2017

The influence of debarking by European Bison (*Bison bonasus*) on the Carpathian forest.

By Laura Gaeta

The influence of debarking by European Bison (*Bison bonasus*) on the Carpathian forest.

By Laura Gaeta

Applied Biology, specialization Animals

Aeres University of Applied sciences

Sat Bătrân, Romania

November 2017

Under guidance of Maaike Cox and Marieke Bos

Cover photo by Angus Walker

Preface

In front of you lies the preliminary report for the graduate thesis of Laura Gaeta, Bachelor student Applied Biology at Aeres University of Applied Sciences. This report is part of a project by WWF Romania and Rewilding Europe on the reintroduction of European bison in the Southern Carpathians. For this project, research has been done on the interaction between the European bison and its habitat. This report focuses on the effects of debarking of European bison on tree mortality.

I would like to thank the following people for their help in the making of this report:

Maaike Cox, Marieke Bos, Ruben Proost, Marije de Haan, Natasja Kruithof and Jorn Wennekes, for their support and feedback during the setup of this research.

Matei A. Miculescu, Daniel Hurduzeu, Florin Halastauan, Catalin Gavrila for sharing their knowledge about the Bison Hillock.

Duncan Hiermeier, Matei A. Miculescu, Daniel Hurduzeu, Florin Halastauan, Oana Mondoc for driving to the different research locations.

Catalin Gavrila, Irenka Vasaliut and Oana Mondoc for helping out with walking the transects.

Catalin Gavrila and Alba I. Rípodas Melero for lending their equipment.

Georg Messerer and Alba I. Rípodas Melero for their help with field practice in tracks and signs.

Patrick Chiroiu for his help with the tree determination.

Alina Satmari and Irenka Vasaliut for their help with ArcGIS.

Tom Huisman for his help with the statistical analysis.

Angus Walker for the cover picture.

Table of contents

Abstract

The Bison Hillock is an area in the Carpathians, Romania and one of the areas where the previously extinct European Bison (*Bison bonasus*) recently has been reintroduced. Although some research on the ecology of the European bison in other areas exist, there was little know about their ecology in the Carpathians. As a result, it is currently not well known how much debarking takes place and what species are targeted. This research is focused on the influence of debarking on the tree mortality in the Carpathian forest. To conduct this research, transects were walked in different areas: Areas with an artificial high density of European bison, areas with a low density of European bison, and areas with no European bison. During those transects, the tree species and the amount of debarking were measured. The results show the frequency of debarking per tree species and average wound size per tree species. Various trends can be seen between debarking and mortality. It also shows the debarking of some species that were previously not known to be debarked. It can be concluded that the current impact of European bison is not damaging to any species, but the combination with logging in the area might cause concern for the future. More research should be done to better predict the future of the Carpathian forest.

Samenvatting

The Bison Hillock is een gebied dat zich in de Karpaten van Roemenië bevind. Het is een van de gebieden waar de voorheen uitgestorven wisent (*Bison bonasus*) recent opnieuw uitgezet is. Ondanks dat er al enig onderzoek naar de ecologie van de wisent is gedaan, is er nog weinig bekend over de ecologie in de Karpaten. Daardoor is er nog weinig bekend over hoeveel bomen er geschild worden door de wisent en welke soorten er gegeten worden. Dit onderzoek focust zich op de invloed van schillen op boomsterfte in de Karpaten. Bij het uitvoeren van dit onderzoek is gebruik gemaakt van het lopen van transecten in verschillende gebieden: Gebieden met een hoge dichtheid van wisenten, gebieden met een lage dichtheid van wisenten en controlegebieden waar geen wisenten aanwezig waren. Op deze transecten werden de boomsoorten geregistreerd en de hoeveelheid beschadigde bast per boom gemeten. De resultaten tonen de frequentie waarop het schillen van bomen plaats vindt per boomsoort. Daarnaast wordt getoond hoe groot de schaden per boom is. Verschillende trends zijn zichtbaar tussen het schillen van bomen en boomsterfte. De resultaten laten ook zien dat een paar boomsoorten geschild worden waarvan voorheen niet bekend was dat deze geschild werden. Er kan worden geconcludeerd dat de huidige impact van wisent niet schadelijk is voor de aanwezige soorten, maar dat dit, in combinatie met houtkap, mogelijk tot bezorgdheid kan leiden in de toekomst. Meer onderzoek zal uitgevoerd moeten worden om de toekomst van de Karpaten beter in beeld te kunnen brengen.

Introduction

The Bison Hillock is an area in the Southern Carpathians of Romania. It is a mountainous area with peaks up to 2190 meters. The area is one of the few areas in Europe to possess well-preserved native flora and fauna. Large portions of the territory comprise forest and non-forest ecosystems; in particular, the mixed Carpathian forest. This ecosystem includes numerous plant communities growing in semi-natural rural areas. The mixed Carpathian forest provides suitable conditions for carnivorous mammals such as the European brown bear (*Ursus arctos arctos*), the Eurasian lynx (Lynx lynx), the European wolf (*Canis lupus*) (Unesco, 2016) and herbivores like the red deer (*Cervus elaphus*) and the roe deer (*Capreolus capreolus*) (Szemethy et al, 2016; Katona, Szemethy, Bleier et al, 2012). This diverse ecosystem also brings an opportunity for a suitable habitat for the European bison (*Bison bonasus*) (Unesco, 2016).

European Bison used to roam across large parts of Europe, but became extinct in the wild in 1926. Only a captive population of 54 individuals remained. Due to a breeding program their number slowly grew, and initiatives started to introduce these populations back into the wild. This was first done in Poland and after that in other countries like Romania (Schmidt , 2014; Vlasakker, 2014) leading to 34 release sites spread across Europe (Figure 1).
In 2014 the WWF Romania brought the first group of European Bison to the Bison Hillock for release, and since then 4 groups of 9 to 17 bison each have been released into the wild (M. A. Miculescu, personal communication, November 2017). Since the release at least 3 calves have been born (Live Bison, 2017).

The European bison is the largest native European herbivore and has a key role in ecosystems. Bison carcasses form a food source for over 40 species of birds, mammals and insects (Kowalczyk, Kerley, 2017). In the summer, the bison primarily feeds on herbs, sedges and foliage (Zielke, Wrage-Mönnig & Müller, 2017) playing an important role in seed dispersion by helping the buildup of seed banks across ecosystems (Jaroszewicz, 2013; Kowalczyk & Kerley, 2017). When the European bison switch to a diet primarily consisting of bark and twigs in winter (Zielke et al, 2017), the browsing can possibly cause significant shifts in the forest ecosystem processes (Fehér, Szemethy & Katona 2016).

Figure 1: All locations of reintroduction sites of European bison in Europe in August 2014 (Vlasakker, 2014).

Studies on several species including red deer, roe deer and wild boar (*Sus scrofa*) have shown that short-term effects of debarking in general can include increased tree mortality. Bark injuries that exceed 90% of the stem perimeter can become deadly to trees due to the blockage of the nutrient flow (Fehér Katona, Bleier, Hejel, & Szemethy, 2014; Fehér et al, 2016). The presence of wounds can also make the tree more susceptible to penetration by fungi (Vasiliauskas & Stenlid, 1998), nematodes (Eidt & Weaver, 1993), bacteria (International Union of Forestry Research, 1963) and animals like insects and birds (Fehér et al, 2014). Studies in red deer and roe deer have shown that long-term effects of debarking can include the building and/or the sustaining of a biodiverse mosaic landscape of woody pastures, grasslands and mixed forests (Vera, Bakker & Olff, 2006; Fehér et al, 2016). This effect can take place because the browsing reduces the survival rate of young trees in areas without shrubs, creating open places in the forests and maintaining meadows and grasslands. These open places, scrubs, meadows and grasslands offer an opportunity for more plant species to grow, for example light-demanding woody species, herbs and grasses. Vice versa, the absence of browsing species can lead to those areas being overgrown into a canopy forest without places for those other species to grow (Vera et all, 2006).

Little is known on the scale of impact of European bison in specific on forest regeneration, forest structure and forest composition and whether these effects have positive or negative influences on the forest ecosystems (Vera et all, 2006; Fehér et al, 2016). Both the short-term and long-term consequences of debarking on stem development and tree survival are not clearly understood yet (Fehér et al, 2016). There is also little known about tree selection in European bison and therefore what trees are more or less susceptible to debarking from European bison. Therefore, the following research question was formulated:

What is the impact of debarking by European bison on tree mortality in the Bison Hillock of the Romanian Carpathians?

- Which tree species are eaten by European bison in the Bison Hillock?
- What is the degree of debarking damage due to the European bison per tree species in the areas of the Bison Hillock that the European bison stay in?
- What is the effect of European bison density on debarking probability?

This information could be used to benefit both the reintroduction and survival of the European bison and the ecosystems they live in. If the interaction between the European bison and its ecosystem is better understood, this could be used to select new release sites for European bison and to monitor current areas European bison has been released in, to detect possible problems and dangers beforehand. It could also help select ecosystems that could profit from the release of European bison or protect ecosystems that would be harmed by the release of European bison. Furthermore, this information could help to understand current problems in the human wildlife conflict between local villagers and the European bison. For example, in fruit trees in orchards being debarked. A better understanding of tree selection and the amount of debarking done by European bison could help in protecting these fruit trees and to increase survival rates.

Methodology

To determine the species and the amount of debarking per area, five areas were selected. This was done with the help of data from GPS collars and the experience of the local rangers. The areas where bison stayed during the winter were chosen as low-density areas (Table 1). The fenced-off bison enclosure and rewilding area, where the bison stay for several months until they are ready to be released, was chosen as a high-density area (Table 1). Unfortunately no other high density areas were available. To make sure data of the high density area is comparable with data from the other areas, the data will be converted to percentages in the results.

For the control areas, two areas without European bison (*Bison bonasus*) were chosen. These areas were chosen on the other side of the main road through Armeniș, Romania. This location was chosen as a control area because the main road forms a barrier for the European bison between the current release area and the mountains on the other sides of the road. Therefore, it was certain that the control area was untouched by bison.

To make sure these areas were comparable, soil type, slope angle and slope side (North, East, South, West) were measured and kept similar where this was possible. Areas were chosen in forests biomes consisting of primarily European beech (*Fagus sylvatica*) on a height between 600 and 900 meters. Additionally, the presence of other animals like red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) was noted for every area to help determine what debarking species could be found in the transects. The presence of these species was determined by tracks and other physical evidence like faeces or hair (Live Bison, 2017).

Table 1: Research areas

Name	Letter	Latitude	Longitude	Hight in meter	Area type	Density
Control area Armeniș	A	45.21	22.29	700	Control	No
Control area 582	B	45.25	22.25	600	Control	No
Bison enclosure	C	45.22	22.45	850	Bison	High
Opposite of enclosure	E	45.22	22.46	850	Bison	Low
Area Pietroasa Mică	F	45.21	22.41	750	Bison	Low

In each area two straight belt-transects were chosen (Figure 2). These transects were each 200 meters long. Each transect has 20 squares of 3 meters by 3 meters in which measurements were taken. These squares were distributed equidistant from each other.

For each square the coordinates, the altitude (Garmin GPSMAP, 2017) and the angle of the slope (Waterpas, 2017) were measured. For each tree in these squares the species was determined if possible. If determination was not possible, the species was marked as unknown. Then the circumference was measured at 1,30 meters from the ground level (C1.30). Every tree under the length of 1,30 was counted as sapling and circumference was not measured.

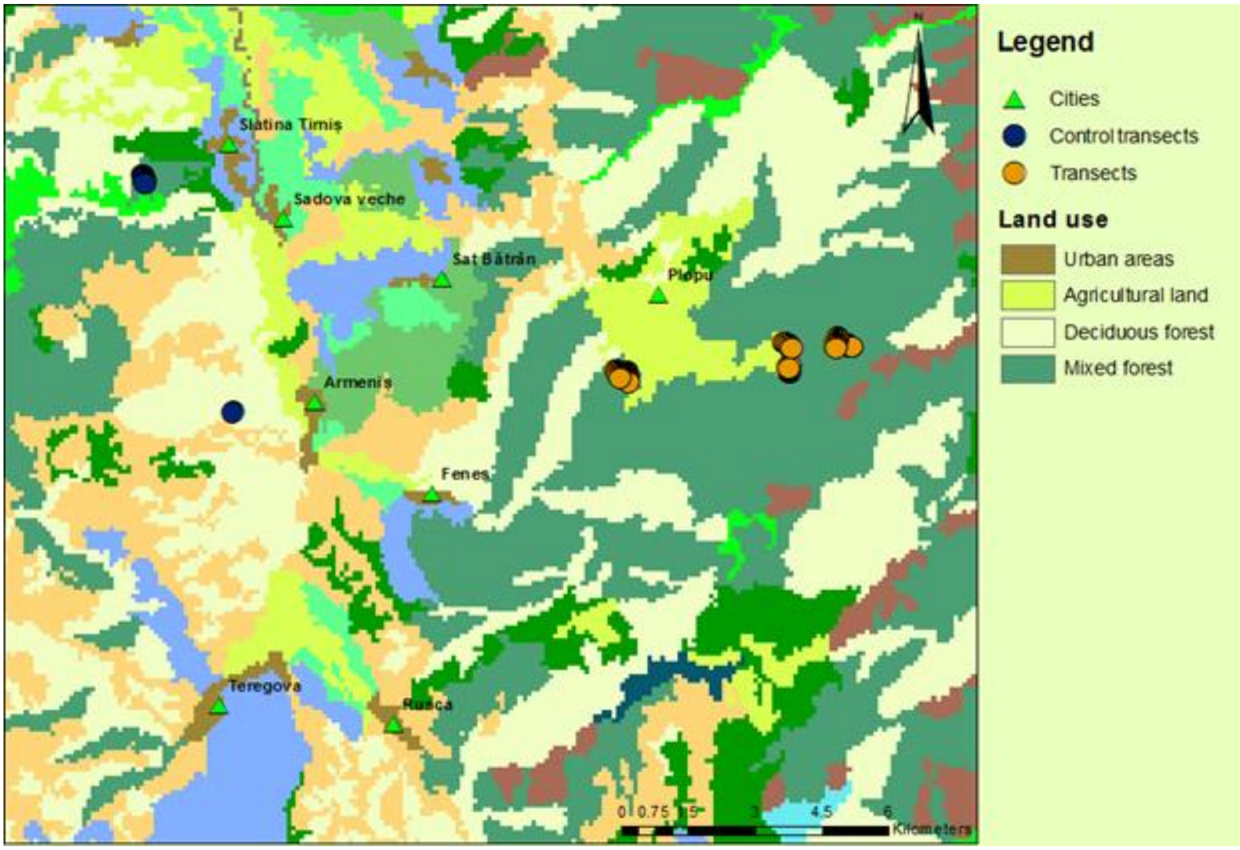


Figure 2: Location of transects

If the tree showed signs of debarking additional measurements were taken. This included the height from the ground up to the lower base of the damage (h), the height from the ground up to the upper base of the damage (H), the width of the wound at the middle of the damaged area (l) and the circumference of the tree(C). Furthermore, the damage was noted as fresh (less than a year old) or old (older than a year).

If the tree was clearly dead, a note was made for the expected cause of death (logging, debarking, uprooting, storm damage or other). Dead trees were defined as being physiologically dead or likely to die within a few months because of a completely destroyed crown or because the whole circumference of the tree had been debarked (Holzwarth et al, 2012).

The species causing the bark damage was determined from physical evidence at the debarking spot (antler, teeth or claw marks) and the height and the shape of the wound (roe deer or bison). If determination was not possible the debarking species was marked as unknown.

Chosen transects were randomized according to the randomized complete blocks method (Greenwood & Robinson, 2006). Each area was given a unique letter, then each transect within an area was given a number 1 or 2. First the numbers of the transects were randomized. Then within each sample number, the letter of the area in which the sample was taken was randomized.

The following formulas were used to calculate the amount of damage per tree. The formula $H_w = (H-h)/2$ and $T = l/2$ were used to calculate the major radius and the minor radius of the wound. Then the formula $W = \pi * H_w * T$ was used to calculate the surface of the wound.

Results

For this research a total of 2.012 trees were measured. Of those trees 746 grow in the high European bison density area, 721 grow in the low bison density areas and 527 grow in the control areas with no European bison present (Table 1). The highest density of trees was found in the high bison density area.

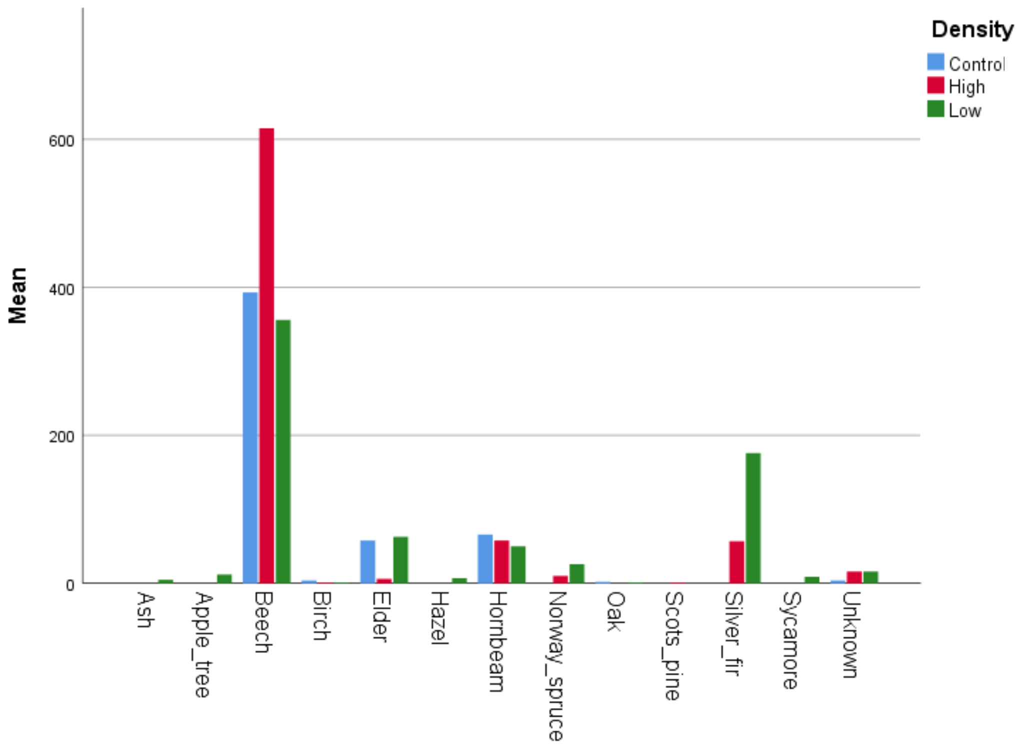
The percentage of the frequency of debarked trees was lowest in the two control areas with 1.79% - 2.42%, followed by the two low bison density areas, where the percentages lay close to 10% (Table 1). In the high bison density area the highest frequency of debarking was found with 21.2%. The percentages of dead trees also varied per area. In the high bison density area a dead percentage of 6.02% was found. This percentage was a bit lower in the low bison density area where the percentage varied from 3.25% to 5.84%. In the control areas the percentages were 1.08% to 2.02%.

Table 1: Number of trees monitored per area.

Area	Bison density	Number of transects	Total number trees	Total number of debarked trees	Percentage debarked trees	Total number of dead trees	Percentage dead trees
S	None	1	248	6	2,42	5	2,02
Z	None	1	279	5	1,79	3	1,08
LA	High	2	764	162	21,20	46	6,02
GP	Low	2	431	43	9,98	14	3,25
KR	Low	2	291	29	9,97	17	5,84

During the transects different species of trees were found. Graph 1 gives an overview of how many trees were found per species and per bison density gradation. European beech (*Fagus sylvatica*) was found the most, over 300 times per area. Over 600 beech trees were found in the high density area. Only five European ash trees (*Fraxinus excelsior*) were found. All of those grew in the low density area. A total of 12 apple trees (*Malus domestica*) were seen. All of these grew in the low density area. A total of six birch trees (*Beluta spec.*) was counted across all three bison density gradations. European common elder (*Sambucus nigra*) was found mostly in the control area and the low density area. Only six of the 127 individuals were found in the high density area. Hazel (*Corylus spec*) was found seven times and only in the low density area. European hornbeam (*Carpinus betulus*) was found in all three bison density gradations in relatively equal numbers. In the control area 66 individuals were counted, 58 individuals were counted in the high bison density area and 50 individuals were counted in the low bison density area. Norway spruce (*Picea abies*) was seen in both the low density area and the high density area. Ten individuals were found in the high density area and 26 individuals were found in the low density area. Only three oak trees (*Quercus spec.*) and only one Scots pine (*Pinus sylvestris*) were seen. European silver fir (*Abies alba*) was found in the low and high bison density areas but not in the control areas. In the high bison density area 57 individuals were seen and in the low bison density area 176 individuals were seen. Only nine sycamore (*Acer pseudoplatanus*) were counted during this research, all of these trees grew in the low density area. Some trees were marked as species unknown. This accounted for four trees in the control area and 16 trees in each of the other areas.

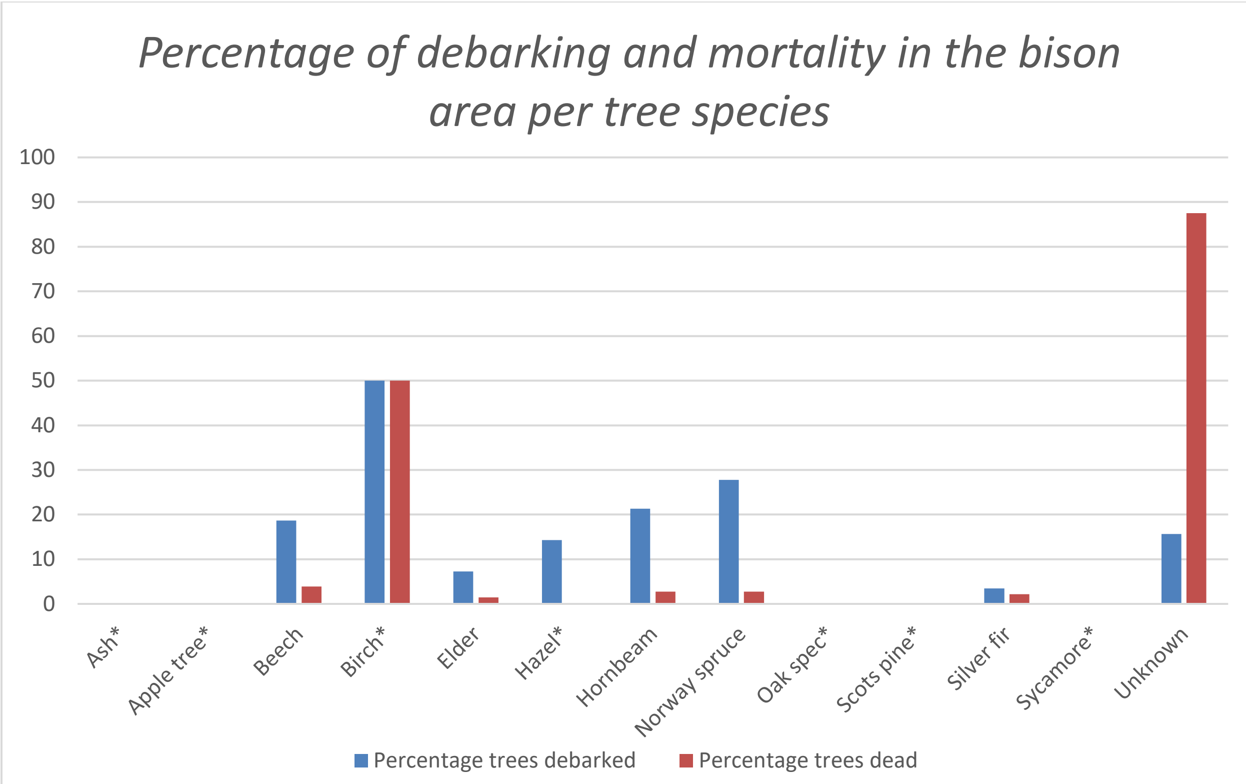
Number of trees found per species and per density of European bison.



Graph 1: Number of trees found per species and per European bison density.

Graph 2 visualizes the frequency in which trees of a certain species were debarked, and in which frequency mortality in species took place. Only trees from the low and high bison density areas were used, to determin the percentages in which trees were debarked. Some species had small sample sizes (under 20 individuals total). Those species were marked with an asterisk.

No European ash, apple tree, oak tree, Scots pine or sycamore were found with any sign of debarking or mortality. In beech, 18.6% of the trees were debarked and 3.9% of the trees were dead. Birch had a very low sample size. In this species only one case of debarking and one case of mortality were found resulting in a percentage of 50% for both debarking and mortality. In European common elder 7.2% of the trees had signs of debarking and 1.4% of the trees was determined to be dead. Of hazel trees, 14.3% was debarked but no dead hazel trees were found. Although 21.3% of the European hornbeam trees were debarked, only 2.7% of the total number of trees was determined to be dead. This difference was even bigger in in Norway spruce. Of the trees, 27.8% were debarked, but only 2.8% of the Norway spruces were found dead. In European silver fir only 3.4% were debarked, but there was still a mortality of 2.1%. The percentage of debarked trees of which the species was not determined is 15.6%. The mortality in the undetermined species was 87.5%.

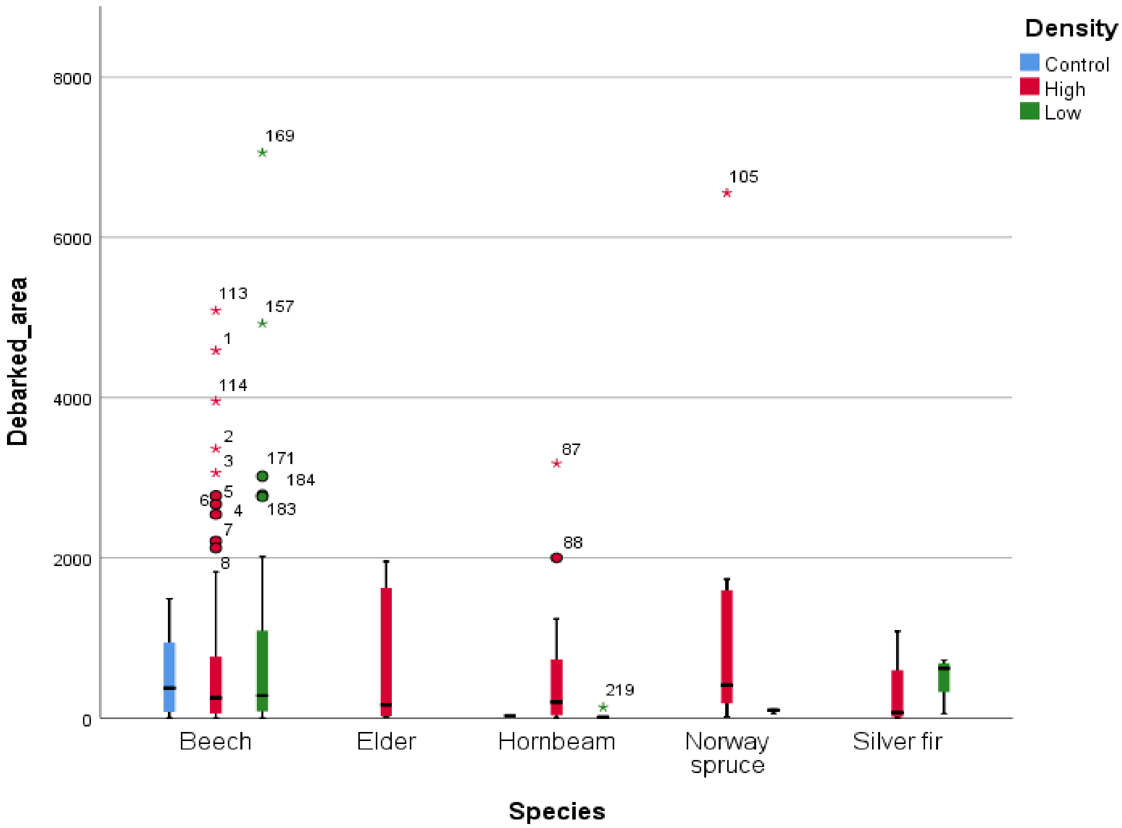


*Graph 2: Percentage of debarking and mortality in the bison area per tree species. * Indicates that less than 20 measurements of this species in total were taken.*

In graph 3 the wound size per species per area was plotted in a boxplot to visualise the spreading of the wound sizes and to compare the mean wound size per species for each bison density gradation. The species were placed on the x-axis, and the wound size in square centimetres was placed on the y-axis. Colours were used to indicate the different gradations of European bison density. If there were less than 20 observations, the sample size was deemed too small and the species was not included in the boxplot.

In European beech, the mean wound size and the distribution of the wound sizes was pretty similar across the different European bison density gradations. There were, however, a lot of outliers, especially in the high density area. The most distant outlier is found in the low bison density area. European common elder was only debarked in the high density area. Therefore, only one distribution is visible in the graph. In European hornbeam the mean does not significantly differ across the different gradations of European bison density. However, the spreading is bigger in the high bison density area. There are also two outliers visible in this area. No Norway spruce were found in the control area. Therefore, no spreading is visible for the control area. The mean in the high bison density area and the mean in the low bison density area differed somewhat from each other, although not significantly. The box was also spread more towards a bigger wound size in the high bison density area. In European silver fir the mean wound size was higher in the low bison density area as in the high bison density area, even though the spreading of the boxes overlapped. There was no significant difference in spreading between the different species.

Amount of debarking per area and per tree species.



Graph 3: Amount of debarking per area and per tree species. On the x-axis the species, on the y-axis the wound size in square centimetre. The colours indicate the density of European bison: Blue for control areas without any presence of European bison, red for areas with a high density of European bison, and green for areas with a low density of European bison.

Discussion

Introduction

The focus of this research is to determine the influence of debarking by the European bison on tree mortality. To measure the influence this research was focused on what species are getting debarked, what the frequency of debarking is, and what the wound size is. The results of these focuses will now be discussed.

Sampling

For this research it was not possible to take two samples from two areas in each European bison density zone. There was only one, relative small, high bison density zone. Therefore, only one area was sampled in the high bison density zone. Due to limited time and limited availability of vehicles only 1 transect was sampled in each control area.

The number of trees measured in the high European bison density area (746) was similar to the number of trees measured in the low bison density area (721), even though the low bison density area had twice as much surface area that was sampled. This would suggest a higher tree density in the high bison density area. There were also only 527 trees in the control area, which had the same amount of surface measured as the high bison density areas. The difference in tree density could be a result of various factors. The first factor could have been that the trees were not always homogenous across all sampling areas, but were from different species and sizes. The size and shade tolerance of the trees could influence the number of trees that is able to grow in an area with a fixed size (Poulson & Platt, 1989). Another factor could have been that the high bison density forest laid on a Southern slope while the other areas laid on a Northern slope. Due to different climate effects, like light hours, warmth, and wind, the forest composition and density on Southern slopes could slightly differ from the Northern slopes. The last factor could be the snow cover in the control area Z. This area was measured last, and since this study was conducted at the end of autumn, it started snowing before the last transect could be sampled. Due to the snow cover, it was very hard to count the saplings. Therefore, it could be that a reduced number of saplings was counted, resulting in a reduced number of trees in this control area.

What is the effect of European bison density on debarking probability?

The percentage of the frequency of trees being debarked per area, and the grade of bison density per area, show a trend, indicating that there might be a relation between the number of bison in an area and the number of debarking spots. This relation would be logical for a few reasons. The presence of bison might increase the total number of bark-eating animals in an area and therefore the number of debarking spots. Another influence might be that bison live in groups and therefore eat in groups. This might result in clusters of debarking, instead of debarking spots being distributed homogenously over the area. It could also simply be because European bison are large animals, and eat more bark than the other bark eating herbivores (Kowalczyk, Taberlet & Coissac et al, 2011; Bugalho & Milne, 2003). More research should be conducted to indicate if there is a correlation between bison density and the number of debarking spots in an area and, if so, which factors could cause this correlation.

The percentage dead trees per area shows barely any trend. This could be because there were multiple factors that could result in the death of a tree. Dead trees with debarking signs (25 out of 80) were found, but also storm or logging (13 out of 80) could be a cause of death. In a lot of cases, the cause of death could not accurately be determined, because the cause of death was no longer visible due to rotting (41 out of 80).

Which tree species are eaten by European bison in the Bison Hillock?

During this research the following species were found: apple tree (*Malus domestica*), birch (*Beluta spec.*), European ash (*Fraxinus excelsior*), European beech (*Fagus sylvatica*), European common elder (*Sambucus nigra*), European hornbeam (*Carpinus betulus*), European silver fir (*Abies alba*), hazel (*Corylus spec.*), Norway spruce (*Picea abies*), oak (*Quercus spec.*), Scots pine (*Pinus sylvestris*) and Sycamore (*Acer pseudoplatanus*). Of these species, the following species were found with signs of debarking: birch , European beech, European common elder, European hornbeam, European silver fir, hazel and Norway spruce. This means that these species were at least eaten by one of the debarking species present in this area, and likely to be eaten by European bison (Kowalczyk et al, 2011; Straus, 1981; Katona et al, 2012).

There was a number of trees (72) were the species was not determined. Mostly of these trees were dead which made the species specific characteristics occasionally unrecognisable. There could have been other species than previously named among those trees. Therefore, some species might have been present and/or debarked but not analysed in this paper. In further research, this problem could be reduced by taking wood samples from the dead trees for further analysis.

What is the degree of debarking damage due to the European bison per tree species in the areas of the Bison Hillock that the European bison stay in?

As shown in graph 1 there was a big difference in the number of trees measured by species. To determine the frequency of debarking per species, the data was converted to percentages. Two species, birch and hazel, had under 20 observations in total. The debarking frequency in these species will not be discussed because the sample size of these species might be too small to give reliable results.

The highest percentage of the frequency of trees of debarked trees per species was found in Norway spruce (28%). This result was unexpected since it was not known by the local rangers that European bison ate bark of Norway spruce. A study in large herbivore diets in Poland confirmed it is indeed possible for European bison to eat bark from Norway spruce (Kowalczyka, Taberlet, Coissac et al, 2011; Krasińska, Krasiński, 2013).

A similarly unexpected result was the fact that a small percentage of silver fir (3.4%) had been debarked. Due to the resin in the tree, nobody expected that European bison would like to debark this species. Due to the large amount of resin on the wounds, it was not possible to determine what species could have caused the damage. No research was found that shows that this species could be debarked by any herbivore. The lowest point of the wound was anywhere from 5 cm to 93 cm of the ground. Therefore, no species could be indicated by the wound height alone. Debarked silver fir were found in areas A (2 out of 25), H (2 out of 32), K (2 out of 21) and R (2 out of 17). In area G, 134 silver fir were found, but not a single one of these trees was debarked. In the other areas, no silver fir were found at all. It remains unclear what species debarked the silver fir and in which areas and/or under what circumstances silver fir will get debarked. To find answer to these questions, more research should be done on this topic.

Both European hornbeam (21%) and European beech (19%) were regularly debarked. It is known that hornbeam is eaten by European bison (Kowalczyka et al, 2011; Krasińska et al, 2013). Less information was available on the debarking of European beech. Some European common elder (7.2%) was eaten by European bison. Litrature showed that other species of elder were eaten by European bison (Krasińska et al, 2013) but no literature on the European common elder was found.

A few oak trees were found, but none of these trees were debarked, although one tree showed tracks of rubbing by wild boar. Litrature suggests that at least European oak (*Quercus robur*) is eaten by European bison (Kowalczyka et al, 2011; M. Krasińska et al, 2013). There are several reasons that could explain why this result was not found. First of all, the sample size was under 20 oaks. It could be that there were too little trees to measure the frequency of debarking. Due to the onset of winter it was also not possible to determine which oak species were present. Therefor it might have been an other species of oak that the European bison does not debark. It could also have been that the European bison has a preference for age. Young trees might be more easy to debark. This research found mostly old oak trees that might be less attractive for European bison.

Research also showed that European bison does feed on the bark of willow trees (*Salix spec*) (Kowalczyka et al, 2011; M. Krasińska et al, 2013). No willow trees were found in this research, but willow trees are known to be growing in other areas of the Carpathians. Therefore, more reseach on debarking in willow should be conducted.

The size of the debarking per tree shows no significant difference between the different species. In beech, all three different density gradations showed a similar average wound size. However, in the other main species, this was not the case. Elder was only debarked in high density area L. Therefore, only an average wound size was determined for the high density area. In both Norway spruce and European hornbeam there seems to be a trend between higher wound size in the high density areas and a lower wound size in low density areas. This difference is not significant though. In silver fir, a different trend was seen, where the average wound size seemed to be higher in the low density area than in high density areas. However, this difference was also not significant.

There are a lot of outliers in wound size, primarily in beech. Outliers were mostly present in the high density area, which might indicate that the wound size increases if the number of trees available per individuals declines. Unfortunately there was no other evidence available to support this hypotheses.

Conclusion

What is the impact of debarking by European bison on tree mortality in the Bison Hillock of the Romanian Carpathians?

Debarking was most frequent in Norway spruce (28%), European hornbeam (21%) and European beech (19%). Therefore, it is to be expected that these species will be influenced the most by debarking. Both European common elder (7.2%) and European silver fir (3.4%) were less frequently debarked by European bison.

Norway spruce, European hornbeam and European beech are all common species in the Carpathian mountains. European common elder and silver fir are also frequently seen. These species all have either a least concern status or are not on the red list of species (IUCN RED LIST, 2018). Therefore, it is not to be expected that these species suffer from a small percentage of mortality due to debarking by European bison. However to be sure that these species do not suffer locally, or will not suffer in the future, a more in depth research could be performed.

The species birch (*Beluta spec.*), hazel (*Corylus spec*), oak (*Quercus spec.*) and willow (Salix spec.) could be debarked by European bison, but sample sizes in this research were too small to indicate if, and in what frecuency these species were debarked. Therefore this research could be repeated in differend areas and/or on a larger scale too measure the influence of European bison density on these species.

The size of the debarking per tree shows no significant difference between the different species. The different species showed either no difference in wound size across the area or only a small trend. Therefore, no clear conclusion could be made on wound size. It is not certain what factors contribute to wound size, and if wound size could be used to measure correlations between debarking and mortality in trees. The hypotheses that the wound size is bigger in high density areas could be tested in further research.

Recommendations

As previously discussed, there seems to be a trend between European bison density and the number of debarking spots found. If assumed that this trend shows a correlation, this would mean that the higher the European bison density gets, the higher the pressure on the forest gets. A little pressure on the forest can have a positive effect, resulting in new micro-habitats and increasing possibilities for biodiversity. However, too much pressure could possibly lead to deforestation(Katona et al, 2012; Stokland, Siitonen & Jonsson, 2012). Since there is a lot of (uncontrolled) logging present in the Carpathian forest, long term effects of these combined forces could lead to more trees dying, than new trees being able to grow.

For these reasons it is recommended to research the following topics:

- How does the density of European bison develop and how do the herds spread out through the Carpathians?
- What (other) migration possibilities are present for European bison in the Carpathians?
- What is the effect of current logging practices on the Carpathian forest?

These research topics could also contribute to current issues around the human-wildlife conflict between European bison and local farmers.

Bibliography

Bugalho, N. & Milne, J. A. (2003) *The composition of the diet of red deer (Cervus elaphus) in a Mediterranean environment: a case of summer nutritional constraint?* Forest Ecology and Management 181: 23-29

Eidt, D. C. & Weaver, C. A. A. (1993). *Control damage by seedling debarking weevil.* Canada: Canadian Forest Service.

Fehér, Á., Katona, K., Bleier, N., Hejel, P., & Szemethy, L. (2014). MONITORING OF UNGULATE IMPACT IN HUNGARIAN FORESTED NATURA 2000 SITES. *Review on Agriculture and Rural Development. 3(1)*

Fehér, Á., Szemethy, L. & Katona, K. (2016). *Selective debarking by ungulates in temperate deciduous forests: preference towards tree species and stem girth.* Springer, Berlin.

Garmin GPSMAP (64s) [GPS device]

Greenwood, J. J. D. & Robinson, R. A. (2006). Principles of Sampeling. From Sutherland, W. J. *Ecological Census Techniques Second edition* (p. 65).

Holzwarth, F. (2012). *Many ways to die – partitioning tree mortality dynamics in a near-natural mixed deciduous forest.* Journal of Ecology.

International Union of Forestry Research. (1963). Internationally dangerous forest tree diseases (911-940).

IUCN Red List of Threatened Species. (2017) *Search.* Retrieved at April 1st 2018, from: Http://www.iucnredlist.org/search

Jaroszewicz, B. (2013). *Endozoochory by European bison influences the build-up of the soil seed bank in subcontinental coniferous forest.* Springer.

Katona, K., Szemethy, L., Bleier, N. & Hajdu, M. (2012). *Can selective deer browsing be considered as damage in Carpathian forests?* St. István University Institute for Widllife Conservation, Hungary.

Kowalczyk, R. & Kerley G. I. H. (2017). De wisent, het legendarische beest in een moderne wereld. *Vakblad natuur bos landschap*, 138 (4- 6).

Kowalczyk, R., Taberlet, P., Coissac, E., Valentini, A., Miquel, C., Kamiński, T. & Wójcik J. M. (2011) I*nfluence of management practices on large herbivore diet—Case of European bison in Białowieża Primeval Forest (Poland)* Forest Ecology and Management, 261: 821-828

Krasińska, M. & Krasiński, Z. A. (2013) European Bison: The Nature Monograph.

Live Bison (2017) Live Bison (1.0.0) [App]. Accesed on November 20th, 2017

Miculescu, M. A. (2017)

Rans, W. M. & Vera, E. S. (2006). *Large herbivores: missing partners of western European light-demanding tree and shrub species?* Cambridge University Press.

Schmidt, A. (2014). How The Near-Extinct European Bison Made A Comeback. *the dodo*, 1-2.

Stockland, J. N., Siitonen, J. & Jonsson B. G. (2012) Biodiversity in Dead Wood.

Szemethy, L., Kovacs, I., Biro, Z. & Heltai, M. (2016). *The background for common integrated management of large carnivores and herbivores in the Carpathians.* Oradea, Romania: NORTH-WESTERN JOURNAL OF ZOOLOGY 12: 122-129.

The British Deer Society. (Not dated). *Fallow deer*. Retrieved at September 29th 2017, from: http://www.bds.org.uk/index.php/advice-education/species/fallow-deer

Unesco. (2016). *Ecological Sciences for Sustainable Development, East Carpathians*. Retrieved at at September 27th 2017, from Unesco: http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/europe-north-america/polandslovakiaukraine/east-carpathians/

Vasiliauskas, R. & Stenlid, J. (1998). *Discoloration following bark stripping wounds on Fraxinus excelsior.* Forest phatology.

Vera, F.W. M., Bakker, E. S. & Olff, H. (2005) *Large herbivores: missing partners of western European light-demanding tree and shrub species?* Cambridge University Press.

Vlasakker, J. V. (2014). *Bison Rewilding Plan 2014–2024.* Rewilding Europe, Nijmegen.

Waterpas (Version 3.14) [App]. Retrieved from Google Play Store on October 20th, 2017

Zielke, L. Wrage-Mönnig, N. & Müller, J. (2017). Seasonal preferences in diet selection of semi-free ranging European bison (Bison bonasus). *European Bison Conservation Newsletter.* 10 (61-70)