the area. However, the area is intersected with a dense network of roads: including minor gravel logging roads, approximatively 0.3 km/km^2, varying from 0 to 1.5 km/km^2 (Zedrosser et al. 2006; Martin 2010). See appendix 1 for the road density map.

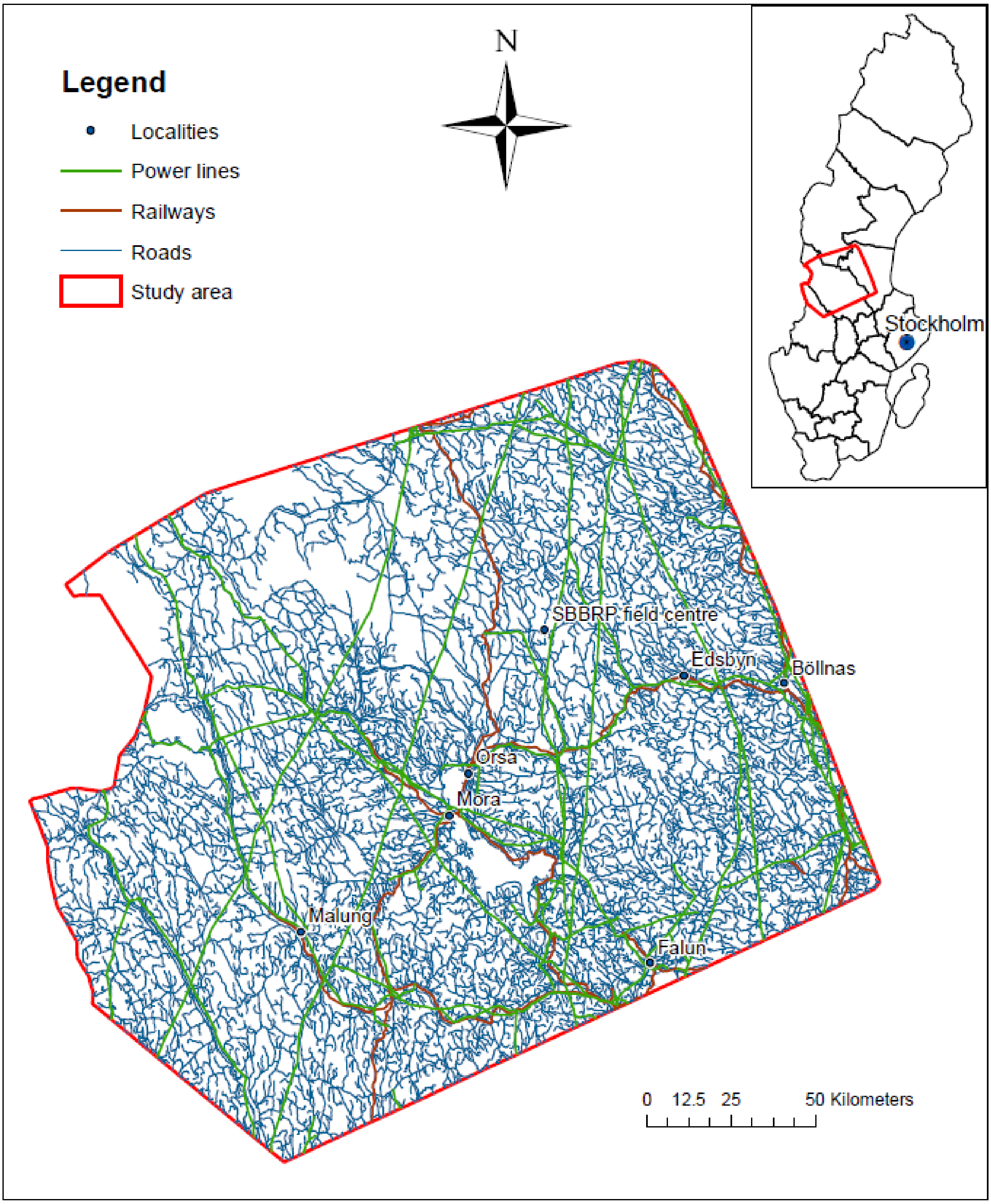


Figure 1. Study area in central Sweden displaying the extent of the road network, the power lines and railways.

The study area is mostly covered by commercial coniferous forests dominated by Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) on a hilly terrain, with elevations between 250 and 650 m above sea level (see appendix 2 for land cover map). The rotation time for timber harvesting is about 100 years (Linder and Östlund 1998). Approximately 8% of the area is recently logged forest (clearcuts, 0 to 10 years old), and 42% of the forest stands are younger than 35 years (Swenson et al. 1999). The density of the brown bear population is approximately 30 individuals/1 000 km² (Bellemain et al. 2005). Every year, 40 to 50 bears are equipped with GPS-GSM collars (Vectronic Aerospace GmBh, Berlin, Germany) within the long-term Scandinavian Brown Bear Research Project (SBBRP). See Arnemo and Fahlman (2011) for details on capture and handling. All animal capture and handling was approved by the Ethical Committee on Animal Experiments in Uppsala, Sweden and the Swedish Environmental Protection Agency (Hertel et al. 2016).

2.2. Collecting location data

Since 1984, the Scandinavian Brown Bear Research Project equips bears each year with radio transmitters (VHF technology) or, since 2003, with GPS-receivers to collect data and develop the database further. The data on brown bear movements treated in this report was collected from 2003 to 2016. Spatial accuracy of the GPS collars was approximately 10 m (Moe et al. 2007; Arnemo and Fahlman 2011). GPS locations were cleaned to keep a GPS fix every hour (locations that are more than one hour apart, or less, were removed from the data set).

I initially used brown bear movement data without discrimination and I later divided them according to season and reproductive status. Seasons were defined as 'mating season' (May 1 – July 15), 'berry season' (July 16 – September 15) and 'hunting season' (September 16 – October 15). The two last seasons correspond to the hyperphagia period (i.e. season when bears feed copiously to gain fat for hibernation). The den emergence season and predenning were discarded as many bears are still in the den and positions are less abundant (fewer bears, collar failures, etc.). Movement data within the seasonal categories was then partitioned by bear reproductive status, resulting in three data sets for each of the three seasons. Reproductive statuses were defined as solitary individuals (mostly males), mothers with cub(s) and subadults (less than three years old).

Locations for linear regressions modelling and movement patterns were within 1 000 metres from roads and electric power lines. Considering the literature on the topic of disturbance caused by linear features and the usual threshold of 500 metres (Kite et al 2016), it was assumed that the response scale would be well below a kilometre. Locations for habitat selection modelling using Maxent were situated within 5 000 metres from electric power lines to observe whether it produced a consistent pattern when afar from the feature. The area within the 1 000 metres buffer zones contained 13.7% of the total number of locations and covered 5 810.5 km² (10.3% of the study area). The area within the 5 000 metres buffer zones contained 55.3% of the total number of locations and covered 21 838.9 km² (38.7% of the study area).

2.3. Spatial data layers

The maps used and presented in this report were created from the Swedish National Land Survey (*Lantmäteriet*) base dataset using the software ArcMap 10.3.1; ESRI 2015. The input layers were: land cover, elevation, roads, electric power lines and a map of Sweden with administrative boundaries. The study area was defined using the minimum convex polygon function on the bear locations data set. Then a new land cover map with a pixel resolution of 25 x 25 m was created by merging the 60 original classes into ten new classes to simplify further treatments and analysis (Maxent and multiple linear regression). The 10 classes are: deciduous forest, young- coniferous forest, mid-aged coniferous forest, old coniferous forest, mixed forest, bog, open area, bare soil, water and urban area. Next, maps of distances from human-made linear features were designed for roads, electric power lines and urban patches using the tool “Euclidean distance” (which calculated for each raster cell the distance to the nearest features specified).

Finally, maps of linear features density were created with different radius values (500, 1 000, 1 500, 2 000 and 5 000 metres) for roads and electric power lines using the tool “Line density”. The maps with different maximum distance were compared during the model selection to keep the most parsimonious one for each bear group, using AIC to rank them. Road type was disregarded, as most roads within the study area are unpaved forestry roads. Powerline type was disregarded as well because of their limited number in the study area, dividing the data would have left too few locations to work with. Density for urban patches was calculated using the tool “Point density”, within a 1 000 metres radius from each raster cell.

2.4. Habitat selection modelling using Maxent

The influence of habitat use caused by disturbance can be evaluated by combining habitat models and remotely sensed data (Saunders et al. 1991, Forman 1995, Hansen et al. 2001). The software program Maxent attempts to estimate the closest probability of species occurrence to uniform, whilst still being subject to environmental constraints (Elith et al. 2011). Maxent is used here for modelling species distributions from presence-only species records. The algorithms minimize the relative entropy between two probability densities (one estimated from the presence data and one, from the landscape) defined in covariate space (Merow et al. 2013). Maxent automatically considers the interactions between predictor variables and can handle both continuous and categorical variables. It uses a set of functions (e.g., linear, quadratic, product, threshold and hinge) to describe and estimate how environmental variables and human disturbances constrain the geographic distribution of species (Elith et al. 2011). Maxent also uses a regularization parameter which is determined empirically to control the over fitting of the model (Farashi et al. 2016). The probability of species occurrence can indicate if a resource is selected, avoided or neither. Habitat selection is defined as the disproportionate use of available conditions and resources and involves responses in space and time to perceived risks and rewards, and avoidance is its opposite (Mayor et al. 2009)

The variables treated by Maxent in this analysis were land cover, slope (rather than elevation because of the homogenous flat to hilly topography of the study area), density of roads (calculated in a 5 000 metres radius because it was proved more relevant during model selection), density of urban area in a 1 000 metres radius (rather than distance to human settlements because of the heavily humanized nature of the study area) and distance to power lines, the main object of this report. The AUC, i.e. area under the ROC (receiver operating characteristic) curve was used to evaluate the model performance. AUC is a measure for model performance that varies from 0 to 1 (Fielding and Bell, 1997). An AUC of 0.50 indicates that the performance of the model was not substantially better than random, whereas a value of 1 indicates a perfect discrimination (Swets 1988). Models with values above 0.75 are considered potentially useful according to Elith 2002. Using the response curves, the relationship between the habitat suitability and distance to power lines was examined for each group of bears. Variable contributions can be interpreted without suspicion as the correlation amongst variables was tested beforehand and all were independent (Pearson correlation coefficient, $r \ll |0.70|$).

The percentage of contribution and permutation for each of the five variables was produced for every bear group to see to which degree each of their spatial distribution was influenced by these variables. To evaluate the contribution, the increase in regularized gain is added to the contribution of the corresponding variable (or subtracted from it if the change to the absolute value of lambda is negative) for each iteration of the training algorithm. For the second estimate (percent of permutation), the values of that variable on training presence and background data are randomly permuted, for each environmental variable in turn. The model is re-evaluated on the permuted data, and the resulting drop in training AUC is shown in a table, normalized to percentages (Jurka 2015).

2.5. Bear movements analysis

A. Extraction of trajectories

The R package (R Development Core Team 2013) adehabitatLT (Calenge 2006) was used to extract bear movement trajectories from the locations data set. The movement distances were calculated as the Euclidean distance between two successive locations and then log transformed to approximate a normal distribution. Locations were delivered with a steady interval of one hour and thus, the distance travelled between two successive points can be regarded as the bear's speed. Step length can be used to link a movement pattern to a specific behaviour. For example, long step lengths in grizzly bears movement patterns have been associated with traveling or searching, whereas short step lengths have been associated with foraging or resting (Blanchard & Knight 1991; Roever et al. 2010; Graham & Stenhouse 2014). Research on brown bear foraging behaviour in Sweden has shown similar associations with movement patterns (Hertel et al. 2016).

To focus the study on the impacts of linear features on bear movement, only trajectories within a range of 1 000 metres from roads and electric power lines were analysed. Considering the literature on the topic of disturbance caused by linear features and the usual threshold of 500 metres (Kite et al 2016), it was assumed that the response scale would be well below a kilometre. To avoid noise in the design of plots showing the evolution of speed according to the distance to linear features all trajectories with a speed inferior to 15 metres per hour were removed, as they are associated with resting (Ordiz et al. 2011; Hertel et al. 2016).

B. Quantification of movement patterns in relation to linear features

Firstly, step lengths were grouped by lags, i.e. classes, of 10 metres from 0 up to 1 000 metres from the feature and plotted in box-and-whisker showing variation of steps length in relation to the distance from the linear features. The demonstrative example for the impact of roads on bear movement was made using all seasons and reproductive status combined, whilst the data was also divided according to season and bears' reproductive status for the impact of power lines. These graphs provide a first insight of the effect of the linear features on bears' movement.

Then coefficients of variation (CV) within each class was calculated and plotted for each bear group to show how CV varies in relation to the distance from the linear feature. CV, i.e. coefficient of dispersion, is defined as the standard deviation (SD) divided by the mean (Brown 2001), with the result reported as a percentage. The main appeal of the CV is that the SDs generally increase or decrease proportionally as the mean increases or decreases, so that division permits the comparison of variates free from scale effects (i.e., it is dimensionless). The CV is therefore a standardization of the SD that allows an easier comparison of variability estimates (Reed et al. 2002). Low CV values represent homogeneity in movement pattern and high values represent heterogeneity (Kite et al. 2016). Thus, Figure 5 (ii) provides a representation of how similarity in movement patterns changes with proximity to the linear features.

Finally, the cumulative sum of differences between the slope value for a given lag, and the average slope value across all lags, was calculated when it was adequate (i.e., when a pattern was detected in the graph showing trends of CV values in relation to distance from features). Slope value for each lag was calculated by dividing the difference of two consecutive CV values ($CV_{i+1} – CV_i$) by the difference of the corresponding distances (from the feature) values ($dist_{i+1} – dist_i$), the mean slope was calculated taking an average across all slope values. Then the maximum cumulative sum value was selected to delineate the response scale because it identifies the distance at which the trend in CV changes from increasing to constant random. This maximum cumulative sum value determined the range to which bears are affected by the feature, i.e. the response scale (Kite et al. 2016).

2.6. Multiple linear regression

To test and quantify the influence of each environmental and human disturbance features variables on bear movements, I used the linear mixed-effects models (LME4) R package (Bates et al. 2015) in R to perform a multiple linear regression. The goal was to model the relationship between the bears' speed and the explanatory variables. I used log-transformed step lengths as the response variable, 'distance to power line' and 'distance to road' as second order polynomial variables, 'slope' and 'land cover' as first order polynomial variable (landcover was factorial variable), all fixed effect variables and 'bear year' (identifier for bear, possibly same bears on different years) as random intercept. The equation of regression was:

log10(speed) ~ poly(epl_distance, 2) + poly(road_distance, 2) + as.factor(soil_occup) + poly(slope) + poly(urban_density) + (1 | bearyear)

Pearson's correlation coefficient (r) was used beforehand to test for collinearity so that only variables that were not strongly correlated ($|r| < 0.7$) were used within models. The results were produced using 'summary' and 'ANOVA' functions in R. The first function produces an estimate for each factor level of the factorial variable (land cover in this case) but does not explain how important the variable is as a whole, thus it was adequately completed with the ANOVA (i.e. analysis of variance) function.

3. Results

3.1. Descriptive statistics

The study was carried out on an area of 56 396.0 km² using locations from bear*years (i.e. the number of bears, same bears being considered as other 'individuals' on different years). 260 power line sections were involved, for a total length of 3 178.0 km and thus a density of 0.056 km/km² for the whole study area. The area within the 1 000 metres buffer zones contained 13.7% of the total number of locations and covered 5 810.5 km² (10.3% of the study area). The area within the 5 000 metres buffer zones contained 55.3% of the total number of locations and covered 21 838.9 km² (38.7% of the study area). Table 1 shows how uneven the number of bear*year and locations are among bear groups, especially in relation to the reproductive status.

Table 1. Number of bear*year and location by reproductive status and time of the year.

Reproductive status	Mating season		Berry season		Hunting season	
	N bear*year	N locations	N bear*year	N locations	N bear*year	N locations
Solitary	121	14579	92	9774	61	3916
Mother with cubs	41	5221	37	4201	22	1155
Subadults	10	2083	10	1356	5	320

The landscape is dominated by coniferous forest (70.55%), divided in three age classes of roughly the same importance, as shown in table 2. Bogs come second in importance with roughly 10%, and water in third place with a bit less than 7%. Other habitats that are open areas, mixed forests, deciduous forests, and bare soils, combined represent a bit less than 12% and urban activities no more than 1.1%, indicating how little surface is occupied by human settlements. (See appendix 2 for the land cover map of the study area).

Table 2. Distribution of land cover types in the study area.

Land cover classes	**Area (km²)**	**Area (%)**
Deciduous forest	1 783.9	3.2
Coniferous forests (young)	11 662.4	20.7
Coniferous forests (mid aged)	14 956.6	26.5
Coniferous forests (old)	13 165.7	23.4
Mixed forests	2 097.0	3.7
Bogs	5 629.9	10.0
Open areas	2 618.7	4.6
Bare soil	62.7	0.11
Water	3 796.7	6.7
Urban activities	622.4	1.1
Total	56 395.8	100

3.2. Habitat selection modelling

A. AUCs

The AUC, i.e. area under the ROC curve, was used to evaluate the model performance, it varies from 0 to 1 (0.50 indicates that the performance of model was not substantially better than random, whereas a value of 1 indicates a perfect discrimination). Table 3 shows that the AUC values obtained here are rather low, especially those for solitary bears and mothers with cub(s) during the mating and berry season (AUC < 0.60).

Table 3. AUC values per bears' reproductive status and season.

Bear group		AUC
Season	Reproductive status	
Mating season	Solitary	0.53
	Mothers	0.57
	Subadults	0.64
Berry season	Solitary	0.54
	Mothers	0.59
	Subadults	0.67
Hunting season	Solitary	0.60
	Mothers	0.71
	Subadults	0.80

B. Analysis of variable contributions

The correlation among variables was tested, again using the Pearson correlation coefficient, and none were correlated ($r << |0.70|$). Hence, variable contributions could be interpreted without suspicion for the use of the response curves, the relationship between the habitat suitability and distance to power line was examined. Percentages of contribution and permutation for each of the five variables were produced for every bear group to see to which degree each of them was influenced by these variables. Contribution in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate (percent of permutation), the values of that variable on training presence and background data are randomly permuted, for each environmental variable in turn. The model is re-evaluated on the permuted data, and the resulting drop in training AUC is shown in a table, normalized to percentages (Jurka 2015).

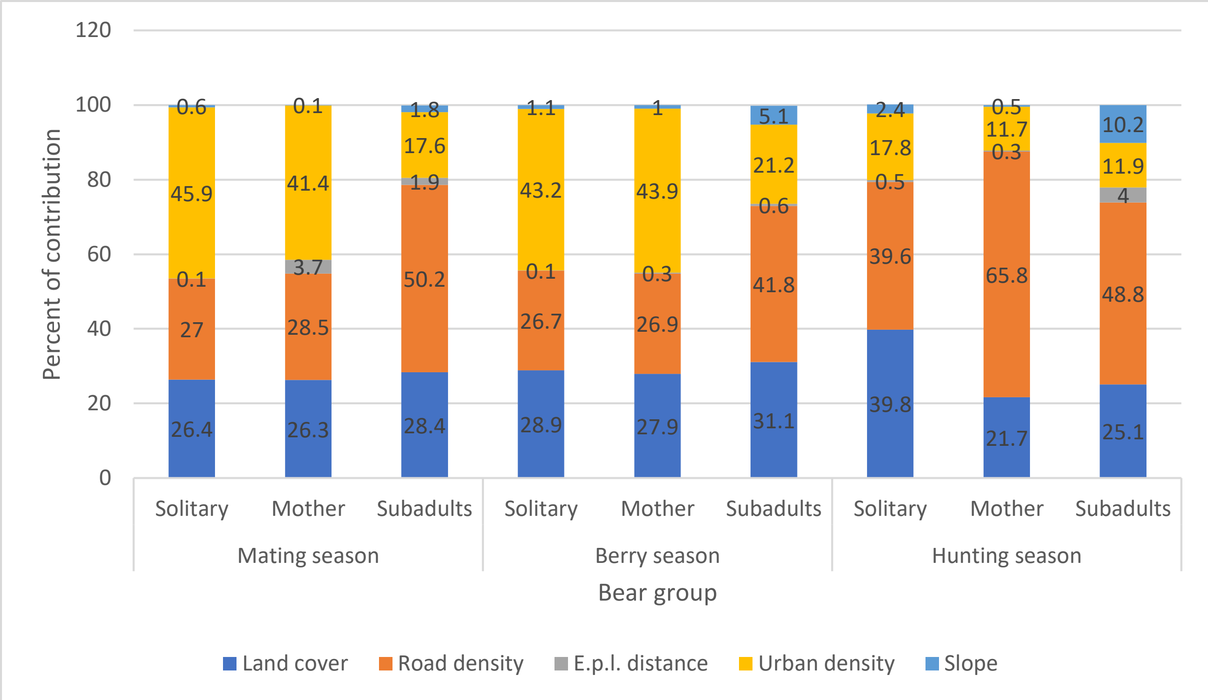


Figure 2. Contribution of variables in relation to the bears' reproductive status and time of the year.

Figure 2 shows that the variable ‘E.p.l distance’ (i.e., distance to electric power line) has little impact on bears’ habitat selection. Still, values for these variables are higher for mother with cub(s) during the mating season (3.7%), subadults during the hunting season (4.0%) and, to a lesser extent, subadults during the mating season (1.9%).

Percentages of permutation, visible in figure 3, indicate that a higher part of the variability is explained by this variable only. With higher values for mothers with cub(s) during the mating season (8.6%), subadults during the mating season (9.0%) and subadults during the hunting season (6.4%).

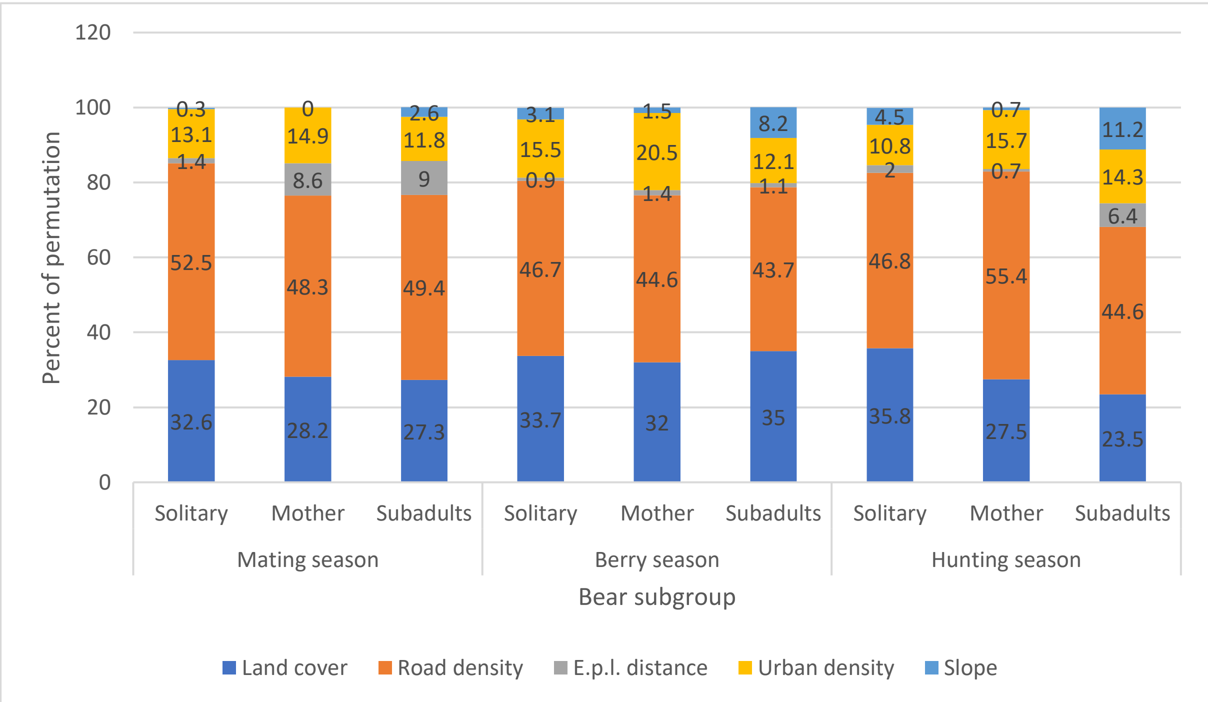


Figure 3. Permutation of variables in relation to the bears' reproductive status and time of the year.

C. Responses of bears in relation to from power lines

The probability of subadults presence, and in a lesser extent mothers with cub(s), always drops within 1 000 m of the power line, with a noticeable peak at 500 m for subadults during the mating season, as shown in Figure 4. By contrast, solitary bears do not seem to be affected by the feature, regardless of the season.

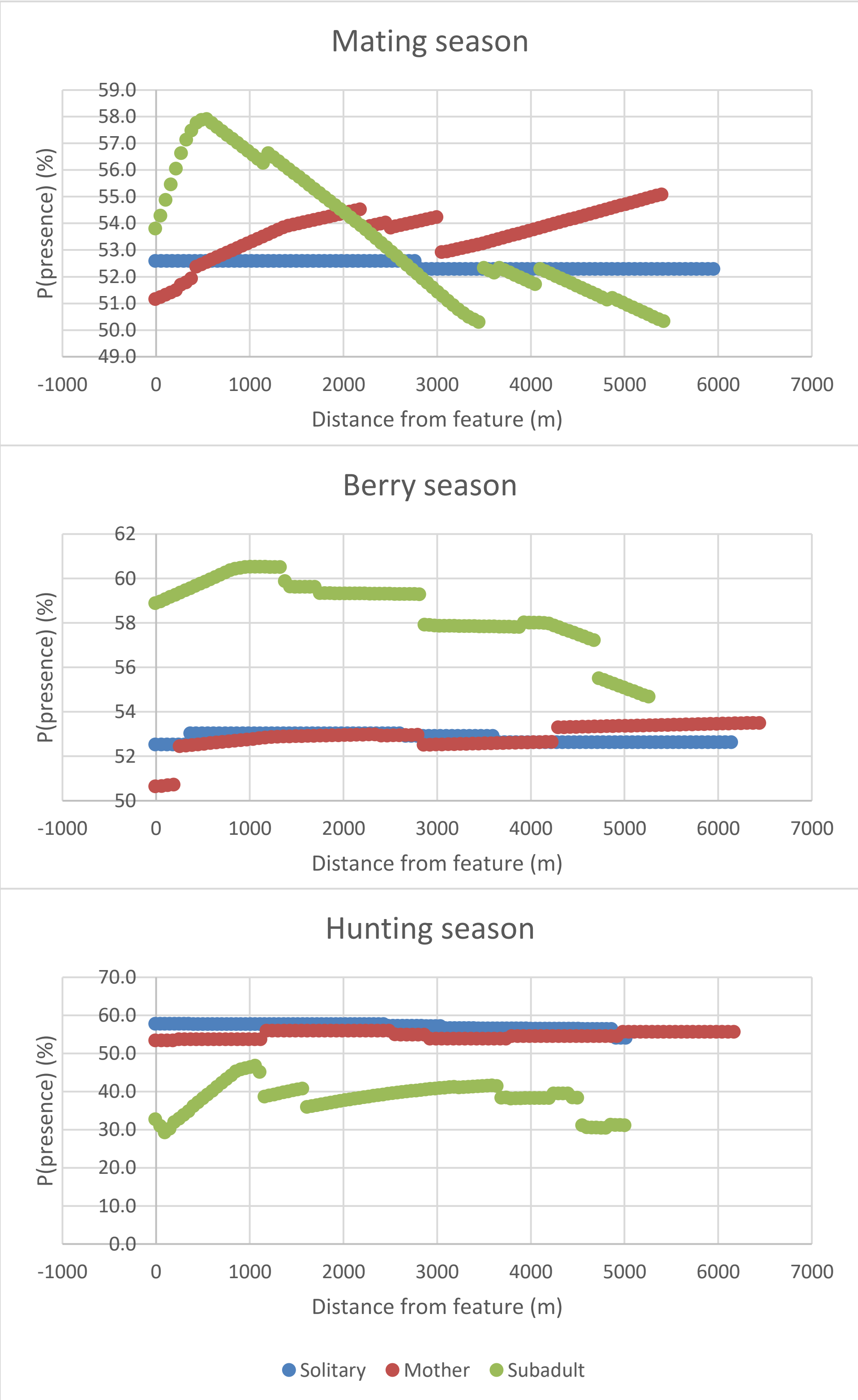


Figure 4. Response curves showing the probability of bear occurrence in relation to the distance from power line.

3.3. Bear movements

A. Results for roads

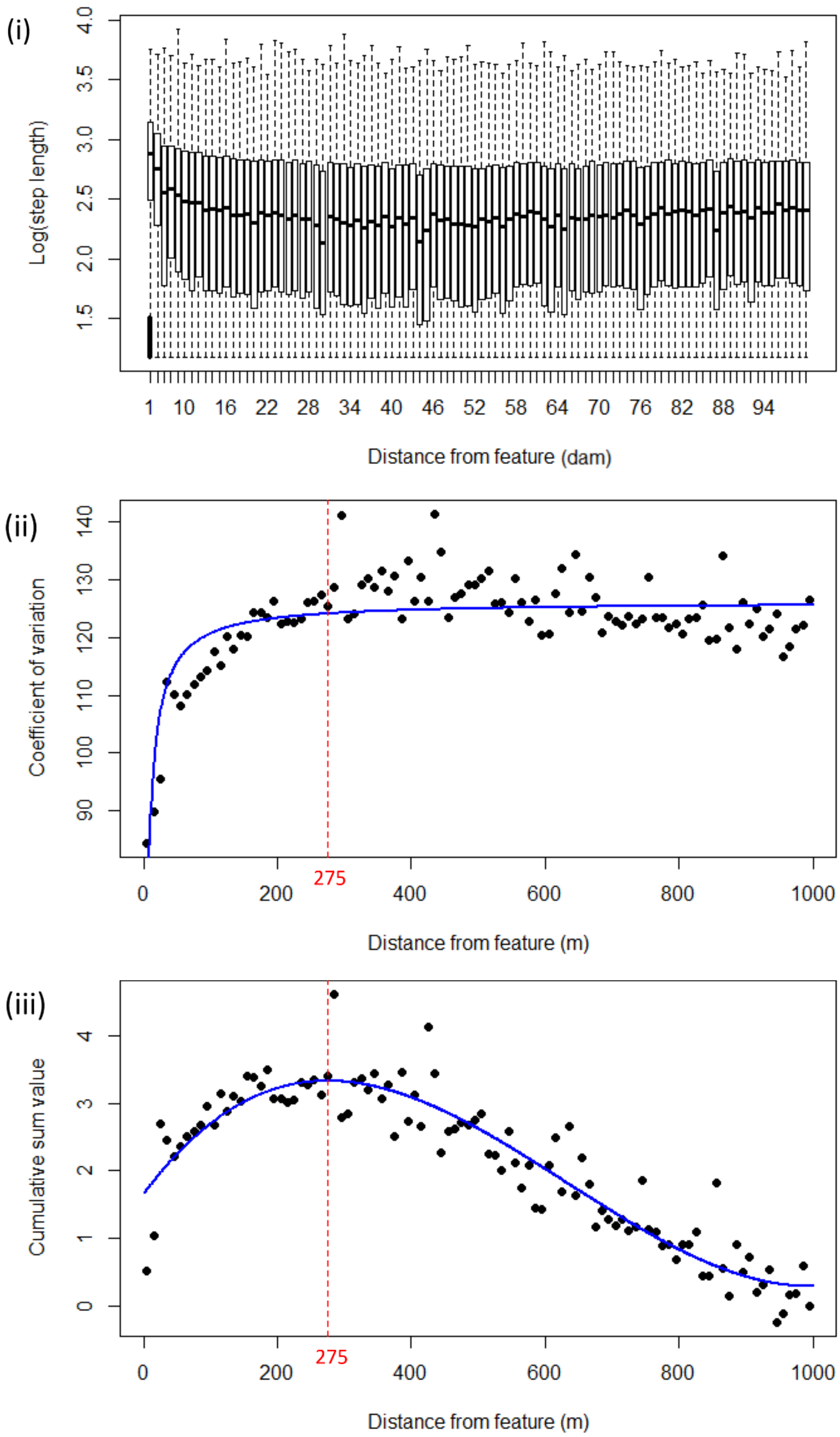


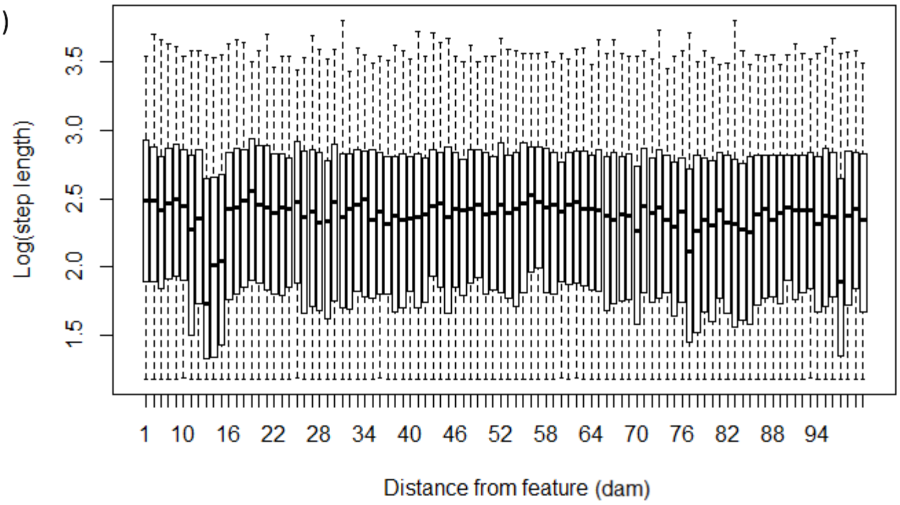
Figure 5. Illustration of the movement analysis (i) Distribution of step length by distance lag relative to road. (ii) The movement parameters in each lag are summarized to a single value using the coefficient of variation and mathematical function is fit to the data to approximate the spatial dependence structure relative to the disturbance feature (fitted line equation $y = 126.164*(1-1/(1+0.22146* x))$, adjusted R^2 =78.1%). (iii) The spatial scale of response is determined using the cumulative sum of differences between the slope value for a given lag, and the average slope across all lags (fitted line equation: $y=1.652 + 0.01343 x - 0.000031 x^2 + 0.0000001 x^3$, adjusted R^2 = 87.2%). The maximum cumulative sum value is selected as the response scale (275m).

I found that bears' speed dramatically increases (more than three times the average speed) as they closer to roads, see Figure 5 (i). Figure 5 (ii) shows a sharp drop of CV values as bears get closer to the roads, indicating a shift of trend in movement rates. Figure 5 (iii) shows a maximum cumulative sum value at 275 m from the roads, which is hence the response scale of roads.

B. Results for power lines

Bears' speed trend does not change as they closer to power lines, as shown in Figure 6 (i). Figure 6 (ii) shows no trend in the evolution of CV values as bears get closer to the power lines, indicating no consistent trend in movement rates. The graph showing the maximum cumulative sum value in relation to distance from the power lines was not produced because of the lack of trend in figure 6 (ii).

(i)



(ii)

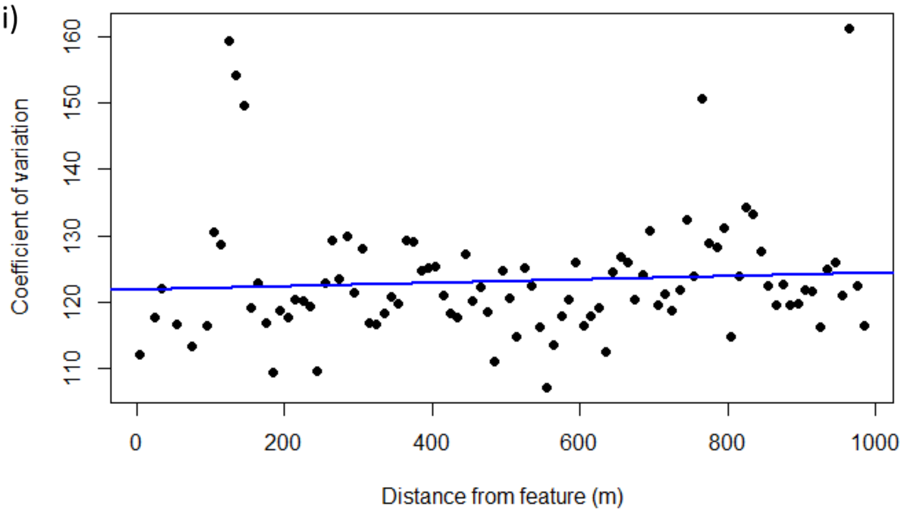


Figure 6. (i) Distribution of step length by distance lag relative to power line. (ii) The movement parameters in each lag are summarized to a single value using the coefficient of variation and a regression line is fit to the data to approximate the spatial dependence structure relative to the disturbance feature (R^2=0.005).

3.4. Multiple linear regression

The multiple linear regression model was applied on the whole data set, then on each bear group and summarized in tables 4, 5 and 6. A negative estimate indicates that the value for the speed (response variable) increases as bears get closer to the linear features and a positive estimate indicates that the value for speed decrease. Table 4 shows that bears' speed decreases when they get closer to roads (solitary bears and mothers with cubs) and closer to electric power lines (solitary bears and subadults) during the mating season. For the other variables, e.g. such as land cover, a positive estimate suggests that bears select for the specific habitat since slower movement are associated with foraging behaviour.

Table 4. Summaries of restricted maximum likelihood and ANOVA for the mating season.

Summary REML	Mating season			All bears x all seasons
Variables	Solitary	Mothers	Subadults	
Distance to power line (1st degree)	***		***	***
Distance to power line (2nd degree)	***	***	*	
Distance to road (1st degree)	**	***		***
Distance to road (2nd degree)	***	***	*	***
Landcover 1: deciduous forest				
Landcover 2: young coniferous forest		**		
Landcover 3: mid-aged coniferous forest		**	.	
Landcover 4: old coniferous forest		*	*	
Landcover 5: mixed forest			*	**
Landcover 6: bogs	*	**		***
Landcover 7: open areas				***
Landcover 8: bare soil				
Landcover 9: water		***		**
Landcover 10: urban area				
Slope	*	***	***	***
Urban density	*		*	**

Summary ANOVA	Mating season			All bears x all seasons
Variables	Solitary	Mothers	Subadults	
Distance to power line	***	***	***	***
Distance to road	***	***	***	***
Land cover	***	***	***	***
Slope	*	***	***	***
Urban density	***		**	**

P value signification codes : '***' = 0.001 '**' = 0.01 '*' = 0.05 '.' = 0.1 ' ' = 1

Sign of estimates: Positive Negative

The bears' speed increases when they get closer to roads (solitary bears and subadults) and decreases as subadults approach electric power lines during the berry season, as shown in table 5.

Table 5. Summaries of restricted maximum likelihood and ANOVA for the berry season.

Summary REML	Berry season			All bears x all seasons
Variables	Solitary	Mothers	Subadults	
Distance to power line (1st degree)			*	***
Distance to power line (2nd degree)				
Distance to road (1st degree)	***		*	***
Distance to road (2nd degree)	***			***
Landcover 1: deciduous forest				
Landcover 2: young coniferous forest			*	
Landcover 3: mid-aged coniferous forest	.			
Landcover 4: old coniferous forest	.			
Landcover 5: mixed forest				**
Landcover 6: bogs	*		***	***
Landcover 7: open areas	*	.		***
Landcover 8: bare soil				
Landcover 9: water	**			**
Landcover 10: urban area				
Slope	***	.		***
Urban density			.	**

Summary ANOVA	Berry season			All bears x all seasons
Variables	Solitary	Mothers	Subadults	
Distance to power line			*	***
Distance to road	***		.	***
Land cover	***	***	***	***
Slope	***	.		***
Urban density			.	**

P value signification codes : '***' = 0.001 '**' = 0.01 '*' = 0.05 '.' = 0.1 ' ' = 1

Sign of estimates: Positive Negative

Table 6 shows that bears' speed increases when they get closer to roads (solitary bears) and increases as subadults approach electric power lines during the hunting season. The few number of significant variables may be due to the lower number of locations for this season.

Table 6. Summaries of restricted maximum likelihood and ANOVA for the hunting season.

Summary REML	Hunting season			All bears x all seasons
Variables	Solitary	Mothers	Subadults	
Distance to power line (1st degree)			***	***
Distance to power line (2nd degree)			**	
Distance to road (1st degree)	**			***
Distance to road (2nd degree)	***	*		***
Landcover 1: deciduous forest				
Landcover 2: young coniferous forest				
Landcover 3: mid-aged coniferous forest				
Landcover 4: old coniferous forest				
Landcover 5: mixed forest				**
Landcover 6: bogs			*	***
Landcover 7: open areas				***
Landcover 8: bare soil				
Landcover 9: water				**
Landcover 10: urban area				
Slope		*		***
Urban density		*		**

Summary ANOVA	Hunting season			All bears x all seasons
Variables	Solitary	Mothers	Subadults	
Distance to power line			***	***
Distance to road	***	*		***
Land cover	**	***	.	***
Slope		*		***
Urban density		*		**

P value signification codes : '***' = 0.001 '**' = 0.01 '*' = 0.05 '.' = 0.1 ' ' = 1

Sign of estimates: Positive Negative

4. Discussion

My research provided three key findings. First, habitat selection modelling showed relatively little influence of power lines on bear behaviour (H1), although power lines explained a greater part of variation in habitat selection for specific reproductive classes and seasons. Those were: mothers with cub(s) during the mating season and subadults during the mating and hunting seasons.

Second, power lines generally appeared to have little influence on the movement behaviour of brown bears (H2), as there was no clear trend in the coefficient of variation in bear movement speed in relation to distance to power lines. In contrast, the illustrative example with roads showed a clear speed increase and behaviour consistency in proximity, up to 275 metres from the feature.

Third, when focusing on the movement behaviour of specific reproductive classes and seasons (H3), power lines appeared to affect subadults during every season and solitary bears during the mating season. Solitary bears appeared to increase their movement rates near power lines during the mating season whereas subadults did the same during the mating and hunting seasons, but appeared to decrease their movement rates during the berry season.

A. Power lines influence on brown bear's habitat selection behaviour (H1)

Differences among species in habitat selection is one of the principal reason allowing them to coexist (Rosenzweig 1981). These differential behaviours are possible because of variation in time and space across landscapes and within habitat patches (Southwood 2017). Behaviour, population density and distribution are directly affected by habitat selection (Rosenzweig 1981) with the spatial distribution of food resources being one of the main underlying cause (McNamara & Houston 1985). Higher quality habitats are usually assumed to increase fitness at a given density, as well as higher densities of animals than poorer patches (Ciarniello et al. 2007). In addition to foraging strategies, studies have shown that avoidance of predation risk can alter habitat selection (Resetarits 2005). Ecology of fear theory indicates that predators can have a greater environmental significance than their number or biomass would suggest. Due to the perceived threat of predator, prey alter their behaviour by dedicating energy to maintaining a constant vigilance and keeping open avenues of escape. Consequently, prey tend to forage in less sensitive habitats, even if the quality of food resource declines (Brown et al. 1999). The brown bear is a good example of natural top predator that lost its apex role to humans (Steyaert et al. 2016). Consequently, the species adopts temporal allocation of antipredator responses towards human footprint (i.e. landscape variables associated with humans) (Hertel et al. 2016).

Electric power lines are characterized by both potential human disturbance and good foraging opportunities. Maxent habitat selection modelling indicated higher influence of power lines for mother with cub(s) during the mating season, subadults during the hunting season (4.0%) and, to a lesser extent, subadults during the mating season (1.9%). Maxent response curves should be interpreted with caution as qualitative insights into bear presence probability rather than proof of a specific habitat selection behaviour. However, we observe that probability of presence of subadults, and to a lesser extent mothers with cub(s), always drops within 1 000 metres of the power lines. In contrast, solitary bears do not seem to be affected at all by the features, regardless of the season. Although it is not a prior goal of this study, figures 2 et 3 show that throughout all seasons the variable 'urban density' matters less to subadults than it does to more older bears, showing evidence of naïve behaviour around human settlements (Elfström et al. 2014). Also, the locations of every group of bears is much more impacted by the variable 'road density' during the hunting season. A quick look to the response curve of the variable shows a trend of avoidance of roads during this dangerous period. These results, confronted with the existing literature, can be used to refine already known hypotheses and formulate new ones.

B. Power lines influence on brown bear movement behaviour (H2)

Animals adopt behaviours affecting survival and reproduction in response to environmental and biological process, and these behaviours can be expressed by movement patterns (Thiebault & Tremblay 2013). Telemetry data allows researcher to study these movement patterns and connect them to specific behaviours (Fleming et al. 2014). When processes are not random, consistent patterns can be observed and can be used as suggestive evidence for developing and testing hypotheses about the biological and ecological processes influencing wildlife movement (Kite et al. 2016). Furthermore, when movement patterns are different in the vicinity of certain landscape features, these hypotheses can be refined.

The movement analysis improves upon the use of a subjective threshold by using a pattern-based approach to identify the spatial scales at which animal movements are influenced, 275 m for roads in my case. This response scale helps to refine research on the underlying processes influencing animal movement (Getis & Boots 1978). Therefore, researchers could improve data treatment for management of wildlife in areas impacted by humans, by generalizing the use of this method to a set of species and features.

Transportation networks influence movements in populations of large and highly mobile species such as the brown bear because roads are used in a predictable or unpredictable way by humans, which can pose a danger or risk to wildlife including bears (Bischof et al. 2017). Consequently, roads are generally avoided by bears in Scandinavia. High road densities have been associated with high grizzly bear mortality rates in west-central Alberta, Canada (Graham et al. 2010) and a maximum response scale to road of 90 metres was estimated, with suspicion of underestimation due to the limited data available on traffic volumes for the study area (Kite et al. 2016).

Effects of a human structures can be very different depending on the species and the feature considered as illustrated in this report. Power lines were compared to roads, and while the first type of feature influenced bear movement so little that I could not determine a response scale or a general trend in speed modification, the second type of feature showed a response scale of 275 m and a sharp increase in speed. Elements of explanation could be that substantial differences exist between those two features, as power lines are not dangerous to pass under and their existence does not automatically facilitate human use (Nellemann et al. 2001) whereas road causes bear mortality and facilitate human ingress within bear habitat (Graham et al. 2010). In addition to this relative safety and tranquillity for bears, power lines constitute an attractive habitat for foraging. For example, Grizzly bear showed heavy use of a pipeline and power line corridor in British Columbia (Canada) because those corridors were among the first areas providing good foraging conditions for bears in spring (Ciarniello et al. 2007).

C. Variation among reproductive classes and seasons of the influence of power lines on brown bear movement behaviour (H3)

As brown bear are very versatile species, zooming in on reproductive classes and seasons showed how critical it is in brown bear research to not look only at general patterns. Adult brown bears dominate in high-quality habitats (e.g. high food availability/quality and low disturbance) whereas females with young and/or subadult individuals are more often reported in low-quality habitats, providing a good example of the despotic behaviour of dominant conspecifics (Elfström et al. 2014). Solitary males and females increase their movement patterns during the mating season when they roam widely to find mates (Steyaert et al. 2012), whereas females with cubs-of-the-year select their resources in less rugged landscapes, more open habitat types, and often in a relative close proximity to certain human-related features (Steyaert et al. 2013). Since the results showed a general avoidance and no distinct trend between solitary bears and mothers with cub(s), it would be risky to conclude that power lines corridors are high- or low-quality habitats for brown bears.

Dispersal in brown bear populations occurs during the mating season and is sex-biased as well, as juvenile males disperse on longer distances from their mothers' home ranges while most of the females establish their breeding home ranges close to their natal areas. Bear populations expansion needs undisturbed corridors to convey migrating bears (Nellemann et al. 2007). The multiple linear regression showed that subadults' speed increased as they got closer to the power lines and so did the movement analysis, with in addition a decrease in CV values, indicating a change in movement pattern (see figure 9 in section 2 of the appendix). This could suggest that subadults could use power line corridors as travel for dispersal and further research (for example, analysis of turning angles) could unveil the type of behaviour adopted by the young bears. Moreover, it was demonstrated that bears forage most selectively in mature forests and on clearcuts because of berry foraging, which is characterized by slow and meandering movements (Hertel et al. 2016). Results of the multiple regression support this theory as subadult bears' speed decreased near power lines during the berry season.

The results suggest that while most bears did not select for power line corridors, subadults foraged these open areas during the berry season. We can assume that young bears have therefore a different sensitivity to the food availability/quality - disturbance equilibrium than their conspecifics.

D. Methodological issues & perspectives

To improve the study of impacts of power lines, further research should assess how turning angles, in addition to step lengths, vary when bear get closer to the power lines. This could deliver new insight on how bears use the feature (e.g. crossing vs traveling alongside). Another way to study the type of behaviour bears adopts when they cross power line would be to examine how their step length varies on a circadian timescale, with individuals equipped with GPS-collar delivering positions at higher frequencies. It would allow researchers to understand how brown bears adjust their daily movement patterns in response to power lines (Moe et al. 2007).

Since a response scale towards power lines could not be determined, another way to run a resource selection function (RSF) or habitat selection modelling with Maxent would be to create a land cover class 'power line' whose width would be defined using other indicators than bear changes in movement pattern (such as sunlight incidence, plant communities, etc). It would enable researchers to determine whether brown bear select or avoid this habitat, or confirm a neutral impact suggested by this report. These methods could also possibly be improved using additional variables (meteorological, environmental and humans) if they were proven to enhance model quality.

Since the biggest disturbance at a local scale does not seem to be the power lines, further research should rather focus on the study of the impact of wind farm construction. Such study can be conducted with direct measures of fitness (survival, reproduction, population growth), by observing how these evolve with the installation of a wind park and its road network, as well as the additional network of power lines (higher densities of power lines near the production site than in the forest). Collecting such data on large carnivores is difficult but it is the most reliable method for understanding the effects human features on habitat quality for animals (Reynolds-Hogland & Mitchell 2007). Luckily the Scandinavian Brown Bear Research Project already has this kind of data in abundance since a long time, to use as a frame of reference. For less fortunate groups of research, an alternative consists in conducting the same type of study only with indirect measure of fitness (such as home range and habitat selection). In such case, the Maxent package or other habitat selection methods could be used to check whether habitat selection changed after the construction of the wind parks and if the bears' responses to human features has changed.

E. Management implications

Should further research discover a degradation of habitat quality for brown bears and other wildlife species, it would be an additional reason for the authorities to promote or to impose electricity companies countervailing measures. Indeed, the development of new corridors within wildlife habitat should be minimized and existing corridors should be made unsuitable as travel routes to reduce the impacts of human development. Avoidance of human-impacted areas by large carnivore can lead to changes in prey behaviour, the latest using humans as shelter against predation (Ripple & Beschta 2004; Laundré et al. 2010). The ecological role of large carnivores, is therefore reduced and local over-abundance of prey can occur (Hebblewhite et al. 2005; Berger 2007; Hebblewhite and Merrill 2008). Ungulate herbivory causes major changes in plant community composition and structure, leading to the dominance of unpalatable, chemically defended plant species in communities (Augustine & Mcnaughton 1998). Additionally, ungulates such as moose (*Alces Alces*), deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) damage trees and lower timber quality during browsing and marking behaviour (bark stripping and fraying) (Edenius et al. 2002; Gill 1992) causing loss of profit for forestry companies.

One way to reduce the potential impacts of overhead power lines could be adapting the clearcuts under the feature into "green corridors". Hence, Svenska kraftnät (the authority responsible for Sweden's transmission system for electricity) could, instead of regular maintenance by shredder, instore edge areas between the corridor and the forest: plant a procession of sizable trees from a variety of species and leaving deadwood on the ground. These edge areas slow down the growth of taller trees (in this case mostly pine, spruce and birch) and can reduce the damages to the nearby trees caused by the wind and brings a whole range meadow flower, insect, mammal and bird species (LIFE Elia, 2011-2017). The brown bear and the communities of plant and animal that it affects could potentially benefit from that increase in biodiversity too.

5. Conclusions

The Maxent modelling demonstrated that power lines have relatively little influence on bear habitat selection behaviour, with variation for specific reproductive classes and seasons. The movement analysis, based on the spatial scales at which consistency in movement patterns is observed in relation to anthropogenic disturbance features, defined a value of proximity for roads (275m) but failed to do the same with power lines. While these values should help supporting the development of more complex ecological questions regarding bear movement, further research based on the analysis of turning angles and circadian movements should improve our understanding of the effects of power lines on brown bear behaviour. Identifying these responses scales could be used to facilitate the integration of telemetry and landscape data by refining parameters in resource selection functions, or by guiding a more in-depth analysis of the processes influencing animal behaviour relative to specific features. Moreover, decision-makers would have access to maps showing the location and extend of areas where wildlife is disturbed. And wildlife management is typically operationalized at the landscape level hence the importance of conducting research at an appropriate scale.

In the context of brown bear reactions and behaviours relative to power lines, some management strategies may include, besides minimizing the development of power lines in bear habitat, making electric transmission lines unsuitable as travel routes to reduce the impacts of human development and restore the edge areas between the corridor and the forest.

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