# How Does Habitat Selection by Brown Bear (*Ursus arctos*) during the Berry Season Change due to Forestry and Human Disturbance

– looking at three different periods of human disturbances

*Hur påverkar skogsbruket och människor brunbjörnens habitatutnyttjande under bär säsongen*
*– Under tre olika perioder av mänsklig påverkan*

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## Abstract

Brown bear (Ursus arctos) is the most widespread large carnivore. It is an apex predator and does not have natural enemies but is hunted by humans in Sweden. During the period July to October their main food resource is bilberry, which contains carbohydrates that are important for their fat resources before entering hibernation. In Sweden, brown bears occur in both managed and non-managed forests, some management practices such as clear-cut have a large impact on the bilberry occurrence. This study looked at how brown bears changed their diurnal habitat selection before, after, and during the bear hunt. Furthermore, I studied how forest management affects bears habitat selection with bilberry as an index. I had position data for 106 female brown bears, the study area was placed in mid-central Sweden, and I used forest information such as age, thinning year, and habitat classes. I fitted an iSSF (integrated step selection function) to analyze brown bear habitat selection. I found that there was a difference between their habitat selection due to human presence and forestry in the different periods, before, during, and after the hunt. During the day there was no difference in habitat use between the three periods except for before hunt during the day were the bears selected for deciduous forests over pine. During the night there was a difference for the forests that had been clear-cut for 6-30 years ago, for all periods. These changes could be due to human presence during the day, resulting in bears selected for these areas during the night becoming more nocturnal. Thinning of the forest influenced the habitat selection of brown bears, during the hunt bears selected thinned forest over pine during the night, but less before the hunt during the day and after the hunt both day and night. Clear-cuts influenced the bear habitat selection and differed between the periods and whether it was day or night. The most common difference compared to pine was that those areas that had been clear-cut were used less than pine, except during the hunt during the night and after the hunt during the night where they were selected more in comparison.



*Keywords:* Brown bear, *Ursus arctos*, Integrated step selection function, habitat selection

## Sammanfattning

Brunbjörnen (Ursus arctos) är det rovdjur som är mest utbredd. Det är en toppredator och har inga naturliga fiender utom att det i Sverige bedrivs årlig björnjakt. Under perioden juli till oktober består björnarnas främsta föda av blåbär, som innehåller kolhydrater som är viktigt för deras fettreserver innan de går i ide. I Sverige förekommer brunbjörnen i både förvaltad skog och orörd skogsmark, några av skogsåtgärderna har en stor påverkan på blåbärs förekomst. I denna studie undersökte jag hur björnarna ändrade sitt habitatutnyttjande mellan dag och natt samt innan, efter och under björnjakten. Jag undersökte även hur skogsförvaltning påverkade habitatutnyttjande med blåbärs förekomst som index. Jag hade positionsdata från 106 björnhonor, studieområdet var placerad i centrala Sverige, och jag använde skoglig information som ålder, gallringsår och habitatklasser. Jag gjorde en iSSF (integrated step selection function) för att analysera björnarnas habitatutnyttjande. Jag hittade att det var en skillnad mellan habitatutnyttjandet kopplat till människans närvaro eller skogsbruket under de olika perioderna innan, under och efter björnjakten. Under dagen fanns det ingen skillnad i habitatutnyttjandet mellan de olika perioderna, med undantag från innan jakten där björnarna valde lövskog över tall. Under natten fanns det en skillnad för skogarna som hade blivit avverkade för mellan 6–30 år sedan, under alla perioder. Dessa förändringar kan vara på grund av människonärvaro under dagen och björnarna föredrar dessa habitat under natten och blir mer nattaktiva. Gallring av skogen påverkade björnarnas habitatutnyttjande under jakten föredrog de gallrad skog över tall då det var natt. Före jakten under dagen och efter jakten både under dagen och natten föredrog de gallrad skog mindre än tall. Avverkningarna påverkade björnarnas habitatutnyttjande och det fanns en skillnad mellan perioderna och om det var dag eller natt. Den mest förekommande skillnaden var att områdena som varit avverkade utnyttjades mindre än tall, förutom under jakten och efter jakten under nätterna när dessa områden var utnyttjade mer än tall.



*Keywords:* Brown bear, *Ursus arctos*, Integrated step selection function, habitat selection

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# Abbreviations

| | |
|---|---|
| SSF | Step selection function |
| iSSF | Integrated step selection function |

# 1. Introduction

Humans can have a negative impact on large carnivores due to competition between human interests, which complicates the conservation of these species. Historically, large carnivore populations have been reduced but have started to increase over the past decades in Europe where Fennoscandia is considered a hot spot. Furthermore, the brown bear *(Ursus arctos)* is one of the most common large carnivore in this area (Chapron et al. 2014). The brown bear is also one of the large carnivore species that is the most widespread (Bojarska & Selva 2012). Carnivores helps to maintain ecosystem diversity and affect the occurrence of prey species such as moose *(Alces alces)* (Tammeleht et al. 2020). Brown bears help to induce top-down effects on prey species (Niedziałkowska et al. 2019), although they have a low mortality impact on yearling and adult moose in Sweden (Dahle et al. 2013).

The brown bear does not have any natural predators, except for humans and is therefore considered an apex predator (Hertel et al. 2016b). They appear to be more active during the mornings and the evenings, thereby showing a diurnal activity pattern (Hertel et al. 2017). In Sweden, the brown bear occurs in the middle and northern parts of the country in the boreal forests (Sverige & Naturvårdsverket 2016). They use sheltered habitats with an opportunity for a good food recourse and occur in both human managed forests and forests that are not altered by humans such as natural forests (*Bears of the world: ecology, conservation and management* 2020). According to SCB (Statistical Central Bureau), approximately 15% of the Swedish forests are protected (Hedeklint 2021). Brown bears are omnivores and during late summer and autumn, they have bilberries as their main food resource (Stenset et al. 2016). During this period, bears spend up to 14 hours a day foraging (Hertel et al. 2016a). Bilberries contain a high amount of carbohydrates and provide fat resources before entering hibernation (Hertel et al. 2018). During years with a low abundance of bilberry, bears have lower reproductive success and the weight of the cubs is significantly lower than during years of high bilberry abundance (Stenset et al. 2016; Hertel et al. 2018). Female brown bears could compensate for the years with low bilberry abundance and low reproductive success in years with high bilberry abundance (Hertel et al. 2018). Brown bears select their home rage in areas with a higher probability of bilberry occurrence (Martin et al. 2010). Furthermore, bilberry abundance is affected by forest management (Hertel et al. 2016a).

In Sweden, the forest management is clear-cut based with a large impact on bilberry production. During the clear-cutting of the forest, the bilberry abundance is heavily decreased due to disturbances of the surface (Kardell & Eriksson 2011). Bilberry plants are sensitive to high light exposure and drought (Tonteri et al. 2016), but also the risk of freezing (Kardell & Eriksson 2011). To prepare the soil for replantation, different scarification methods are used, which often damage the roots of the bilberry plants and create a decrease in abundance (Colton et al. 2021). Bilberries are also less abundant in young forests (Eldegard et al. 2019). The plants are slowly starting to recover as the canopy starts to close (Kardell & Eriksson 2011; Colton et al. 2021). When the canopy is closed, the amount of bilberry produced is reduced due to lack of light but starts to increase after a thinning when the canopy opens. The higher amount of light increases, bilberry production and provides a food resource for the brown bear (Colton et al. 2021). There is a difference in bilberry abundance when it comes to different types of forests and berries occur in lower abundance in deciduous forests compared to spruce or pine forests, and the abundance is also increasing with the forest age (Eldegard et al. 2019).

There have been previous studies looking at forest age and brown bear habitat selection. In a study made in Clear Hills and Western Alberta, the authors show that bears used young stand the least (age 7-10) and stands in the age of 30-40. They found that the optimal habitat was middle age stand in the age of 10-30 (Colton et al. 2021).

Brown bears are also affected by other disturbances than forest management. In Sweden, brown bears also have a recreational value such as game. The history of bear hunting goes back 80 years, and today it is usually done by baying hunting dogs that mark the position of the bear. Bear hunting is starting to increase as a recreational value (Le Grand et al. 2019), and the hunting period collides with the time that the bear starts to increase its berry intake before hibernation (Hertel et al. 2016b). This can lead to bears selecting areas with lower food abundance to lower their mortality risk, for example, avoiding open forests that would provide more food (Hertel et al. 2016b). Females that had a lower food intake during this period risk having a lower body mass together with their yearlings (Hertel et al. 2016a). Although bears recreational value has increased, some people have a fear of bears, asking for management measures to reduce this conflict (Moen et al. 2012; Støen et al. 2018). For example, there are recommendations for people working in the forest or using the forest for recreational value such as berry picking to make noise or avoid dense stands (Støen et al. 2018).

Previous studies have shown that brown bears are more affected by hunting than by human encounters (Le Grand et al. 2019). They change their foraging patterns to

avoid human encounters during the high-risk periods of the day and do not compensate for the loss of the foraging. Bears with a better condition can change their foraging pattern and compensate for the loss easier than those with a poor condition (Hertel et al. 2016b). Furthermore, they avoid areas where there is a chance to encounter humans and use more remote areas (Hertel et al. 2016b). When the brown bear population is starting to increase even more, brown bears become almost forced to have habitats close to humans and human settlements (Martin et al. 2010). Specifically, they are affected by habitat loss due to forestry and the increase of infrastructure (Nellemann et al. 2007), which makes it difficult for bears to avoid humans since humans are everywhere (Martin et al. 2010). Several studies have looked at how the bear uses areas with high human presence and in several cases the brown bear avoids these areas or flees upon approach (Nellemann et al. 2007; Martin et al. 2010; Moen et al. 2012).

The large impact that forest management has on the brown bear habitats, together with the increased human disturbance in form of activities (e.g., hunting and berry picking) makes it interesting to investigate how brown bears adapt their behavior to these changes. The study will focus on the selection for different habitat classes by the brown bear in relation to previous forest management and human impact. I will address the following questions.

- How does forest management affect the forest stand utilization by brown bears as an index of bilberry occurrence?
- Do bears change their diurnal habitat use before, after, and during hunt during their active time of the day?

# 2. Material and Method

## 2.1. Study area

The study area covers Dalarna county and Gävleborg county in midcentral Sweden (Hertel et al. 2016b) and is placed in the taiga (Swenson et al. 1999). Both counties have forests dominated by forest management and the field layer is dominated by bilberries (*Vaccinium myrtillus*), lingonberries (*Vaccinium vitis-idaea*), and crowberries *(Empetrum hermaphoditium*) (Hertel et al. 2016b). The main tree species are Scots pine *(Pinus sylvestris)*, Norway spruce *(Picea abies),* and some deciduous trees, for example, birch *(Betula pubescens),* and aspen *(Populus tremula)* (Swenson et al. 1999). The climate varies depending on the season (Swenson et al. 1999). In the winter, the mean temperature in Dalarna county is -7 degrees Celsius and during it is summer 13 degrees Celsius (Sjökvist et al. u.å.). In Gävleborg county, the mean temperature is -7 degrees Celsius in the winter and during summer it is 14 degrees Celsius (Nylén et al. u.å.). Snow cover lasts from October to May or around 170 days of the year (Swenson et al. 1999). The bilberry in Scandinavia starts to flower during the spring in May and starts to produce berries during June – July (Hertel et al. 2018).


*Figure 1: Map over the Swedish counties with the study area marked in a square. Copyright © Hans Högman 2020-07-03*

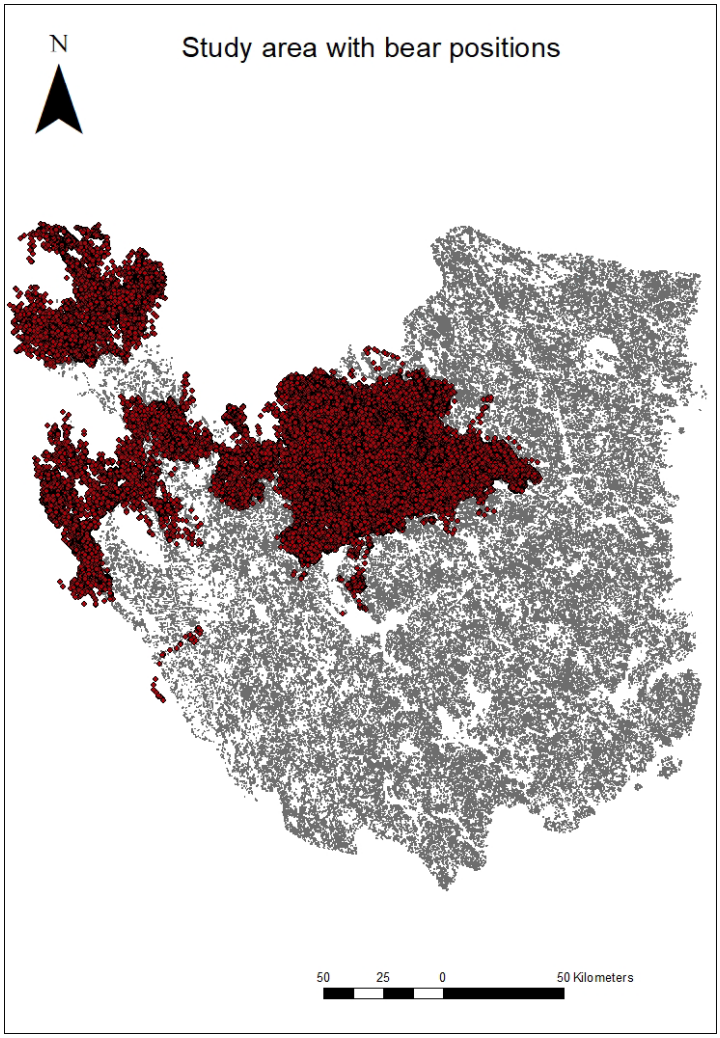


*Figure 2: Map over the study area with bear positions (red points)*

For the year 2021, the annual bear hunt for the study area started on the 21st of August (Cambronero 2021; Dickson 2021). In Gävleborg county, it was allowed to hunt a total of 70 bears in 2021 (Cambronero 2021), while in Dalarna county the quota was set to 48 bears in 2021 (Dickson 2021). The bear hunt lasts until the 15th of October or until the bear licenses are filled. Hunting bears is allowed to be done with a maximum of two dogs and only people with hunting rights are allowed to hunt on the hunting ground (Cambronero 2021; Dickson 2021).

## 2.2. Preparation of raster data and bear data

First, I updated the land cover map with geospatial information about clear-cuts for the study area between the years 1997 to 2021 received from the Swedish Forest Agency (www.skogsstyrelsen.se downloaded October 3rd, 2021). The geospatial information provided the year of when the clear-cut occurred, the location, and the size. A raster was created with categories for each clear-cut year and was combined with a map of the national ground cover from the Swedish Environmental Protection Agency's (SEPA) (www.naturvardsverket.se downloaded October 3rd, 2021). The ground cover data provided different land cover classes. In the study, I summarized those land cover classes into five habitat classes relevant for bear biology: pine, spruce, mixed, deciduous, and non-forest. The habitat class called non-forest included open land, water, wetland, and human land. I chose to include these forest habitats since the bears prefer sheltered habitats with the possibility for food (*Bears of the world: ecology, conservation and management* 2020), which is provided in these habitat classes except the non-forested areas that do not provide shelter. Furthermore, bilberry prefers areas where it is are not exposed to too much sun (Kardell & Eriksson 2011), which is the risk in the non-forest areas. Bilberry also occurs in higher abundance in pine and spruce forests compared to deciduous forests (Eldegard et al. 2019), I therefore expect that there would be a difference in preferences when it comes to those habitat classes.

The forest data provided by Sveaskog, from 1990 until 2021, included information about the age of the different forest stands, their basal area, number of thinnings, the years of the thinning, habitat class, age, and the year it was clear-cut. I used information regarding the thinnings and the year it was clear-cut. I created three classes for the years since clear-cut: 1) clear-cuts six years old or less, 2) clear-cuts 6-15 years old and 3) clear-cuts 15-30 years old. Those intervals were conducted, because usually the regeneration after a clear-cut is done within 6 years, whereas the pre-commercial thinning is done on forest between the age of 5-10 years old (Roberge et al. 2020). I defined those intervals to see how the bears utilized these areas depending on how long ago the clear-cut was, because the clear-cut has a large effect on bilberry occurrence and it takes a long time for it to recover (Kardell & Eriksson 2011). If the clear-cut was older than the bear position within a given pixel, it was classified as a pine forest. I assumed that all clear-cuts were of pine forests, since pine is one of the most common species in the study area, for that reason it was also used as an intercept.

Next, I linked the year of the thinning and the bear position. If the thinning was older than the bear position within a given pixel, it was classified as NA, otherwise, the information of the thinning was used.

The bear data provided by the Scandinavian Brown Bear Project was from 2003 until 2021 and had information about the position of the bear (latitude, longitude), the timestamp when the position was logged (every 30 minutes), the sex of the bear, object id, if the received location was a resting position (bed) or not. The bear data was imported to RStudio (version 1.3.1093). I selected active female bears within the study area (i.e., rejected those positions that were beds), latitude, longitude, and timestamp for the different positions.

Before using the Step Selection Function (SSF), I prepared two data sets for the analysis. One containing the information about the forest stands from Sveaskog, (e.g. thinning year) together with the clear-cut information this data was limited to the forests that Sveaskog owned. The other data set contained only information about the ground cover data and information about clear-cuts and covered the whole study area. Both data sets were prepared and analyzed in the same way.

By selecting whole hour positions and every second hour intervals, I ensured equal time intervals for all bears over the study period. By using the Suncalc (Package suncalc version 0.5.0) function, I categorized each position as day or night according to its timestamp (i.e. whether it was before or after sunrise/ sunset). Each timestamp was also given what Julian day it was. Each bear is identified by a unique ID and only bear individuals with enough steps/GPS positions (steps > 1500) were included in the analysis.

Before starting my analysis, I looked if any of my coefficients were correlated and found that the number of thinning and the thinning year was correlated (p>0,6) and decided to only use the time since last thinning.

All geodata was transformed into the coordinate system SWEREF99.

## 2.3. The analysis in SSF

I applied the Step Selection function (SSF, R package amt version 0.1.4) to analyze the habitat selection by bears over time. In the habitat selection, I extracted covariates (i.e. habitat classes, forest age, time since last thinning, and clear-cut age class) at the end step to receive habitat selection by the brown bear (Signer et al. 2019).

The data was divided into three periods according to bear hunting activity and berry season: 1) before the bear hunt (July 1$^{st}$ until August 20$^{th}$ ) when there is a less human disturbance, hereafter called *before the hunt,* 2) during the bear hunt (August 21$^{st}$, until September 30$^{th}$ ) to see how the human disturbance affects bears' habitat

utilization, hereafter *during the hunt*, and 3) after the bear hunt (during October before denning) to see how bears utilize habitats after the bear hunt, but also when it coincides with moose hunt that starts in the early September (Neumann & Ericsson 2018), hereafter *after the hunt*. Those months were used since that time of the year is when the bears are foraging berries before hibernation (Hertel et al. 2016b). Those periods were also divided into day and night, resulting in a total of six models that were analyzed separately. The bears can change their foraging patterns to avoid humans during periods of the day (Hertel et al. 2016b). The models were divided into these periods to see if the foraging is affected by the bear hunt that occurs in August/September and to see if their diurnal behavior changes over time.

The SSF and iSSF (integrated SSF) analyze animal movements and habitat selections with information about environmental covariates (Signer et al. 2019). Furthermore, it takes the information of the position during a given timestamp to create steps (Thurfjell et al. 2014), which were later paired with five random steps. I analyzed how the different brown bear individuals utilize the different habitat classes over time by fitting a conditional logistic regression, where the binomial response variable was either the observed step or a random step. The explanatory variables described the habitat where a given step ended and consisted of variables such as forest age and time since last thinning. In the data set that included only information from the ground cover, I used a subset of 50% random sampled without replacement of the data set due to computer limitation. I considered a significant difference if the confidence interval of the estimated coefficient was at least two standard errors away, thereby presenting a 5% significance level.

# 3. Results

The number of bears included in the analysis was 106 individual females on the whole data set and 53 for the subset.

## 3.1. Difference in habitat use day and night

This analysis included only the ground cover data, had a 50% subset of the original bear data that showed that there was a difference in habitat selection between day and night in some periods (Figure 3). Female brown bears selected for deciduous forest over pine during the day and 6-15 years old clear-cuts during the night (Fig 3). The female brown bears showed no selection for any of the other habitats other than pine forests.

During the hunt during day, the female brown bears showed no difference in the selection preferences compared to pine forest (Figure 3). During the night, the female bears showed a significant difference in selection for the forest that had been clear-cut for 6-15 years old and 15-30 years old. The female brown bears showed no selection for either of the other habitat other than pine forests.

After the bear hunt, the female bears did not select for any other of the habitat classes compared to pine during the day (Figure 3). In contrast, bears selected more for clear-cuts done 6-15 years ago and 15-30 years ago compared to pine forest during the night. The female brown bears showed no selection for either of the other habitat other than pine forests.

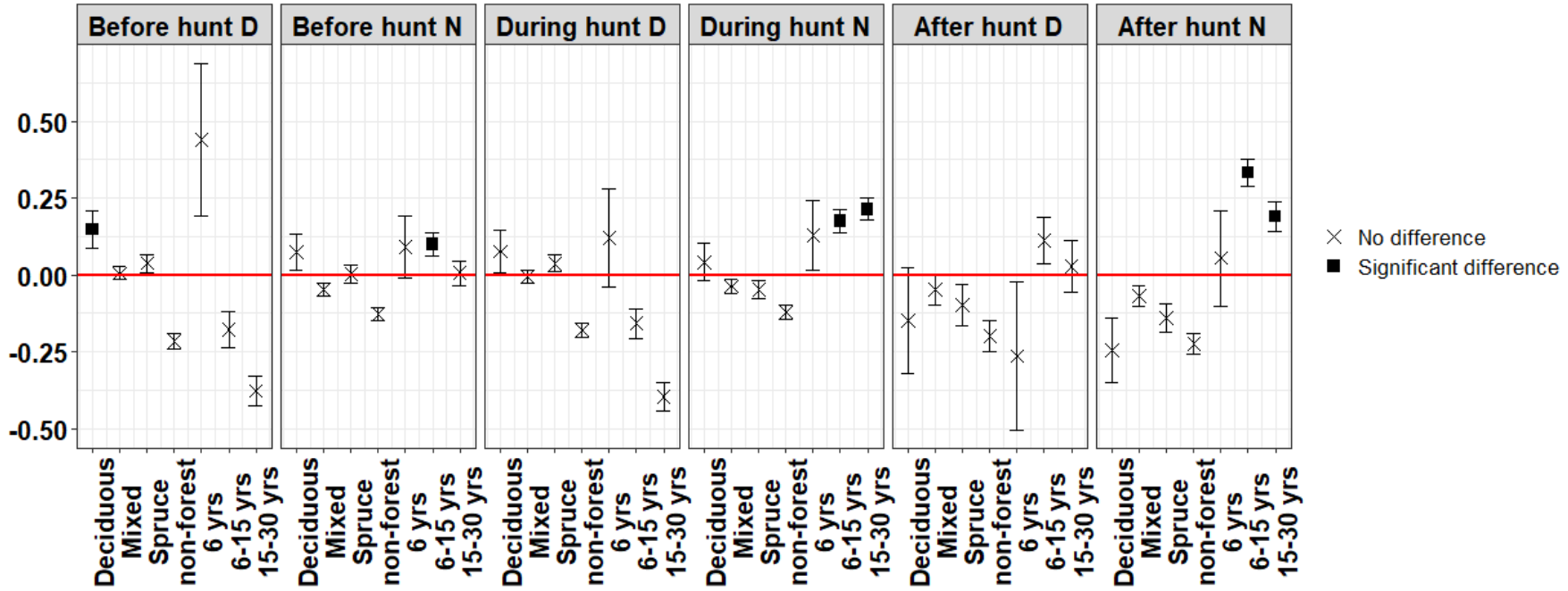


Figure 3: Statistical results given by the Step Selection Function (SSF) on bear habitat selection using only ground cover data and 50% of the data created. Pine as an intercept and showing how the other habitat classes are selected in relation to the intercept. The results are shown for each period before the hunt, during the hunt, and after the hunt, night, and day. 6-years: forests that have been clear-cut within the last six years. 6-15 years: forests that have been clear-cut between 6-15 years ago. 15-30 years: forests that have been clear-cut between 15 and 30 years ago. Before the hunt, July until August 20$^{th}$, during the hunt is from August 21$^{st}$ and September, and after the hunt is during October. Non-forest includes arable land, open land, water, wetland, and human land.

## 3.2. Forest management effect on habitat use

Before the hunt during the night, the brown bears selected mixed forest and non-forested areas significantly less than pine forests (Table 1). Thinning did not have any effect on their utilization nor did forest age or time since clear-cut. In contrast, during the day, the bears selected against both forests that had been clear-cut within six years ago or less and non-forested areas less than pine. There was also a lower selection for the forests that have been thinned.

During the bear hunt during the night, the brown bears selected for mixed forest and non-forested areas less than pine forests (Table 2). While they selected more for forests that were clear-cut within six years ago or less and between 6-15 years ago compared to the pine forest. The brown bears also showed a selection for thinned forest over pine forest. During the day, they selected less of the forest that were six years or younger and non-forested areas compared to the pine forest. The bears showed no selection for thinned forests.

After the bear hunt during the night, the brown bears selected for mixed and spruce forest significantly less than pine forests (Table 3). The bears were also selected for forests that were clear-cut between 6-15 years ago and six years ago less compared to pine forests. Despite this selection, they preferred older forests, the older the more they selected for it. The thinned forests were selected significantly less than pine forests. During the day, the bears selected mixed forests and forests that had been thinned significantly less compared to pine forests.

*Table 1: Statistical results containing the value and direction of the coefficient given by the conditional logistic regression within the Step Selection Function (SSF) to describe female Brown bear habitat selection in central Sweden (bear data from 2003 until 2021). Pine forest as intercept. Standard error, z value, and P-value for the three periods before the bear hunt, during the hunting, and after the hunt, separated into the night, and day. The analysis included only bear position within the forest company land, including a total of 53 female brown bears. Significant difference in bold and 0.00 = < 0,0001*

**Before hunt**

| | **Night** | | | | **Day** | | | |
|---|---|---|---|---|---|---|---|---|
| *Habitat Class* | **Coeff** | **Se** | **Z** | **P** | **Coeff** | **Se** | **Z** | **P** |
| *Deciduous* | -1,9e-01 | 1,6e-01 | -1,18 | 0,24 | 6,1e-2 | 8,3e-2 | 0,74 | 0,46 |
| *Mixed* | -1,7e-01 | 5,5e-02 | -3,13 | **0,00** | -1,4e-2 | 3,2e-2 | -0,45 | 0,64 |
| *Spruce* | 1,8e-2 | 7,6e-2 | 0,23 | 0,82 | 4,5e-2 | 4,3e-2 | 1,05 | 0,29 |
| *6 years* | 3,8e-2 | 6,3e-2 | 0,60 | 0,54 | -4,6e-1 | 5,5e-2 | -8,36 | **0,00** |
| *6-15 years* | 5,9e-2 | 7,2e-2 | 0,82 | 0,41 | -1,2e-1 | 5,3e-2 | -2,27 | **0,00** |
| *15-30 years* | 5,0e-2 | 2,2e-1 | 0,22 | 0,82 | 2,0e-1 | 1,4e-1 | 1,46 | 0,15 |
| *Non-forest* | -2,1e-1 | 4,7e-2 | -4,42 | **0,00** | -2,4e-1 | 3,1e-2 | -7,59 | **0,00** |
| *After Thinning* | 1,6e-6 | 1,9e-5 | 0,09 | 0,93 | -4,6e-5 | 1,2e-5 | -3,83 | **0,00** |
| *Age* | -2,8e-4 | 3,4e-4 | -0,83 | 0,41 | 4,4e-4 | 2,1e-4 | 2,05 | 0,40 |

6-years: forests that have been clear-cut within the last six years. 6-15 years: forests that have been clear-cut between 6-15 years ago. 15-30 years: forests that have been clear-cut between 15 and 30 years ago. Before the hunt, July 1st until August 20th, during the hunt is from August 21st and September 30th, and after the hunt is during October. Non-forest includes arable land, open land, water, wetland, and human land.

*Table 2: Statistical results containing the value and direction of the coefficient given by the conditional logistic regression within the Step Selection Function (SSF) to describe female Brown bear habitat selection in central Sweden (bear data from 2003 until 2021). Pine forest as intercept. Standard error, z value, and P-value for the three periods before the bear hunt, during the hunting, and after the hunt, separated into the night, and day. The analysis included only bear position within the forest company land, including a total of 53 female brown bears. Significant difference in bold and 0.00 = < 0,0001*

**During hunt**

| | **Night** | | | | **Day** | | | |
|---|---|---|---|---|---|---|---|---|
| *Habitat Class* | **Coeff** | **Se** | **Z** | **P** | **Coeff** | **Se** | **Z** | **P** |
| *Deciduous* | -4,3e-2 | 1,6e-1 | -0,27 | 0,79 | 1,5e-1 | 1,3e-1 | 1,62 | 0,25 |
| *Mixed* | -1,7e-1 | 6,2e-2 | -2,71 | **0,00** | -4,5e-2 | 4,7e-2 | -0,95 | 0,34 |
| *Spruce* | -6,8e-2 | 8,5e-2 | 0,80 | 0,43 | 8,2e-2 | 6,4e-2 | 1,29 | 0,20 |
| *6 years* | 1,7e-1 | 6,0e-2 | 2,85 | **0,00** | -2,8e-1 | 6,9e-2 | -4,09 | **0,00** |
| *6-15 years* | 2,9e-01 | 7,2e-2 | 4,00 | **0,00** | -7,3e-2 | 7,6e-2 | -0,97 | 0,33 |
| *15-30 years* | -8,4e-2 | 2,5e-1 | -0,34 | 0,73 | 1,9e-2 | 1,8e-1 | 0,11 | 0,92 |
| *Non-forest* | -2,4e-1 | 5,3e-2 | -4,54 | **0,00** | -1,8e-1 | 4,2e-2 | -4,19 | **0,00** |
| *After Thinning* | 4,6e-5 | 2,0e-5 | 2,38 | **0,02** | -3,4e-5 | 1,7e-5 | -1,98 | 0,05 |
| *Age* | -3,9e-4 | 3,6e-4 | -1,09 | 0,27 | 4,52e-4 | 3,0e-4 | 1,53 | 0,13 |

6-years: forests that have been clear-cut within the last six years. 6-15 years: forests that have been clear-cut between 6-15 years ago. 15-30 years: forests that have been clear-cut between 15 and 30 years ago. Before the hunt, July 1st until August 20th, during the hunt is from August 21st and September 30th, and after the hunt is during October. Non-forest includes arable land, open land, water, wetland, and human land.

*Table 3 Statistical results containing the value and direction of the coefficient given by the conditional logistic regression within the Step Selection Function (SSF) to describe female Brown bear habitat selection in central Sweden (bear data from 2003 until 2021). Pine forest as intercept. Standard error, z value, and P-value for the three periods before the bear hunt, during the hunting, and after the hunt, separated into the night, and day. The analysis included only bear position within the forest company land, including a total of 53 female brown bears. Significant difference in bold and 0.00 = < 0,0001*

**After Hunt**

| | **Night** | | | | **Day** | | | |
|---|---|---|---|---|---|---|---|---|
| *Habitat Class* | **Coeff** | **Se** | **Z** | **P** | **Coeff** | **Se** | **Z** | **P** |
| *Deciduous* | -0,89 | 0,44 | -2,04 | **0,04** | -1,6e-1 | 3,1e-1 | -0,50 | 0,62 |
| *Mixed* | -0,34 | 0,10 | -3,51 | **0,00** | -2,2e-1 | 9,3e-2 | -2,33 | **0,02** |
| *Spruce* | -0,45 | 0,16 | -2,91 | **0,00** | -2,4e-1 | 1,5e-1 | -1,62 | 0,10 |
| *6 years* | 0,44 | 0,10 | 4,37 | **0,00** | -1,4e-1 | 1,2e-1 | -1,19 | 0,23 |
| *6-15 years* | 0,12 | 0,11 | -1,06 | 0,29 | -3,4e-1 | 1,4e-1 | -2,46 | **0,01** |
| *15-30 years* | -2,82 | 1,01 | -2,80 | **0,00** | -3,2e-1 | 3,4e-1 | -0,94 | 0,35 |
| *Non-forest* | -0,14 | 0,08 | -1,83 | 0,07 | -1,1e-1 | 7,3e-2 | -1,44 | 0,15 |
| *After Thinning* | -0,00 | 0,00 | -3,41 | **0,00** | -9,2e-5 | 3,6e-5 | -2,53 | **0,01** |
| *Age* | 0,00 | 0,00 | 3,54 | **0,00** | 1,6e-3 | 5,5e-4 | 2,83 | **0,00** |

6-years: forests that have been clear-cut within the last six years. 6-15 years: forests that have been clear-cut between 6-15 years ago. 15-30 years: forests that have been clear-cut between 15 and 30 years ago. Before the hunt, July 1st until August 20th, during the hunt is from August 21st and September 30th, and after the hunt is during October. Non-forest includes arable land, open land, water, wetland, and human land.

# 4. Discussion

In the analysis, I found that human disturbances influenced the brown bears habitat selection during the different periods of the berry season.

## 4.1. Do bears change their diurnal habitat use before, after, and during hunt during their active time of the day?

My results suggest that bears have a different habitat selection during the day and night, suggesting an impact from human disturbances during the berry season.

During the day, the female brown bears did not show any selection for other habitat classes than pine, exception for before hunt where bears selected for deciduous forests. This could be because humans utilize the forest for recreation purposes such as berry picking (Støen et al. 2018) and the bears avoid areas where there is a risk of encountering humans (Hertel et al. 2016b). Furthermore, brown bears have a bimodal activity pattern and are more active during the early morning and afternoon (Hertel et al. 2017). In areas, with human presence, brown bears tend to become more nocturnal (Hertel et al. 2016b).

During the night, there was a preference in selection by the brown bears for clearcut forests between 6 and 30 years old. This selection was found, during all periods. Apart from this, there was no difference in selection during the day for these periods. The difference between day and night could be due to human presence during the day, resulting in the bears becoming more nocturnal (Hertel et al. 2016b). Furthermore, bears avoid areas where there is a risk of encountering humans (Hertel et al. 2016b), increasing the use of open areas during the night. The bear hunt is done with baying hunting dogs and the bears are more affected by the hunt itself than other human presence (Le Grand et al. 2019). There are still other activities such as moose hunting (Neumann & Ericsson 2018) that take place after the bear hunt or berry picking could occur in all periods (Støen et al. 2018), which could be affecting the brown bears and their movement. Neither of the other habitat classes showed any selection other than pine forest for the night. This could be that humans were not present during the time or not in the same habitat as the brown bear and therefore did not disturb the bears.

## 4.2. How does forest management affect forest stand utilization by brown bears as an index of bilberry occurrence?

When it comes the forest management, my results suggest an impact from forest management on bear habitat selection, yet, also that human activity may affect bears selection pattern.

During the hunt, bears selected for thinned forests more than pine forests during the night. Brown bears tend to avoid areas where there are humans present (Nellemann et al. 2007; Martin et al. 2010; Moen et al. 2012; Hertel et al. 2016b), and become more nocturnal (Hertel et al. 2016b). This could be why bears selected for these areas more than pine during the night. In a previous study, they found that bilberry production increased after a thinning as the canopy opens (Colton et al. 2021), potentially making these forests a preferred forage area for berries and selected during the night. In my results, I also found that brown bears selected for thinned forest less during the day before hunt and after hunt during both day and night. Although, they might be provided with more food in the thinned forest, there could be other disturbances. For example, before the hunt, humans use these forests for berry picking (Støen et al. 2018), which may lead to bears avoiding these forests. The thinning might also have exposed the bilberry plants to too much sun or created drought, which reduces the bilberry production (Tonteri et al. 2016). After the hunt, in October, it coincides with moose hunt which also provides human and dogs presence.

When it comes to other forest management practices in this study, the clear-cut, I have three categories depending on how long ago the clear-cut was done and representing different stages of potential berry occurrence: six years ago, and younger, between 6-15 years ago, and between 15-30 years ago. Both before the hunt during the hunt, during the day bears selected for the habitats clear-cut for six years or less significantly less than pine. The bears also selected for habitat clear-cut for 6-15 years ago less during the hunt and after hunting during the day. After the hunt at night, they selected for forest clear-cut for 15-30 years ago less than pine. During a clear-cut, the ground gets disturbed, and the amount of bilberry is heavily reduced (Kardell & Eriksson 2011). Furthermore, the scarification after a clear-cut could damage the roots (Colton et al. 2021). The bilberry plants also get more exposed to sunlight, which also could reduce the bilberry abundance, because they are sensitive to too much sun and drought (Tonteri et al. 2016). This could explain why bears selected for these areas less. Human presence could also be one reason that the brown bears selected these areas less during the day. These areas might not provide enough shelter for the bears (*Bears of the world: ecology, conservation and management* 2020) and increase the risk of being detected by humans and are therefore

selected less. Both during the hunt and after the hunt, bears selected for stand six years or younger, and 6-15 years more after the hunt significant more during the night. This is interesting since the bilberry abundance should be less in these areas due to disturbances from the clear-cut (Kardell & Eriksson 2011). During human presence, brown bears tend to become more nocturnal (Hertel et al. 2016b), which is the case both during and after the hunt. Although, it would be more likely that bears prefer thinned stands with a higher likelihood of berry abundance (Colton et al. 2021).

For the selection among the forest habitat classes, pine, spruce, deciduous and non-forested areas, my results suggest that there was a difference in selection between the periods, before, during, and after the hunt. Bears selected for non-forested areas significantly less during all periods, except after hunt, both during day and night. This could be due to an increased human presence for example, for berry picking (Støen et al. 2018) and moose hunt (Neumann & Ericsson 2018) in the forests, which force the bears to select for non-forested areas. The bears selected for mixed forest less before the hunt and after the hunt, day and night and during hunt during the night. After the hunt, during the night the bears selected for deciduous forests less than pine, but there was no difference in the other periods. In a study by Eldegard et al. (2019), they found that bilberry occurred less in the mixed and deciduous forest compared to pine and spruce (Eldegard et al. 2019). This could explain the selection and why bears preferred pine over these forest types. On one occasion, after hunting during the night, the bears selected for spruce forest less than pine. It could be that after the hunt coincides with moose hunt which also provides human and dogs presence.

If I compare my results to a previous study done in Clear Hills and Westen Alberta (Colton et al. 2021), I can see that they are similar in some ways, although we did not have the same time intervals. The authors concluded that bears used younger stands during certain seasons, which in my case this was true for the periods during and after the bear hunt during the night. In these two periods, the bears selected for clear-cuts six or 6-15 years old. Colton et al. (2021) also found that the forests best suited for bears were those who had been clear-cut for 10-30 years ago, whereas I found that the older forest was more preferred. Previous studies have also shown that female brown bears select habitats for higher bilberry probability, which were mature forests (Hertel et al. 2016a; Eldegard et al. 2019). That would in my study mean that the brown bears would have chosen habitats that were 30 years and older, which I found after the hunting season both day and night. Furthermore, the bears would not have selected habitats that had been clear-cut for six years ago or less, because of the disturbance the clear-cut creates on the ground (Kardell & Eriksson 2011). This was the case both during the hunt and after the hunt during the night. This selection could be a result of bears being disturbed by humans and selected

areas with a lower bilberry abundance due to human disturbance during the day and avoid human encounters (Hertel et al. 2016a).

To improve the study, the start of the annual moose hunt (September) should be included in the study design since it could affect the results due to increased human and dog presence during the daytime. The human presence is not measured in this study but is based upon literature, but a measurement of human activity would give better results in form of disturbance. The analysis could also be improved by including information on the bilberry coverage from the national forest taxation. The forest management is limited to Sveaskogs management practices, and the results might look different if I used management information from other landowners. The statement that assumed that all clear-cut forests are pine is a bold statement and the results might be improved if the actual forests type were included. Bear response could also be a result of hormonal changes or other human disturbances such as mushroom picking that are not mentioned in this study.

Previous studies showed that bilberries occur more abundant in areas with intermediate productivity (Eldegard et al. 2019). It would be interesting to further investigate how the forest site productivity affects the utilization by the bear. Do bears select areas with more bilberry due to productivity? Furthermore, how does the basal area affect the selection by brown bears, for example do denser forests get selected more or less? In my results, I can see that the differences regarding forest management practices or forest type (e.g., spruce, pine) were stronger than those that could be due to human disturbances. It would therefore be interesting to see how bears who never have been exposed to humans would react, for example, if they would more likely be more affected by human encounters than bears that have lived closed to human settlements.

# 5. Conclusion

There were some differences between bear habitat selection due to human presence and forestry in the different periods; before, during, and after the hunt. During the day, there was no difference in habitat use between the three periods, except for before hunt during the day were the bears selected for deciduous forests over pine. Before the hunt, clear-cuts were selected less during the day and there was no difference during the night. During the hunt, the clear-cut areas between 6-15 and six years or less were selected less during the night, while clear-cuts done six years ago or less were selected more during the day. After the hunt six-year-old clear-cuts or less were selected more while clear-cuts between 15-30 years old were selected less, and during the day clear-cuts for 6-15 years ago were also selected less. These changes could be due to human presence during the day, making the bears selected for these areas during the night and become more nocturnal. Thinning of the forest influenced the habitat selection of brown bears during the hunt as they selected thinned forest over pine during the night, but selected less for them before the hunt during the day and after the hunt both day and night. Clear-cuts influence the bear habitat selection and differ between the periods and whether it was day or night.

These results could help to adapt the forest management to help the brown bear conservation, because we can see how the brown bears tend to respond to management practices, but also in the conservation work to help find suitable habitats for brown bears.

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