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The influence of forestry stands treatments on brown bears (*Ursus arctos*) habitat selection in Sweden – an option for Alberta forestry?

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Foto: Anna Maria Petré

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Skogsskötselåtgärders påverkan på brunbjörnens (*Ursus arctos*) habitatval i Sverige – ett alternativ för skogsbruket i Alberta?

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Keywords: forestry treatments, stand treatments, habitat selection, commercial thinning, pre-commercial thinning, Ursus arctos, bears, forest management and foraging

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Abstract

The brown bear population in Alberta, Canada has been decreasing, while the Swedish has been increasing and all the affecting parameters are not known. This study examined the difference in these populations to see if an explanation could be found in differences between the forest management. The aim of the paper was to see if stand treatments had an influence of brown bears habitat selection in autumn in Sweden and how the results can be used in Alberta. This was done by analyzing bear positions in Sweden with forest data, and comparing forest management data for the study area in Sweden with forest management data for Alberta. The results displayed that mature forests over 60 years that have been commercially thinned are selected by bears rather than forests over 60 years that have not been commercially thinned in. From pre-commercial thinning no conclusions for bears in general could be done, but males tend to select for stands that has been pre-commercial thinned. Forest management in the two study areas differs with the emphasis on pre-commercial thinning and commercial thinning being carried out in Sweden but not in Alberta.

The conclusion is that forest management influences bears habitat selection during autumn and the theory is that thinning increases the berry production by opening up the canopy and increasing the nutrient availability. Alberta might be able to promote their bear population by thinning, however experiments should be done to see if there is an increase in berry production in Alberta as in Sweden.

Sammanfattning

Alberta, Canada har under en längre tid haft en minskande björnpopulation. I motsats har Sverige har haft en kraftigt växande stam. Denna studie ämnar svara på huruvida björnens habitatval påverkas av skogsskötselåtgärder på hösten samt hur resultaten kan användas i Alberta. För att uppnå syftet med uppsatsen har björnpositioner analyserats tillsammans med skoglig data i Sverige och därefter blivit jämförd med skogsdata från studieområden, ett i Sverige och ett i Alberta. Resultatet påvisar att björnar i Sverige selecterar gallrad skog över 60 år framför ogallrad skog över 60 år för födosök under hösten. För röjning kunde inte några generella slutsatser dras för samtliga björnar, men hanar visas selektera röjd skog framför oröjd skog. Skogsbruket skiljer sig mellan Sverige och Alberta. Den största skillnaden återfinns framförallt vad gäller röjning och gallring, som utförs i Sverige men inte i Alberta.

Slutsatsen är därför att skogsskötseln påverkar björnens habitatval i Sverige under hösten och därmed eventuellt också björnpopulationen i sig. Detta tros bero på att gallring och röjning gynnar bärproduktionen genom ökad näringstillgång och ljusinsläpp. Alberta kanske kan gynna sin björnpopulation med gallring. Först bör dock försök genomföras i Alberta, för att se huruvida åtgärderna resulterar i ökad bärproduktion som i Sverige.

Introduction

Research has been carried out to understand how forest management affects bears (McLellan & Hovey 2001 and Nielsen et al. 2004 and Nielsen et al. 2008) A study in process (unpublished manuscript Nielsen et al 2012) show how brown bears (*Ursus arctos*) select clear-cuts in two study areas, one in Alberta, and the other one in Sweden. The results concluded that brown bears select regenerating clear-cut sites (forested areas that once have been cut, but might now have a mature stand) more than other available habitats. Swedish bears selected stands 20–40 years post-harvest and Albertan bears selected stand 10–25 years post-harvest but this varied between season and sex. The difference were greatest in the autumn. Stewart et al. (2012) also showed that bears selected for regenerating clear-cuts with seasonal and sex variation. Another study concluded that bears in Southeast British Columbia selected for 50–70 year old wildfire areas, riparian forest or open forest (canopy closure <30%) and avoided regenerating clear-cuts less than 40 years old that had been planted or left for naturally regenerating for conifers (McLellan & Hovey, 2001). These differences, in comparable studies, are suggested by Nielsen et al. (2004) to be due to differences in the landscape and availability of different habitats such as natural disturbance. Where natural disturbances and natural openings are suppressed, as they are in fire-suppressed forests, bears might select for clear-cuts as a substitute, but where natural openings occurs they avoid clear-cuts. Andisons (1998) study shows that the area of the upper foothills in Alberta, historically had a fire regime of 100 years, and the same can be expected for Dalarna, Sweden (Granström & Niklasson 2003 and Sander 2005). Engström (2000) results suggest that the burned area is less than one percent of what it was before, due to early fire suppression. Fire suppression reduces open structure habitats, including those required by bears (Pease & Mattson 1990 and McLellan & Hovey 2001). Nielsen et al. (2004) showed that bears select for clear cuts with low impact scarification (i.e. bracke or shark-fin barrel dragging), and avoided high impact scarifications (Donaren mounding). No research, to my knowledge, has been conducted to show how specific forest management treatments, such as thinning or other site history, affects the habitat selection of bears.

Canadian grizzly bear (*Ursus arctos horribillis*) and the European brown bear (*Ursus arctos arctos*) are the same specie but two different sub-species (Schwartz et al. 2003). The Scandinavian bear population has increased since 1930 and had a yearly average increase of 4.5% between 1998 and 2007 (Kindberg et al. 2011) and the population is seen as *viable* by the Swedish Species Information Centre. The bear population is partly limited by legal hunting in Sweden today (Kindberg et al. 2011). The Albertan bear population is viewed as *threatened* by Alberta´s Wildlife Act (Government of Alberta 2012) and the restricted bear hunting was stopped in 2006 (Government of Alberta 2010). The bear populations in Canada and Sweden have comparable life-history characteristics and diets (Dahle et al. 1998, Munro et al. 2006). In Alberta the limiting factors are not well known but suggestion includes low reproductive rate, low immigration and an increasing alternation of habitat (Albertan Grizzly Bear Recovery Team 2008). The most common reason for deaths of brown bears in South West Canada and North West United States is human caused, such as self-defense from humans encountering a bear and illegal hunting (McLellan et al. 1999).

Table 1. Comparison between the Swedish and Albertan bear population. Data from: Seather et al. (1998)., Zedrosser. (2006)., Kindberg. et al. (2011). & Steyaert et al. (2012).

	Alberta	Sweden
Total numbers of bears	691	3,300
Total area (km²)	220,616	250,000
Latitude (°)	54	61
Elevation (meter)	600 – 3,500	200 – 1,000
Number of bears/1000 km²	3.1	13.2
Population trend	Decreasing	Increasing
Population status	May be at risk	Viable
Age of average female primiparity	6	5.2
Mean litter size	2.0	2.3
Average female body mass (kg)	129	117
Food consumption in spring	Ungulates and insects	Ungulates and insects
Food consumption in late summer and fall	Grass, herbs and berries (*Shepherdia* and *Vaccinium*)	Grass, herbs and berries (*Echinaceae*)
Access to salmon	No	No
Hunting permitted	No	Yes

Forestry

Forestry is a generic term for activities where forests are used for production of timber for subsequent processing and use. Generally the forest can be managed with two different systems, clear-cutting system or continuous-cover system (Albrektson et al. 2012). The clear-cut system is the most dominating system where an even-aged forest is desired and the normal silvicultural treatments are clear-cutting, regeneration, scarification, pre-commercial thinning and commercial thinning. In a young forest with high stem numbers, pre-commercial thinning is a treatment to select the stems desired to shape the future stand. The treatment strives to achieve better conditions by removing stems, for an increase in profit by increasing volume production in the stems left after the pre-commercial thinning (Pettersson et al. 2007). Commercial thinning is carried out for the same reason, but the trees are older and profit can be made directly from the treatment (Swedish Forest Agency 2005). The continuous-cover system has a desired state with uneven-aged stands where selective-cutting is the normal silvicultural treatment (Albrektson et al. 2012). In the continuous-cover forestry one strives for a static stand with equal proportions of old and young trees through time. The variation between stands will be low in contrast to clear-cutting where different stands will be in different stages.

Important for forest management is forest *growth*, measured and calculated in many different ways (height, diameter, volume per tree or per area, or mean over a timespan). The ground condition has a natural capacity to produce fiber, depending on location in the landscape, availability of nutritions, sunlight, water etc. All the factors that influence productivity also influence the *Site Productivity*, that is measured in m^3sk/ha/year (volume wood produced each year, in an area of one hectare). The management does not directly affect the site productivity and the *ability* to produce wood, but it can affect the *amount* wood produced, i.e. growth/yield. *Site Index* (SI) is an index of the site productivity corresponding to the maximum theoretical yield that can be produced during optimal management. There is a discussion of which of the systems, clear-cutting or continuous-cover, that achieves the highest *yield* and who is better for biodiversity but the results differs (Cafferata 1997, Tahvonen 2009, and Spreer 2010). Both systems can be managed in different ways and are therefore hard to compare.

Swedish forestry

The last ice-age in Sweden ended approximately 10 000 years ago and since then, trees have re-colonized, both from the south and north (Swedish Forest Agency 2005). Forestry in Sweden has been a major industry for hundreds of years and left marks and influenced the landscape. In 1280 the first forest-company was founded in Sweden and in early 1400s laws restricted how forests should be cut (Holmberg 2005). In 1905 the Swedish Forest Agency started and at the same time forest-owners where restricted by law to assure regeneration after cuttings.

In Sweden 55% of the land area is productive forest (Swedish Forest Agency 2011), consisting mainly of boreal forests in the north and boreo-nemoral in the south and some nemoral forests (National Thematic Atlas 2000). Today, the biggest group of landowner in Sweden consists of individual private land owners with 50% of the productive forests. Private company own 25% and state companies own 14% (Swedish Forest Agency 2011). The remaining 11% are owned by villages, churches or other organizations.

The most dominant tree species are spruce (*Picea abies*), pine (*Pinus sylvestris*) and birch (*Betula sp*) and the mean site productivity is 5,3m^3sk/ha/year (Swedish Forest Agency 2011). Most of the forests are managed with the clear-cutting system and each year 0.87% of the productive forest is clear-cut. Other common silvicultural treatments are pre-commercial thinning and commercial tinning and they are implemented on 1.4% resp. 1.2% of the productive forest area each year (Swedish National Forest Inventory). The annual cuts for different tree species are; pine 30%, spruce 57% and deciduous 13% of total volume. It is at the same level as ten years ago, but has increased to decrease again during that time (Swedish Forest Agency 2011). Planting is carried out on 72% of the clear-cuts, and leaving for natural regeneration on 21%. These two methods are the most commonly used while seeding is carried out on 4% of the regenerating area. Seeding is more common in northern Sweden where it is performed on 9% of the regenerated area (Swedish Forest Agency 2011).

Twenty percentage of the field vegetation in Dalarna Sweden is covered by blue- and lingon-berries shrubs, *Vaccinium myrtillus* and *V. vitis-idaea*, (Swedish National Forest Inventory). Results from a study made by Kardell and Eriksson (1990) concluded that the blue berry production after a commercial thinning immediately decreased, but in a nine year period increased with a total of 47%. The lingon berries (*Vaccinium vitis-idaea*) began to increase immediately the year after a commercial thinning and had a total increase of 176% during a nine year period. After the nine year period blue berry production was still increasing while the lingon berry production had started to decrease. The increase of shrubs is thought to be because of better light conditions and higher availability of nutrients. The study also showed that blue berry production increased after fertilization (31%) while the lingon berries decreased (23%).

Albertan forestry

In 1867 the *British North America Act* was signed by most provinces and each province started to possess their own public lands and the timber, but Alberta did not sign until 1930 (Bourchier and Stanton 2012). Alberta is divided in two main areas, where the managing of public land differs. In the southeast (42%) the public land is managed mostly for agriculture, recreation etc. and in the north and northwest of Alberta (58%), public land is managed for timber production, energy development and watersheds etc. (Government of Alberta 2011a).

The main forest tenure type by which companies can lease land, is the Forest Management Agreement which stands for 68% of the forest harvest in Alberta. Timber Quota with Conifers Timber License accounts for 15% and Timber Quota with Deciduous Timber License for 6% of the harvesting (Government of Alberta 2011b). Most of the timber harvest in Alberta is cut by clear-cutting methods and the use of continuous-cover forestry was in 2010-2011 less than 2% of the harvested area and commercial thinning where carried out on only 1% of the harvested area (Government of Alberta 2011c).

The annual allowable cut in 2010/2011 permited a harvest of 60% conifers and 40% deciduous. Over a ten year period, 2001-2010, the allowable cut increased with 27% for conifers and for deciduous increased with 16% (Government of Alberta 2011d). Generally, from 1997 the annual allowable cut has not been achieved for deciduous, but it has been met for conifers.

To plant or to leave for natural regeneration are the two most common methods for reforestation. On the clear-cuts planted, 55% is planted with pine and 45% with spruce (less than 0.5% else). Seeding is uncommon (Government of Alberta 2011e).

Hypothesis

A study in process (unpublished manuscript Nielsen et al 2012) has looked at the use of regenerated clear-cuts, by bears in Alberta and Sweden, and found sesonal differences in use of forest-age classes of 0 – 9, 10 – 25, 26–60 and 60+ years. The goal of my thesis is to continue on that work and see if the difference in selection may be explained by differences in forest management. If data allows, a suggestion about how forest could be managed to enhance the bear population in Canada, Alberta will be given.

$\mathbf{H_1}$: Bears significantly select pre-commercial thinned and commercial thinned stands when foraging during autumn, because thinning open up stands and increase berry production.

$\mathbf{H_2}$: The forest management differs between Sweden and Alberta, due to dissimilar forest management.

The corresponding null-hypothesis are:

$\mathbf{H_{0(1)}}$: Bears in Dalarna select forest habitat as available.

$H_{0(2)}$: The extent of forest treatments in Alberta and Sweden are the same.

The first hypothesis will be tested by analyzing bear positions within their home range area and see what stands bears in Dalarna selects for. The second hypothesis will be tested by comparing forest management data from both countries and field visits to both. Studying resource selection can be done in different ways and levels. This work will look into third-order-selection which is on the level of habitat selection within the home range (Johnson 1980). Focus will be to look at stands that differ in management between Sweden and Alberta, and in the different age classes set by the study in process (unpublished manuscript Nielsen et al 2012). Forest data will be collected from forest companies.

Material and methods

Study areas

The study area in Sweden is the southern study area from the Scandinavian Bear Project and is situated in the county of Dalarna, mid-east Sweden (61˚N, 14˚E). The size of the Swedish area is 24,040 km^2. The mean average temperature ranges from 14°C in the summer to -9°C in the winter with a growing season of 160 days per year (Swedes Meteorological and Hydrological Institute 2004). The elevation ranges from 200 meters to 1000 m above sea level with a timberline at 750 m. Not much of the study area is above the timberline. Most of the forests in the area have been managed for a long time but the area is still interspersed with many natural bogs and lakes.

The Canadian area is considerable alike the Swedish with the biggest difference in the global position where the Canadian lies further South (54˚N). The latitude difference between the study areas is compensated by the Canadian study area with a higher altitude, 600‒3500 m (vs. 200‒1000 m). The study in process (unpublished manuscript Nielsen et al 2012) refers to Beckingham et al. 1996, *Field guide to ecosites of west-central Alberta*, to show that the average temperature in the study area differs between 12°C in the summer to -6°C in the winter and with a growing season around 170 days.

Important for this study is that the ecology and food consumption by both populations are similar, and studies in both Canada and Sweden shows that the major diet in autumn are berries, herbs and grass (Dahle et al. 1998, Munro et al. 2006).

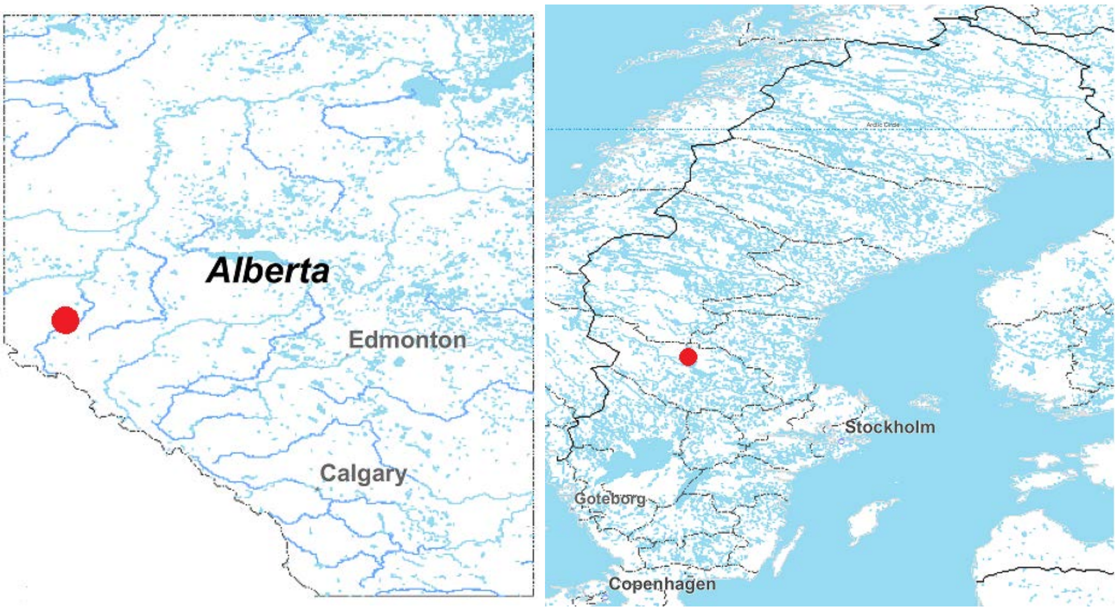

Figure 1: Map over the study areas, Alberta to the left and Sweden to the right. Copyright ESRI.

Data

Local level comparison and habitat selection

Data on; *age*, *height*, *SI*, *stem number*, *volume*, *species proportion*, *years* of clear-cut, *other cuttings*, *pre-commercial thinning*, *commercial thinning* and *fertilization* was collected on forest stands in Sweden. The total area was 4,510 km^2 and data came from the forest companies; Bergvik (39%), Sveaskog (33%), Orsa Besparingsskog (18%), Holmen (7%) and Älvdalens Besparingsskog (3%). Note that data from individual private land owners is unavailable and therefore missing. A mean of 35% (3–94%) of each home range area has missing data which can be any category, such as; water, fields or villages. The majority is expected to be forests outside the original study area and individual private owned forests. To limit the variables of all forest treatments, focus of the work was to see differences in pre-commercial thinning and commercial thinning and what factors they might affect. To compare this data from different companies all the data was changed to the same format (i.e. m^3, ha, years etc.).

The GPS positions used in the study are from the Scandinavian Bear Project on bears collected during 2010. The capture and handling of bears is described in Arnemo et al. (2011). The GPS collars (VECTRONIC Aerospace GmbH, Berlin, Germany) had a relocation frequency of 30 minutes, except some that had every minute or tenth minute. The time frame was limited to nocturnal (6–12 PM) and crepuscular (3–8 AM) times in September-October as only the nocturnal and crepuscular positions were used and this is the normal feeding hours for bears (Moe et al. 2007). Resting time was avoided because of potential difference in habitat selection. Only the months of September- October were used as the study in process (unpublished manuscript Nielsen et al 2012) showed this to be the time of the year with the biggest differences in selection of clear-cuts between Sweden and Alberta and berries and herbs are the basic food recourse for bears (Dahle et al. 1998). In total GPS-positions from 30 bears were used for this study, 16 females, 11 males and 3 females with cubs of the year COY (cubs of the year).

The data was added to a GIS database with georeferencing and a polygon layer with only the selected attributes of forest data on each stand was created. Home range area was built with 100 % Minimum Convex Polygons (MCP) for each bear´s yearly home range and joined with the forest data. The total area for all the home ranges was 24,042 km^2 and the mean area of one home range area was 801 km^2 with forest data on 65% of the area. Many of the home range areas were overlapping and therefore the area with forest data and the total area of home ranges can differ. All stands in a bear's home range area were defined either as selected when visited, or avoided when not visited. Since the home range areas were overlapping, one stand might be selected by one bear and avoided by another. In the results, this will lead to that the total number of selection and avoidance of stands are greater that the number of stands.

Statistics and data management

The statistical program R (R Core Team 2012) was used for analysis and data management. All stands missing SI (Stand Index) and age were removed from the data since the vast majority of them were impediment soil and was not supposed to be included in the study. On stands where age was above 10 years but height, SI, stem number or volume was zero, the data where considered to be missing. The data contains in total 59,610 stands and missing data were; height 50%, SI 2%, stem number 5%, volume 5% and species proportion 18%. For the forest management treatments 13% of the stands were pre-commercial thinned, 15% were commercial thinned, 14% were fertilized and 3% were other cuttings.

Analyzing the data bears were categorized in groups; *All bears*, *Females*, *Males* and *Females with COY*. Student´s t-test and histograms were created for all groups of bears to get a general understanding of the data. *Fisher´s exact test* was used on all groups of bears and age classes of 0‒9, 10‒25, 26‒60 and 60+ years to analyze the hypothesis that management treatments influence bears habitat selection bears (H_1). Fisher´s exact test are used since it is often considered good on smaller samples (Andrés & Tejedor 1995) but criticized to be too conservative, but the results differs (Andrés & Tejedor 1995 and Upton 1982).The results are given in *odds ratio*s which is a quota between two parameters odds. The test is non-parametric and used when data is not normal distributed. The results are seen as statistically significant at $p < 0.05$.

The regional comparison of forest management

To compare the forest state and management in Dalarna and Alberta on regional level, data from the Swedish Forest Agency (2011) and the Canadian Grizzly Bear Program was used. For data collected in Sweden the study area is 5% of the total area in Dalarna, and the study area is located in the northeastern Dalarna. The data from Alberta are only form the study area.

A journey was made to both study areas to have a better understanding of the similarities and differences in the ecosystems. The achieved impression will be discussed in the *Discussion* section.

Results

Local habitat selection by brown bears in Sweden

All bears, *Males* and *Females with COY (cubs of the year)* selects for commercial thinned stands in age class 60+ over non-commercial thinned stands in age class 60+. Females with COY select for commercial thinned stand over non-commercial thinned stands in all age classes. *Males'* selects for pre-commercial thinned stands in age class *all ages* before non-pre-commercial thinned stands in age class *all ages*. The hypothesis about forest treatments influencing bears habitat selection (H_1) is confirmed and the null hypothesis ($H_{0(1)}$) rejected (table 2).

Table 2. Odds ratio and p-value for the different operations of pre-commercial thinning and commercial thinning in age classes for all groups. If the odds ratio is above 1 the age class is selected. Significant levels are *P<0.05, **P<0.01, ***0.001 and Ns are P>0.05. Missing columns are due to lack of fitting data i.e. non treatment done in that age class or no visits.

Age class	Odds ratio pre-com. thinning	Significance	Odds ratio for com. thinning	Significance
All bears				
0-9	1.3	Ns		
10- 25	0.81	Ns	0.32	Ns
26- 60	1.1	Ns	0.71	Ns
60+	0.76	Ns	1.3	**
All ages	1.1	Ns	0.91	Ns
Females				
0-9	0.92	Ns		
10- 25	0.81	Ns		
26- 60	0.78	Ns	0.40	Ns
60+	0.65	Ns	1.3	Ns
All ages	0.83	Ns	0.85	Ns
Males				
0-9	1.5	Ns		
10- 25	0.87	Ns	0.52	Ns
26- 60	1.4	*	0.97	Ns
60+	0.96	Ns	1.4	*
All ages	1.3	**	0.96	Ns
Females with COY				
0-9	1.7	Ns		
10- 25	0.79	Ns		
26- 60	1.1	Ns	1.4	Ns
60+			4.8	***
All ages	1.1	Ns	3.7	***

There is a difference in the selection between years in pre-commercial thinning and commercial thinning for the group *All bears*. For *Males* only pre-commercial thinning was statistically significant, for *Females* both of the treatments was statistically significant and for *Females with COY* only commercial thinning had a statistical difference. Important for all the groups are also the differences in age, height and stem number. This gives further confirmation to the hypothesis that forest treatment influence bears habitat selection (H_1) and rejects the null hypothesis ($H_{0(1)}$). The means for all the attributes and groups are shown in table 3, 4, 5 and 6.

Table 3. Mean values of attributes for used vs. non-used stands, for *All bears* with corresponded p-value. For the management treatments, the year of the treatment is given. Note, that for some of the data the mean does not give a representative value since the data is not normally distributed. Total number of stands are 59,610. Ns are not significant P>0.05 and significant levels are *P<0.05, **P<0.01, ***0.001

Attribute	Mean used	Mean non-used	p-values from t-test
Age (year)	60	67	***
Height (meter)	8.6	10.8	***
SI (m^3sk/ha/year)	19.1	19.8	***
Stem number	1331	1210	***
Volume (m^3)	106	130	***
Clear-cuts	1999	1999	Ns
Other cuttings	2000	2000	Ns
Com. thinning	1995	1997	***
Pre-com. thinning	1998	1995	***
Fertilization	1988	1988	Ns
Pine proportion	77.0	67.2	***
Spruce proportion	14.7	24.8	***
Deciduous proportion	4.7	5.5	***
Contorta proportion (%)	3.3	2.2	***

Table 4. Mean values of attributes for used vs. non-used stands, for *Males* with corresponded p-value. For the management treatments, the year of the treatment is given. Note, that for some of the data the mean does not give a representative value since the data is not normally distributed. Total number of stands are 59,610. Ns are not significant P>0.05 and significant levels are *P<0.05, **P<0.01, ***0.001

Attribute	Mean used	Mean non-used	p-values from t-test
Age (year)	51	66	***
Height (meter)	7.0	11.0	***
SI (m^3sk/ha/year)	19.8	19.8	Ns
Stem number	1544	1224	***
Volume (m^3)	99.5	131.4	***
Clear-cuts	1999	1999	Ns
Other cuttings	2002	2000	Ns
Com. thinning	1997	1996	Ns
Pre-com. thinning	1998	1995	***
Fertilization	1989	1988	Ns
Pine proportion	76.2	68.6	***
Spruce proportion	15.0	23.7	***
Deciduous proportion	5.0	5.5	Ns
Contorta proportion	3.5	2.0	**

Table 5. Mean values of attributes for used vs. non-used stands, for *Females* with corresponded p-value. For the management treatments, the year of the treatment is given. Note, that for some of the data the mean does not give a representative value since the data is not normally distributed. Total number of stands are 59,610. Ns are not significant P>0.05 and significant levels are *P<0.05, **P<0.01, ***0.001

Attribute	Mean used	Mean non-used	p-values from t-test
Age (year)	68	67	Ns
Height (meter)	9.8	9.8	Ns
SI (m^3sk/ha/year)	18.5	19.7	***
Stem number	1200	1181	Ns
Volume (m^3)	112.6	126.9	***
Clear-cuts	1997	1999	*
Other cuttings	1998	1999	Ns
Com. thinning	1993	1997	***
Pre- com. thinning	1998	1995	*
Fertilization	1997	1989	**
Pine proportion	77.9	64.2	***
Spruce proportion	14.3	27.4	***
Deciduous proportion	4.4	5.4	***
Contorta proportion	3.2	2.6	Ns

Table 6. Mean values of attributes for used vs. non-used stands, for *Females with COY* with corresponding p-value. For the management treatments, the year of the treatment is given. Note that for some of the data the mean does not give a representative value since the data is normally distributed. Total number of stands are 59,610. Ns are not significant P>0.05 and significant levels are *P<0.05, **P<0.01, ***0.001

Attribute	Mean used	Mean non-used	p-values from t-test
Age (year)	66	67	Ns
Height (meter)	10.4	9.9	Ns
SI (m^3sk/ha/year)	19.0	18.7	Ns
Stem number	966	1119	*
Volume (m^3)	98.7	109.0	Ns
Clear-cuts	2004	1999	***
Other cuttings	2002	2000	Ns
Com- thinning	1993	1997	***
Pre- com. thinning	1996	1995	Ns
Fertilization	1986	1988	*
Pine proportion	75.4	58.4	***
Spruce proportion	15.0	27.5	***
Deciduous proportion	5.2	7.8	***
Contorta proportion	5.7	3.8	Ns

Regional comparison of forest management

The forest management treatments differ between the two study areas in the aspect of site preparation, pre-commercial thinning and commercial thinning. This confirms the hypothesis that forest management is Sweden and Alberta differs (H_2) and the null hypothesis ($H_{0(2)}$) is rejected. There are also other differences between the general forest state in the two areas such as the size of cut-blocks and the proportion deciduous. Numbers for forest state and management can be seen in table 7.

Table 7. Comparison between the Swedish and Canadian study area. Notice the measure unit for tree composition. While the Swedish display total volume, the Albertan displays area of dominated species. *Citizens* only display the number of permanent people living there. Data from Swedish Forest Agency 2011 and Alberta Vegetation Inventory

	Study area Sweden	Study area Alberta
Total area of study area (km²)	23,510	91,930
Forested area (%)	80.3%	99.8%
Mean growth (m³/ha/yr.)	5	2
Site preparation (% of harvested area)	75%	28%
Pre-thinned area (% of productive forest a year)	1.4%	0.0%
Thinned area (% of productive forest a year)	1.2%	0.0%
Harvested area /year (% of productive forest)	0.96	0.67%
Mean age (year)	67	81
Mean area for clear-cuts (ha)	4	31
Human population/km²	9.9	0.0
Percentage Scotts pine *Pinus sylvestris* (volume)	53%	
Percentage Norwegian spruce *Picea abiers* (volume)	35%	
Percentage Birch *Betula sp* (volume)	10%	
Other species	2%	
Percentage Contorta *Pinus contorta* (volume for Sweden area for Alberta)	1%	35%
Percentage area Trebling aspen Populus tremuloides (area)		27%
Percentage area White spruce *Picea glauca* (area)		14%
Other species (area)		17%
Percentage area Black spruce *Picea mariana* (area)		7%

Discussion

The local comparison and habitat selection should be interpreted with caution. The mean age, as an example, show that *All bears* select for younger stands, but bears use younger stands and stands over 100 years but only to lesser degree stands between 50- 100 years old. The data for the used mean age has not been statistical tested but it show that information might be missed if the means are used without caution. *Males* select for younger, shorter, less dense stands with lower stem numbers (table 4). *Females* and *Females with COY* do not show a clear selection for these parameters and tends to be the groups that really makes a selection for either young stands or stands older than 100 years. *Females with COY* selecting for commercial thinned stands and that *Males* select commercial pre-thinned stands confirms the hypothesis that management treatments influences bears habitat selection. The reason for bears to select for pre-commercial thinned stands and commercial thinned stands could be higher berry production in these forest stands. These stands are expected to hold more lingon berries (*Vaccinium vitis-idaea*) five years after commercial thinning and the blue berry production is expected to reach its maximum sometime after nine years after commercial thinning (Kardell & Eriksson 1990). Interestingly the blue berry (*Vaccinium myrtillus*) production has after nine years not reached the maximum production and might still be increasing. The results of selected thinned stands indicate that the increased berry production lasts for around 15 years. If my theory is correct, that bears selects for pre-commercial thinned stands and commercial thinned stands because of higher berry production, then one might expect that all bears should choose them. I found no support for this. *Males'* selects for pre-commercial thinned stands while *Females with COY* selects for commercially thinned stands. This can be an attempt for the *Females with COY* to avoid *Males* since it is known that male bears practice infanticide (Steyaert 2012).The main infanticide period is in June and my study is carried out on data from September - October, implying something else might be causing the females to distance them from males or that they prefer a more open habitat. The mortality of cubs in Sweden is known to be higher in Sweden compared with Canada (Steyaert 2012).

The regional comparison of the forest management in Sweden and Alberta, and the hypothesis that they differed was confirmed with the aspect of site preparation, pre-commercial thinning and commercial thinning. This gives an idea of the differences but what is missing in the results is the historical use of the forests and the difference in composition in the *forested area*. In Alberta, the last 35 years (1973 – 2008) has seen an increase in stand replacing disturbances (cut-blocks, roads, oil sites etc.) of 11% per year (White et al. 2011). I could not find exactly the same data for Sweden but in Dalarna the productive forested area was 72% in 1968-72, and 67% in 2007-11, a yearly loss of 0.1% (Forest Statistics from the Swedish National Forest Inventory. 1998 & 2011). To the Swedish data, disturbances as clear-cuts, pre-commercial thinning and commercial thinning should be added, probably around 3.5% a year (Swedish Forest Agency 2011). Swedish forests have been under the influence of human impact for a far greater time and the mature Swedish stands are not similar to the mature stands in Canada that has never been clear-cut before, even if both are grouped as *forested area*. Sweden has a more stable forest situation than Canada who suffers of a more extensive habitat loss. Most of the regenerating clear-cuts in Alberta are younger than 30 years old (Alberta Vegetation Inventory) and it is not known how these stands will look like when fully matured. In table 7 differences in showing species composition, it should be noticed important data about non dominated species might be missing in Alberta.

The season and time of the day for GPS-positions (September - October, nocturnal and crepuscular) were chosen because of a study in process comparing Alberta and Sweden showed differences during these (unpublished manuscript Nielsen et al 2012). My results might not be the only explanation and other factors as distance to hiding cover or roads can be of importance. The selection for pre-commercial thinned and commercial thinned stands, by some groups, could explain why the Swedish bears selected for older, once cut stands compared to the Albertan bears (unpublished manuscript Nielsen et al 2012). This thesis cannot say if bears would select for mature and commercial thinned stands with less stem numbers if un-touched forests had been available. The results that *All bears* selects for open stands that has been thinned (if over 60 years) and have a lower volume might suggest that a “natural state of forest” with bigger local variations and natural dynamics, especially fire disturbances, would be preferred. Since they are rare the described forests are selected. It is important to understand that the reason why vast forests with a large variation does not exists, is because the lack of fire regime and this is the because of the modern society and not only the forest owners. It is also likely that forest managed with the clear-cut system, with pre-commercial thinning and commercial thinning, would be preferred over forest managed by continuous cover system since the later hold a more homogenous age structure over time in a stand. This is also confirmed by McLellan and Hovey (2001) study showing that bears select for disturbed forests.

High pine percentage is positive correlated and selected by bears (table 3). These stands are expected to have a more open canopy than spruce stands, allowing more light penetration and better conditions for berries. Bears selecting for stands with lower deciduous percentage, higher contorta percentage and some groups selecting for pre-commercial thinned and commercial thinned forest indicate that they prefer well managed forests. The differences in tree composition in Sweden and Alberta, and the fact that the Swedish bears select for pine dominated stands, shall not be interpreted as implying that planting more pine would profit the bear in Alberta, but rather support the fact that open stands with sunlight penetrating the canopy might be good.

The field survey in Sweden supported that the parts of the stands that were used was representative for the whole stand. Otherwise it could easily been openings, edges and non-representative parts that were used and the collected data about the forest management and stand characteristics would not be representative. This is not my impression. To be sure, further analysis of bear movement should be included. A general impression when comparing both study areas is that the Swedish habitat holds more berries. This could be due to drought or different berry species with other ecology, the Canadians reserchers agree to this. Another explanation could be that the stands in Alberta are much denser in general because of no pre-commercial thinning. The denser stands reach the state of canopy closure faster and the competition for sunlight, nutrition and water are higher. This is thought by Kardell and Eriksson (1990) to have a bad effect on the berry production. Two photos of the different stands can be seen in figure 2. The pictures seem very different but these were the two most similar I could found. This was the young stand with most berries I saw during my three weeks visit.

Figure 2. The Swedish photo, on top, is taken in a newly pre-commercial thinned pine (*Pinus sylvestris*) stand and shows the understory vegetation of blue berries and lingon berries. The Albertan photo, on the bottom, is taken in a pine (Pinus contorta) stand that has not been pre-commercial thinned and does hold most Labrador tea (*Ledum groenlandicum*) and small amounts berries (cannot be seen in the photo). Photos by Anna Maria Petré

Limitations

Forest data from the forest companies are good but has limitations. Especially stem number and volume has a low precision, standard errors ranges from 14 to 26%, while height, SI, tree composition and age are better estimated with reasonable precision or better (Ståhl 1992). The accuracy of the forest management treatments is harder to estimate. The biggest error in the management treatment data is probable a miss in updating the data. In the study some of the data has not been used when it was thought to be mistakes in it. The error was sorted out by using the age data, which was considered to be one of the best parameters to rely on. If the age in the data is wrong, more of the data might be wrong.

In this study it is important to point out that even though we have a lot of data, we do not have the individual private land owners and there are some general consistent differences between the forest owned by companies and private land owners. This means that the study does not have a random sample of forest stands and bias because of that might occur. Example; private land owners in Dalarna general have a higher standing volume, 135 m3sk/ha, that privately owned forest companies, 118 m3sk/ha (Swedish Forest Agency 2011). A mean of 35% of the home range areas in the study are missing data. Most of this comes from a few home ranges and if this study is to be continued they shall be considered to be removed. It is important to remember that the study can only compare the selection between the available habitats. This means that the study cannot say if managed forest in general is selected or not by bears since un-managed forest, that has not been fire suppressed are rare (Cedergren 2008).

The estimation of home range area can be done in many different ways (Harries et al. 1990). In this study the method with Minimum Convex Polygon (MCP) was chosen. The reason for that was because it was fast and well known in this kind of studies. Critics against the method is that it is thought to affect sample size (Worton 1987).

Management implementation

In Sweden the food is not limiting the bear population to the extent that the bear population cannot grow. It is possible that the current forest management is positive for the bear. If improved bear habitat is desired, it would probably include decrease site preparation damages and do more thinning on sites that already hold berries. Better riparian buffer zones could also be a measurement taken since bears select them in Canada (McLellan & Hovey, 2001). In recent years there has been a discussion of the loss of pine stands and that more spruce is planted (Swedish Forest Agency. 2010). This might not be a good development for the bears because it leads to a greater habitat change and my results show that they select for pine dominated stands but many other factors might also affect.

In Alberta the limitation for the bear population is not well known, but human impact is important. One vital action should be to reduce the mortality of bears by humans (McLellan et al. 1999). Perhaps special applied forest managing i.e. pre-commercial thinning and commercial thinning can concentrate the bears to an area where there are less human impact and therefore help the bear population to restoration. If this would be done, pre-commercial thinning and commercial thinning should be carried out in stands with lower SI and naturally already holds berries. It is not likely that commercial thinning in random stands, will increase the berry production. It is preferable the stands that holds berries from before are thinned since it is shown in Sweden that the increase of berry production after thinning comes mostly from vegetative dispersal and not new establishment (Kardell & Eriksson 1990).The same study shows that lingon berries increased after clear-cutting with 158% if no site preparation was done but for blue berries this showed a decrease of 56%. With site preparation the increase is replaced with a decrease of -14% for lingon berries and -72% for blue berries. To create more berries for bears in Alberta a slight change in site preparation could be considered. The best way to increase berry production would be to start in a young stand, that stills holds berries from after the clear-cut, avoid high disturbance form site preparation, perform pre-commercial thinning and then when the stands are old enough they can be commercial thinned.

Suggestions for further work

If Alberta would like to increase the food recourse for bears pre-commercial thinning and commercial thinning might be a solution. It must be tested, if the berries response to thinning works the same way in Alberta, as they do in Sweden. This would be one of the most important parts of future research on this subject. To get a positive response from the bears, food must be the limiting resource or the management is not likely to have the desired effect. The study should be carried out in young stands that already hold berries and pre-commercial thinned before they are commercially thinned. If matured stands with high amount of berry shrubs already exist, commercial thinning is likely to work there as well. These kinds of studies are normal carried out over a long time, preferable over a stand generation, even if faster changes might be recognized earlier.

This study just looked at the bear positions during the foraging time and concluded that pre-commercial thinned and commercial thinned stands where preferred at this particular time by some bears. Data with bear positions over the whole active period is available and to analyze them, would be desirable. It is possible that bears might select thinned stands during the foraging time, but avoid them at other times. If food is not the limiting resource a change in the management might even have a bad effect on the population, decreasing good denning sites or something not at all measured in this study. By looking at data from a longer time series, a more detailed study could be done to detect if *Females with COY* tries to avoid males by choosing another kind of forest habitat, mature forests, that has been commercial thinned, while the *Males*, selects for younger pre-thinned forests. This could be correlated to the fact that bears practice infanticide and that the forest management could influence it.

In the Swedish forestry there is a discussion about security due to a higher risk of getting injured by bears, while preforming pre-commercial thinning. In this aspect it could be interesting to do a regression and detect the features of the most visited stands. There are data from Moe et al. (2007) showing that bears uses young forests in May – July to a lesser degree during their day rest. In July – August it was no such clear connection. If similar data could be recognized for more detailed type of stands, the pre-commercial thinning can be done when the risk for encounter is at lowest.

Conclusions

Pre-commercial thinned forests in the Swedish study area are not selected by all bears as a group but by male bears. Commercial thinned forests over 60 years old are selected by the group all bears, probably because of higher berry production. The major differences in Swedish and Canadian forestry are the forest management methods, where Sweden does more pre-commercial thinning and commercial thinning than Alberta. The limitations of the bear population in Alberta are not well known. If food is showed to be one of them, pre-commercial thinning and commercial thinning might be a good way to increase the food. Done in the right stands together with lower impact from site preparation it is thought to have an effect of higher berry production.

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