The perspective of forest regeneration with new wildlife migration possibilities

A research performed in "Het Nationale Park De Hoge Veluwe" on the effects on forest regeneration when free migration of ungulates is possible after putting two wildlife crossings into use

A thesis at the University of Applied Sciences Van Hall Larenstein

Bas Kuipers;
Frank van Wanrooij;
Laurens den Breeje.

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Colophon

A thesis at the University of Applied Sciences Van Hall Larenstein, under the direction of Ad Olsthoorn

Comissioned by "Het Nationale Park De Hoge Veluwe", under the direction of Jakob Leidekker

University of Applied Sciences
VAN HALL LARENSTEIN
PART OF WAGENINGEN UR

stichting het nationale park
de hoge veluwe

Preface

This thesis is submitted for the requirements for a Bachelor's Degree in "Forestry and Nature Management" at Van Hall Larenstein for the authors. The project was preformed from August 2012 until December 2012. Our supervisor on the project has been Jakob Leidekker head operational management at "Het Nationale Park De Hoge Veluwe". The thesis has been made solely by the authors.

We, Bas Kuipers, Frank van Wanrooij and Laurens den Breeje, contacted each other in April of the year 2012. Together we searched for a thesis assignment that suited us all. The product of the eventual thesis assignment is now in your hands. The project has been a great experience and we would like to thank the following persons that made this thesis possible:

- **Jakob Leidekker**, for giving us this opportunity and his excellent guidance;
- **Ad Olsthoorn**, for his guidance and his ideas that supported us during the writing of this thesis;
- **Jan den Ouden (WUR)**, for his guidance during the evaluation of the inventory method and also the compliment he gaves us for the dataset;
- **Johan Wensink**, for sharing his knowledge of the game animals in the NP;
- **Jaap Krul** and **Dirk Lieftink**, for the data of the game animals in Deelerwoud and Planken Wambuis and the tour in these areas.

We also like to thank the rest of the employees of Het Nationale Park De Hoge Veluwe for making us feel welcome in the organisation and facilitating our thesis.

Writing this thesis has been hard. But in the process of writing we feel we have learned a lot and our initial knowledge has changed and grown! We have dealt with a lot of subjects in an attempt to give this thesis a broad perspective. We hope that you as reader will have an interesting read.

Bas Kuipers, Frank van Wanrooij and Laurens den Breeje. Hoenderloo, December 2012

Summary

As part of the "Ecological main structure" the province of Gelderland strives to make the migration for ungulates possible on the Veluwe. "Het Nationale Park De Hoge Veluwe" (in this thesis shortened as "the NP") and "Vereniging Natuurmonumenten" are collaborating to reach this goal of the province of Gelderland.

2 wildlife crossings have been build, but are not yet operational because the fence around the NP is still in place. The fence will be lowered at the place of the wildlife crossings. These wildlife crossing make a connection across:

- The Delenseweg (N804), north of the military airport Deelen to the Deelerwoud of Natuurmonumenten.
- The Harderwijkerweg (N310), near Oud Reemst to the Planken Wambuis of Natuurmonumenten.

The NP has concerns about the effects that free migration of ungulates will have on Natura2000 species, Natura2000 habitats and on the forest regeneration/wood production. Mindful of these concerns, the NP started a multiannual monitoring program to the effects of free migration of ungulates. In 2011 the NP commissioned a study on the amount of browsing-, fraying- and bark stripping damage to regenerated trees caused by Red deer (*Cervus elaphus*) and Roe deer (*Capreolus capreolus*). The goal of the study was compiling a method to inventory the damage and to form a baseline for the multiannual monitoring program. However, the inventory of 2011 did not provide enough data to form a firm baseline and the developed method did not provided all the required data.

In this thesis the method of 2011 is revised and a total of 40 plots have been placed, marked and inventoried. In each plot the following measurements were performed on every tree:

- Tree species
- Height of the tree, divided in height classes
- Top shoot browsing
- Fraying damage
- Bark stripping

In this thesis a total of 13.211 regenerated trees are inventoried. Half of the inventoried trees are broad-leaved species (6.865) and the other half is coniferous species (6.346).

1.833 (13,87%) of all inventoried trees are browsed. 99,4% of the browsed trees are broad-leaved species. The higher the trees, the less browsing damage to the top shoot is found.

90 (0,68%) of all inventoried trees are frayed. There is no clear preference for broad-leaved species or coniferous species. The higher the regenerated tree, the more fraying damage is found.

Only 1 regenerated tree (Birch) is found with bark stripping damage.

In addition to the inventory a literature study was performed on the subject of migration and the ecology of Red deer, Roe deer and Fallow Deer (*Dama dama*) in order to give a preliminary estimation on the effects of free migration. Three possible scenarios are compiled. The scenarios, their effect on regenerated trees and the effects on forest development are:

Scenario 1: Fallow deer migrates from the Deelerwoud to the NP

Effects on regenerated trees:
- Less browsing on all regenerated trees
- The browsing on coniferous trees is negligible

Result on forest development:
- The effects on forest development are minimal

Scenario 2: Red deer is resting in the Planken Wambuis and is foraging in the NP

Effects on regenerated trees:
- Browsing on broad-leaved trees will increase
- Browsing on coniferous trees will increase

Result on forest development:
- Fewer broad-leaved trees will grow above browsing height
- The browsing on coniferous trees is still negligible for forest development

Scenario 3: The intended population sizes of the deer species are increased

Effects on regenerated trees:
- Browsing on broad-leaved trees will increase with a big amount
- Browsing on coniferous trees will increase

Result on forest development:
- Broad-leaved species are limited in height growth
- Broad-leaved species will decline in number
- The browsing on coniferous trees will damage the trees but the tree species will not suffer in numbers because of it.

A DVD is attached to the back of this report. This DVD contains: the dataset for the multiannual monitoring program, GIS data of the maps shown in the thesis, photos of the plots, the data per plot, the dataset of 2011 and the calculations, the graphs from chapter 4 "Results" and possible new plot locations.

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Table 2.2	www.hogeveluwe.nl Stichting Het Nationale Park De Hoge Veluwe, 2012[A] Stichting Het Nationale Park De Hoge Veluwe, 2012[B] Lieftink, 2012 Spek, 2012

Chapter 1 Introduction

In this chapter the backgrounds, the problem definition, the framework and the goal of this thesis are discussed. Furthermore, the main research question and sub-questions of this thesis are presented.

There are terms used in this thesis were the definition of the term is open to interpretation which could lead to confusion. To avoid this confusion a definition list of used terms can be found in attachment 2.

1.1 What led to the drafting of this thesis?

As part of the "Ecological main structure" (in Dutch called "Ecologische Hoofdstructuur" or "EHS") the Province of Gelderland strives to make the migration for wild ungulates possible on the Veluwe. This is in line with the policy document "Veluwe 2010" which includes the project "Hart van de Veluwe". "Het Nationale Park De Hoge Veluwe" (in this thesis shortened as "NP") and "Vereniging Natuurmonumenten" are collaborating to reach this goal of the Province of Gelderland (Groot Bruinderink, et al., 2008). Migration routes are planned between the NP and the surrounding areas (see figure 1.1) (Vreugdenhil, et al., 2000):

1. Accross the Delenseweg (N804), north of the military airport Deelen, to the "Deelerwoud" of Natuurmonumenten. This connection (a wildlife crossing at ground level) is already realized.
2. Accross the Harderwijkerweg (N310), near Oud Reemst, to the "Planken Wambuis" of Natuurmonumenten. This connection (a wildlife bridge) is already realized.
3. Accross the Apeldoornseweg (N304), to the military base and practice ground "De Harskamp". This connection is not yet realized and therefore it is not taken account in this thesis.

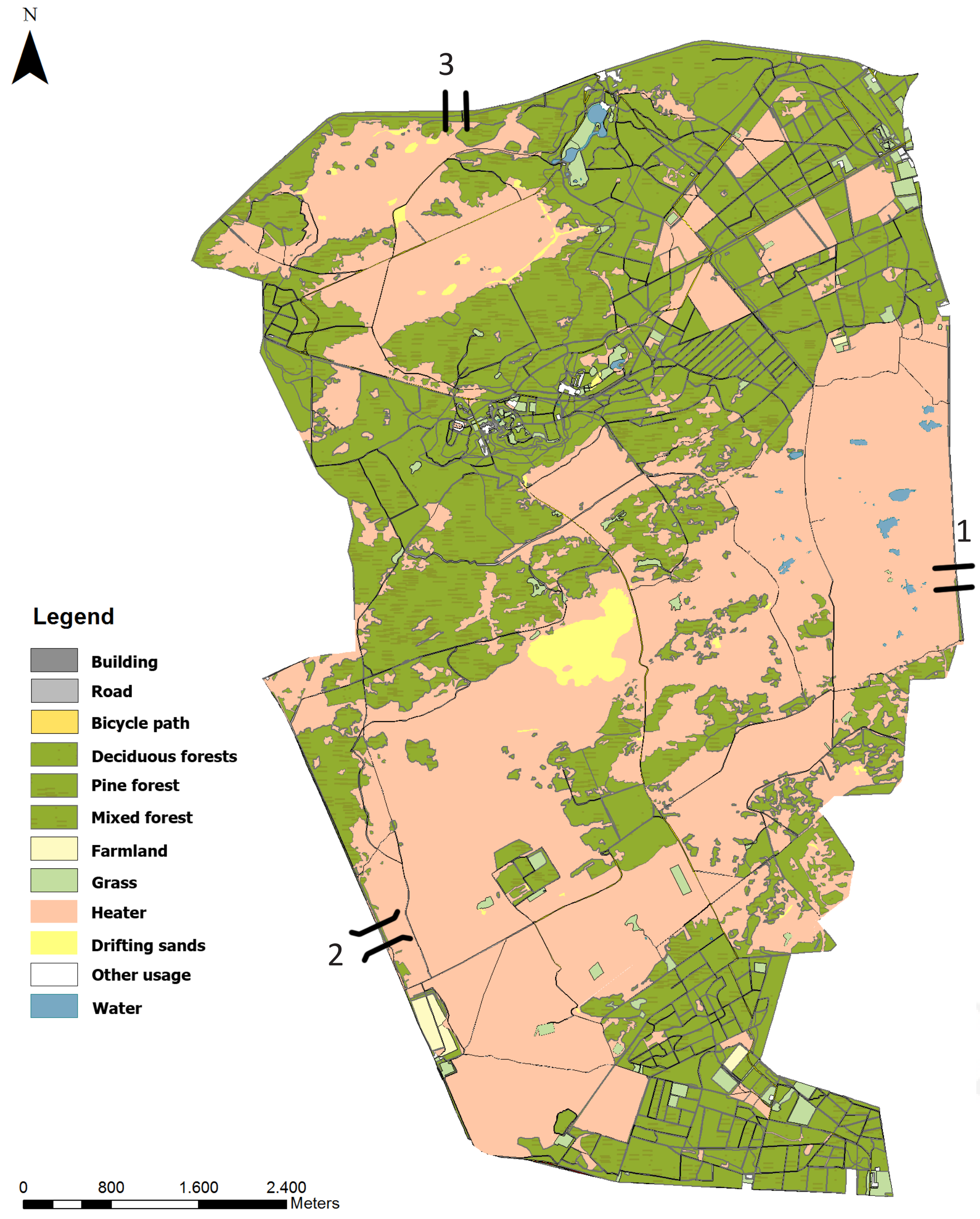


Figure 1.1: The location of the wildlife connections

The wildlife crossings are necessary for the wildlife connections. The wildlife crossings make it possible for the ungulates to cross the road safely. Before the wildlife connections can be used the fence surrounding the NP needs to be lowered at the wildlife crossings.

The lowering of the fence around the NP at the Delenseweg and Harderwijkerweg was planned for October 2012 (Leidekker, 2012). This date has not been achieved because the preperations were not ready in time.

The NP agreed to wildlife migration if a multiannual monitoring of the migration of Red deer (*Cervus elaphus*), Roe deer (*Capreolus capreolus*), Fallow deer (*Dama Dama*) and Wild boar (*Sus scrofa*) is performed. The Mouflon (*Ovis gmelini musimo*) is restrained from migration. Swing gates (see figure 1.2) placed by the wildlife crossings must prevent the Mouflon from getting through, while the Wild boar will be able to pass (Wensink, 2012). Red deer, Roe deer and Fallow deer can jump over the lowered parts of the fence. This part is lowered from 2 meters high to 1 meter high. Infrared cameras with movement detection have been placed at the wildlife crossings (see figure 1.3) to monitor the migration of the ungulates. These cameras are not operational at the time of this thesis.

The condition of monitoring was introduced because the NP has to adhere to European obligations. These obligations state that the NP has to maintain the present Natura2000 species and habitats. The NP has concerns about the effects that free migration of ungulates will have on Natura2000 species, - habitats and the forest regeneration/wood production (Leidekker, 2012). To give insight into the concerns about the forest regeneration/wood production the NP set up a multiannual monitoring program and commissioned a study on the amount of browsing-, fraying- and bark stripping damage to regenerated trees caused by ungulates. This study was performed in 2011 by Stefan Pronk student at "Hogeschool INHolland Delft" (Pronk, 2012). He compiled a method to inventory the damage and used this method to inventory 19 plots.


Figure 1.2: The swing gate at the wildlife crossing by the Delenseweg


Figure 1.3: The infrared camera by the Delenseweg

1.2 Problem definition

The goal of the inventory performed in 2011 (Pronk, 2012) was to form a baseline for the multiannual monitoring program. The data from the following years can be compared with the baseline to give insight and possible answers on what the effects of free migration are. However, the method used in the inventory of 2011 did not provide enough data to make a firm baseline.

1.3 Framework

As part of the final phase of the program "Bos- en Natuurbeheer" at Van Hall Larenstein (hereinafter called "VHL") the students Bas Kuipers, Frank van Wanrooij and Laurens den Breeje write a thesis for the NP.

1.4 Goals of this thesis

This thesis has the following goals:

- To evaluate and supplement the method used in the inventory of 2011 on browsing-, fraying- and bark stripping damage to regenerated trees caused by ungulates
- To gather sufficient data needed to make a baseline usable for the multiannual monitoring program
- To provide theoretical insight into the potential effects free migration of ungulates can have on forest regeneration and forest development

The target audiences for this thesis are the (nature) management personnel of the NP and the researchers preforming the inventory in the future. Furthermore the research is performed in conduct with the guidelines for a graduation research given by VHL.

1.5 Research questions

Main research question

'What are the effects of free migration of ungulates on the forest development in "Het Nationale Park De Hoge Veluwe"? '

Sub questions

- What additions and changes can be made to the method used in 2011?
- How much browsing-, fraying- and bark stripping damage to regenerated trees caused by ungulates is there currently in the NP?
- What is the relation between the current browsing-, fraying- and bark stripping damage and the density of deer species in the NP?
- What effects can free migration of ungulates have on the population size and/or composition of deer species in the NP?
- What are the effects on forest development if the deer population and/or deer composition changes?

1.6 Conditions

- In this thesis there is not enough time available to thoroughly research all the questions the NP has. Therefore the thesis is focused on the required method for the inventory, the completing of the baseline and a preliminary estimation of the potential effects free migration of ungulates will have on the forest regeneration and the forest development within the NP
- The research will be carried out within the fences of the NP
- The extend in which data is collected for the baseline is within the demands of the NP and realistic within the given time for the thesis
- The thesis is performed according to the graduation guidelines of VHL and within the demands of the NP
- After the opening of the migration routes no new data will be added to the baseline
- The collection and processing of field data needs to be replicable in the most accurate way possible. This way, a reliable database can be formed over the years
- The project focuses itself on forest regeneration. Regenerated trees on heathlands and drifting sands are not inventoried

1.7 Assumptions

The following assumptions are made for this thesis:

- **"The whole of the NP is viable habitat for Red and Roe deer."**
  This assumption is applicable in calculations where the surface area of the NP is used. The total of 5.000 hectares of the NP is used and not the surface area that is actually usable habitat for the deer species. In reality not the whole NP is usable habitat for Red deer and Roe deer because some parts of the NP are fenced in. Other parts are not suitable because there is no food or coverage like on the drifting sands. Extensive research is needed to indicate the area of usable habitat. There was no time available in this thesis to perform this research.

- **"No ungulate can cross the fence that surrounds the NP"**.
  In theory a Red deer cannot jump over a fence of 2 meters in height. When in reality they can (Wensink, 2012). However, this seldom happens.

- **"The effects of Wild boar and Mouflon on established regenerated trees in the forest are negligible".**
  Wild boar and Mouflon are also present in the NP. Wild boar does not have a substantial effect on established forest regeneration. Wild boar does however influence new regeneration by creating seedbeds through grubbing. Also wild boar influence the quantity and the composition of forest regeneration by eating seeds. By the time the regeneration is established the Wild boar has no big impact anymore (Ouden, 2012).
  Mouflons forage mostly on heathlands (Wensink, 2012; Jansen, et al., 2012). It can be said that the effects of Wild boar and Mouflon on established regenerated trees in the forest are negligible (Ouden, 2012). Therefore Wild boar and Mouflon are not taken into account in this thesis.

- **"Red and Roe deer only eat trees"**.
  Red deer and Roe deer eat more than just trees. Other vegetation throughout the NP like grass and herbs are essential food sources. Red deer have a balanced diet with a certain proportion of "juice food" and "high fibre food". Trees are part of the high fibre food and they cannot be replaced with juice food (Wensink, 2012). In this thesis other food sources are not inventoried or taken into account in the calculations. This is done because of 2 reasons: firstly, this thesis is only focused on the effects of free migration on the regenerated trees, on the forest development and on the deer species. Secondly, the proportion of juice and high fibre food is invariable. This means that when the amount of consumed high fibre food (regenerated trees) changes, the amount of consumed juice food (grass and herbs) changes in the same proportion.

Chapter 2 Theoretical framework

This chapter contains background information concerning deer species present in the NP and the surrounding areas. This information is required for a correct interpretation of the results which are presented in chapter 4 “Results”.

Paragraph 2.4 “Traces of browsing, fraying and bark stripping” contains examples of different kinds of damage to regenerated trees. Recognizing these damages is necessary to be able to repeat the inventory in the following years. This information is an addition to the inventory method which is presented in chapter 3 “Method”.

2.1 Ecology of deer species

Species	Feeding behaviour	Social behaviour	Period of fraying	Additional information
Red deer	• Intermediate feeder[6] • Browsing up to 2 meters high[4]. • Not a picky eater[7] • 1 Red deer is equivalent to 2 Fallow deer [14]	• For the bigger part of the year males (stags[9]) live in groups (herds[9]). Females (hinds[9]) with young ones (calfs[9]) live in other herds • Home-range approximately 500 ha[10] • In August the male groups disperse. In the mating season (the rut[9]) in September and October males join groups of females to impregnate fertile females. In this period the males are hostile to other males[1]	• Adult males rub the velvet off their full-grown antler in the second half of July • Young males do this in August and September[7]	
Roe deer	• Browser[6] • Browsing up to 1.20 meters high[4] • A very picky eater[8]	• Both male (buck[9]) and female (doe[9]) are territorial to other Roe deer from the same gender from April until November. The rest of the year Roe deer can live in groups (herds[9]), which can vary in size and composition • The need to form groups is stronger in an open landscape than in a forest[7] • Home-range approximately 20 to 30 ha[13]	• Males rub the velvet off their full-grown antler between January and April • From April until November adult males mark their territory by fraying[7]	• The Roe deer is sensitive for stress and disturbances caused by humans and other ungulates [8]
Fallow deer (absent in the NP)	• Intermediate feeder[6] • Browsing up to 1.50 meters high[3] • Not a picky eater[2] • More of a grazer than a browser compared to Red deer[7], especially in winter[5] • 2 Fallow deer are equivalent to 1 Red deer [14]	• Males (bucks[9]) and females (does[9]) with young ones (fawns[9]) live in seperate groups (herds[9]) • Home-range of males approximately 1.000 ha and of females approximately 200 ha[12] • In the mating season (the rut[9]) a male conquers a small spot in a "central mating area" and he waits for females to wander in this spot. Males are territorial to other males in this period. • When living in low density the behaviour during the rut is similar to the Red deer[2]	• Males rub the velvet off their full-grown antler in August or the beginning of September[2]	• Can live in high density up to 180 animals per 100 ha[5] • Is curious and explores new areas[2]

Table 2.1: Ecology of deer species.

References: 1 (Borst, 2010), 2 (Hoorn, 2006), 3 (forestry.gov.uk), 4 (Pronk, 2012), 5 (Minderhoud, 2009), 6 (Wieren, 1997), 7 (Borst, 2008), 8 (Velde, 2008), 9 (bds.org.uk), 10 (Hennepe, 2012), 11 (kenniscentrum-reeen.nl), 12 (Borkowski, 2007), 13 (Saïd, 2005) 14 (Vergeniging het Edelhert, 2011).

Factors on density of deer populations

The density of the ungulates and therefore the (browsing) pressure on the vegetation depends on more than one factor. Figure 2.1 shows all the factors that have an effect on Roe deer population and the ways in which they can affect each other. The causes of wildlife damage are integrated in a complex structure, which is composed of a plurality of individual factors. When researching wildlife damage these factors should not be treated individual but they should be treated as an entire interactive system. Therefore it cannot be said which factor is more important. However it can be said that without deer there is no browsing.

In this thesis the factors on the deer density and amount of browsing damage are taken into account for both Roe and Red deer in order to give a complete answer to the main research question (see paragraph 1.5 "Main research question").

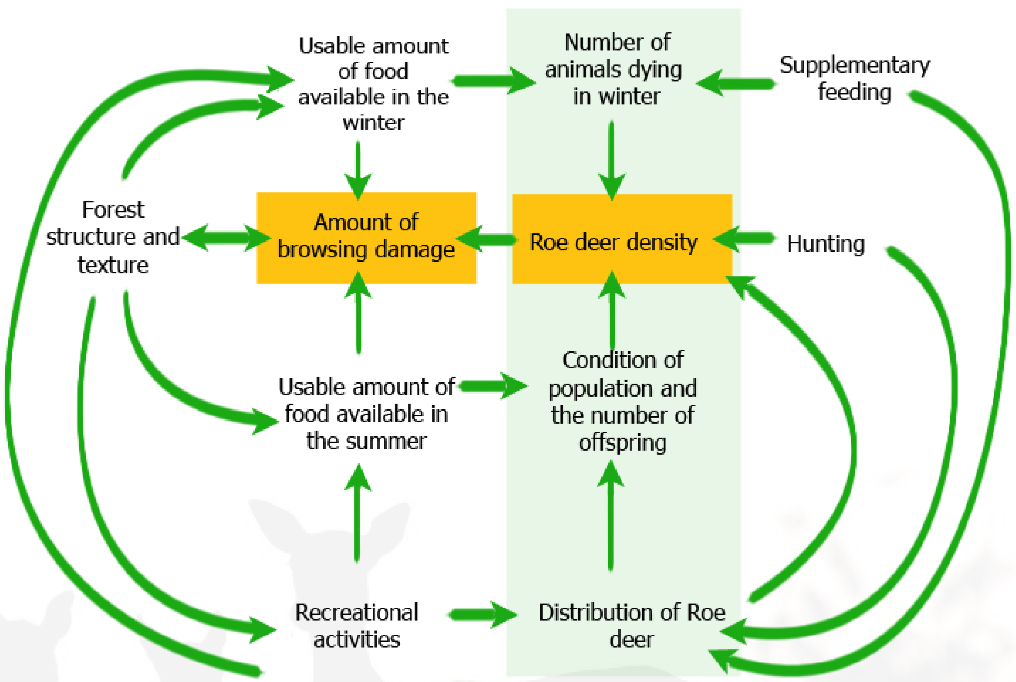


Figure 2.1: Factors on Roe deer population and how they can affect each other

2.2 Population size

The numbers in table 2.2 are the corrected spring countings of 2012. The intermediate feeders are the number of Red deer plus half the number of Fallow deer. This because 2 Fallow deer equals to 1 Red deer in food consumption. The number of browsers is equal to the number of Roe deer. This is because Roe deer is the only browser for deer species.

	The NP		Deelerwoud		Planken Wambuis	
	5000 ha [1]	Per 100 ha	1350 ha [3]	Per 100 ha	±2270 ha [3]	Per 100 ha
Red deer	196 [2]	4	280 [5]	21	162 [4]	7
Roe deer	183 [3]	4	± 35 [4]	± 2,6	± 75 [4]	3
Fallow deer	0 [2]	0	287 [5]	21	0 [4]	0
Total deer species	379	8	602	45	237	10
Intermediate feeders	196	4	424	31	162	7
Browsers	183	4	± 35	± 2,6	± 75	± 3,3

Table 2.2: Population in spring 2012. Reverences: 1 (hogeveluwe.nl), 2 (Stichting Het Nationale Park De Hoge Veluwe, 2012[a]), 3 (Stichting Het Nationale Park De Hoge Veluwe, 2012[b]), 4 (Lieftink, 2012), 5 (Spek, 2012).

2.3 Population management of ungulates

2.3.1 The NP

The NP has set a base population size of 200 Red deer, 50 Wild boar and 200 Mouflons (Beek, 2009). For Roe deer no base population size is set. Deer and Mouflon populations are rather stable throughout the years. The population size of Wild boar can however fluctuate because off the growth increase when there is enough food. When there is a mast year the population of Wild boar can increase with 225% (Borst, 2008). Secondly the set base population is not always reached. This is caused by the difficulty of hunting the Wild boar.
Since 1998 the NP has stopped actively hunting Roe deer. Only sick or hurt Roe deer are shot, which are approximately 10 to 20 animals each year (Velde, 2008).
In the NP the used hunting methods are stalking and stand hunting. Stand hunting is the preferred method (Wensink, 2012). Hunting happens with “guest hunters”. These guest hunters hunt by stand hunting, while the game keepers prefer stalking.
The NP hunts in the period from the 1st of August till the 1st of September and from the 1st of October till the 15th of February. This means that the deer can take part in the rut without disturbance. (Wensink, 2012).

2.3.2 Deelerwoud

Natuurmonumenten stopped with hunting on all deer species in the Deelerwoud as an experiment in 2001 (Huysentruyt, 2011). The populations are allowed to grow and the effects are monitored. This experiment has been evaluated in 2006 (Belle, 2006) and in 2011 (Huysentruyt, 2011). The management policy of the experiment is adopted for now. To what extent this policy of no hunting will be maintained, is not decided yet (Krul, 2012).

2.3.3 Planken Wambuis

The Planken Wambuis is part of the Natuurmonumenten management area southwest Veluwe. For the entire southwest Veluwe a population size is set of 205 Red deer and a flexible population size between 60 and 100 Wild boar. The population of Roe deer regulates itself naturally and no base population size is set. There is no base population size set specifically for the Planken Wambuis (Lieftink, 2012).
In the Planken Wambuis the preferred hunting method is stalking (Lieftink, 2012). In the Planken Wambuis the hunting is only preformed by the game keepers. The Planken Wambuis uses as hunting period the 1st of August till the 15th of February (Lieftink, 2012).

2.4 Traces of browsing, fraying and bark stripping

The following paragraphs give the definition and images of browsing- fraying- and bark stripping damage.

2.4.1 Browsing damage

Definition

In this thesis “browsing” refers to the feeding or gnawing by ungulates on buds, foliage and twigs of the top shoot of regenerated trees. The top shoot is the dominant vertical on-going shoot of the tree.

Difference between deer and rodent browsing

During the inventory browsing caused by rodents is found. The difference between browsing caused by ungulates and browsing caused by rodents is easily distinguished.
All deer species produces a ragged edge on browsed twigs. This is because of the lack of teeth in the front upper jaw. The front teeth of rodents (like rabbits) produce a sharp knife like cut (forestry.gov.uk). Examples are given in figure 2.2.

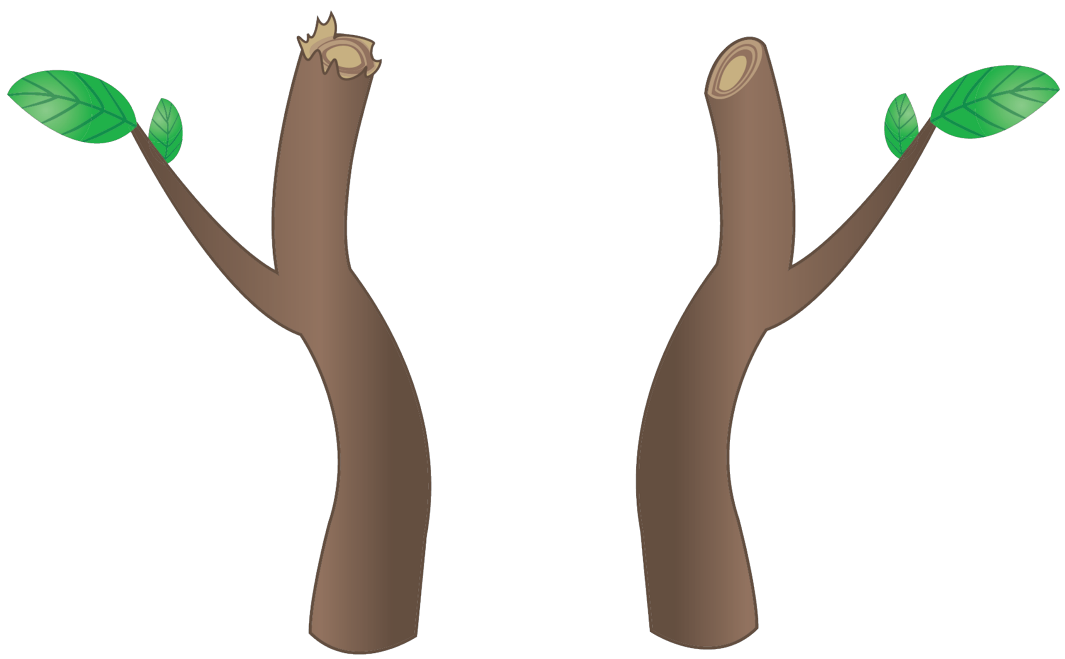


Figure 2.2: Differences in browsing damage. Left deer, right rodent.

Height of browsing

The height of browsing damage can be an indicator for the deer species responsible for the damage. Red deer can reach 2 meters high, Fallow deer can reach 1.50 meters and Roe deer can reach 1.20 meters as shown in figure 2.3.

If a tree is above the maximum browsing height only lower branches can be browsed and the top shoot cannot be reached. Figure 2.4 shows a Holly where the branches are browsed every year but the top shoot is above browsing height.

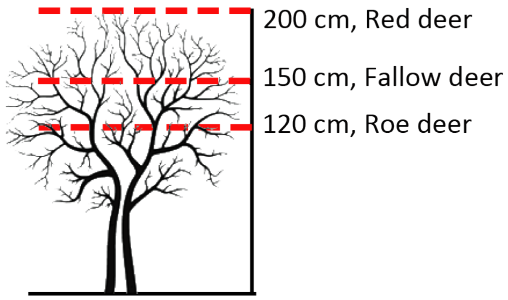


Figure 2.3: Maximum browsing height

Figure 2.4: Top shoot above browsing height.

Moment of browsing

When the dominant bud on the top shoot is not browsed this bud will continue with the length growth in the following growing season. When the dominant end-bud on the top shoot is browsed a sub-dominant bud takes over the length growth in the next growing season and becomes the new dominant top shoot. A distinction is made in which year the browsing damage has occurred. In this thesis this was either:

- In 2011, shown in figure 2.5
- In 2012, shown in figure 2.6
- In both years, shown in figure 2.7

In next year's inventory (during summer or autumn 2013) browsing damage in the years 2012 and 2013 or both of these years are inventoried.

In figure 2.6 an end-bud is shown that is browsed in the year 2011 (red circle 1). In the next growing season (in 2012) a sub-dominant bud took over the length growth. This new dominant shoot has not been browsed in this year (in 2012). During the inventory this tree is recorded as "browsing 2011".

Figure 2.5: Browsing damage done only in 2011.

In figure 2.7 an end-bud is shown that is browsed in the year 2012. During the inventory this tree is recorded as "browsing 2012". In the next growing season (in 2013) a sub-dominant bud will take over the length growth.

Figure 2.6: Browsing damage done only in 2012.

Figure 2.8 shows an example of a top shoot browsed in 2011 (see red circle 1) and in 2012 (see red circle 2). After the dominant bud on the top shoot was browsed in 2011 a sub-dominant bud took over the length growth of the shoot in 2012. During the inventory this tree is recorded as "browsing 2011 and browsing 2012".

Figure 2.7: Browsing damage done in both 2011 and 2012.

If a tree was browsed more than two years ago the tree was not recorded as browsed. This is presented in figure 2.8.

Figure 2.8: Browsing damage done several years ago.

Complex example

Categorizing these damages is not always easy. Figure 2.9 shows an example of a regenerated tree which is difficult to categorize. The top shoot of this tree has been browsed in 2011 (see red circle 1). A sub-dominant bud took over the length growth. This is the twig with the red circle 2 at the end. In 2012 the top shoot was spared (red circle 2). So there is browsing in 2011 and not in 2012. Also the lower shoot has been browsed in 2012 (red circle 3). No sub-dominant bud has taken over the length growth, this will happen next growing season. Because this shoot is not the top shoot the damage is not noted as browsing damage.

In the inventory of this thesis this tree was noted as “browsed in 2011“ but not browsed in 2012.

Figure 2.9: End-bud of top shoot intact.

Intact end-buds

In some cases only the foliage is browsed and the buds are still intact as shown in Figure 2.10. This kind of damage has no effect on the future shape of the tree. Therefore the damage has no effect on the suitability for wood production. This kind of damage has not been counted as browsing damage in this thesis.

Figure 2.10: Browsed foliage

Tree species

In the NP mostly broad-leaved tree species are browsed (as shown in graph 4.12). But also coniferous tree species are browsed as shown in the figure 2.11 and 2.12.

Figure 2.11: Browsing damage on Larch.

Figure 2.12: Browsing damage on Douglas fir.

Figure 2.13: Frayed small tree.

Figure 2.14: Frayed tree with carvings.

2.4.2 Fraying

Fraying is the act of rubbing antlers to a tree trunk or branch in order to remove 'velvet' from the new antlers or to mark territories (Wensen, 2012; forestry.gov.uk). Examples of fraying damages can be seen in figure 2.14, 2.15 and 2.16.

The deer species in the NP are mostly bound to the "animal retreat zones" during the day to avoid contact with visitors. While waiting for the people to leave the NP the deer can fray trees out of boredom (Wensink, 2012).

Fraying damage can look like damage caused by other factors like logging activities. To distinguish fraying from other types of damage the surroundings can be observed for traces that indicate the cause of the damage. For example when there is a harvester path the assumption can be made that the damage is caused by a harvester.

Traces that indicate fraying are pieces of bark left on the upper side of the damage (as seen in figure 2.13) and/or carvings in the tree trunk (as seen in figure 2.14). However, this is not always clear to see. Therefore, the surrounding must always be observed for other causes that may have caused the damage.

Sometimes the top is broken because of fraying (as seen in figure 2.15). When this was encountered the current height was measured and if possible a note was made of the original height.

Figure 2.15: Broken top shoot because of fraying.

2.4.3 Bark stripping

When food is scarce or when there is a shortage of certain nutrients ungulates are likely to strip the bark of tree trunks and branches (Figure 2.16). This is mostly done in winter. Deer species use the incisors in the lower jaw to strip the bark (Borst, 2010). After one or two growing seasons the teeth marks fade away (Pronk, 2012).

Figure 2.16: Stripped trees

Chapter 3 Method

No research can be conducted without set guidelines and fixed measures. This chapter gives an overview of these guidelines and measures. The first part of this chapter explains why the NP is divided into sections, the way in which the location of a plot is chosen, how a plot is set up and how the name of a plot is defined. The second part of this chapter will present the parameters and the way data on these parameters is collected. Finally, justification of any changes to the method used in 2011 (Pronk, 2012) are given.

3.1 Sections

Just as in the inventory of 2011 (Pronk, 2012) the NP is divided into 3 sections. Due to the lack of visual reference points in the field the section borders were altered in 2012 to improve the efficiency of future inventories. The borders have been altered to run along clearly recognizable landmarks. For example bicycle paths or natural borders between the forest and heather fields. Figure 3.1 gives an overview of the position of these new section borders. The placement of these borders was influenced by two main factors, namely: dominant tree species and soil characteristics. These two factors play a large role in the tree regeneration and the composition of tree species. The composition of the forest regeneration is one of the major factors which creates habitat suitability for Roe deer and Red deer (Ouden, 2012). It is also possible to process data per section.

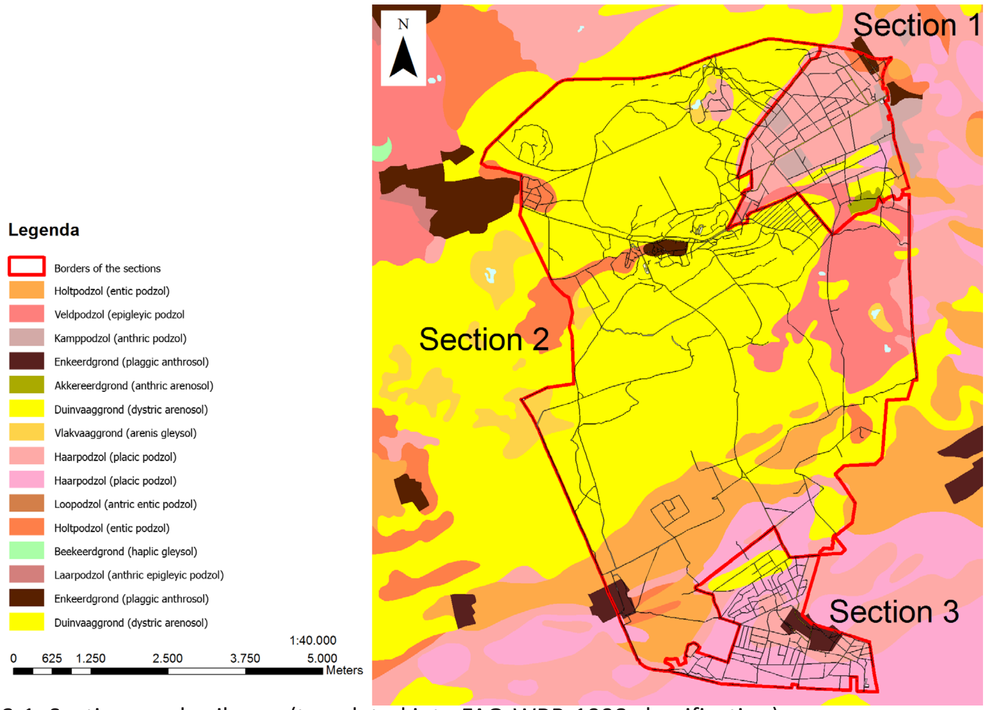


Figure 3.1: Sections and soil map (translated into FAO-WRB-1998 classification)

3.2 Research areas

This thesis is part of a multiannual monitoring program which started in the fall of 2011. Part of this monitoring program was the inventory of 19 plots to create a baseline for the multiannual monitoring program. Because the inventory of 2011 did not provide enough data to form a baseline 21 new plots were added to the 19 existing plots. The locations of these plots were selected using the following conditions:

- The plot is located within the fence of the NP
- The plot is located in the forest (for example not in heather fields)
- The plot is accessible for both Roe deer and Red deer, with the exception for plots placed in exclosures
- The plot contains regeneration with a height of more than 10 cm
- The majority of the regeneration is smaller than 2 meters in height
- The regeneration surface area is big enough to contain all of the subplots (see sub paragraph 3.3.2 “Setup and orientation of a plot”) preferably in the direction north to south (24 meters long)

In addition to these conditions other factors played a role in the choice of the plot location. These factors are described below:

- When choosing a location the number of regenerated trees in that location is important. The more trees present, the more potential data can be gathered
- Some areas in the NP are off-limits for visitors. These areas serve as a retreat for the animals. The animals are bound to these areas for the bigger part of their day (Wensink, 2012). For these areas it is assumed that there is a bigger potential for browsing-, fraying- and bark stripping damage. Where possible at least one plot is placed in each ”animal retreat zone”
- The NP made exclosures to either observe the potential growth of tree regeneration or to protect young planted trees. Both have the purpose to protect an area against influences from ungulates. When the circumstances both inside and outside the exclosure are the comparable, 1 plot is placed inside the exclosure and 1 plot is placed outside. Both inventories can be compared to measure how much influence browsing has on forest regeneration in that area (Suchant, et al., 2011)
- All plots are evenly spread over the NP, within the sections, over the dominant tree species and broadleaf and coniferous trees

3.3 Inventory method

This paragraph explains what a plot looks like, how the plot is set up and how a plot is named.

3.3.1 Dimension of the plot

A plot is a large rectangle which is divided into 6 subplots. Each subplot is 3 meters wide and 4 meters long. A whole plot is 24 meters long (see figure 3.2). The subplots are numbered 1 to 6 from north to south.

3.3.2 Setup and orientation of the plot

If an appropriate location is found a wooden post with a white top is hammered into the ground in the middle of the north side of the plot. On the top of this northern wooden post the name of the plot is written with a red permanent marker. From this northern post an orange polyester string of exactly 24 meters long is rolled out in southern direction, specified with a compass. This string is used to define the length and orientation of the plot and to divide the plot into 6 subplots. For the division of the subplots, knots have been placed in the string every 4 meters. When this is done, 3 meter long PVC pipes are placed right-angled under each knot to mark the width of the individual subplots. The plots can be seen in figure 3.3 and figure 3.4.

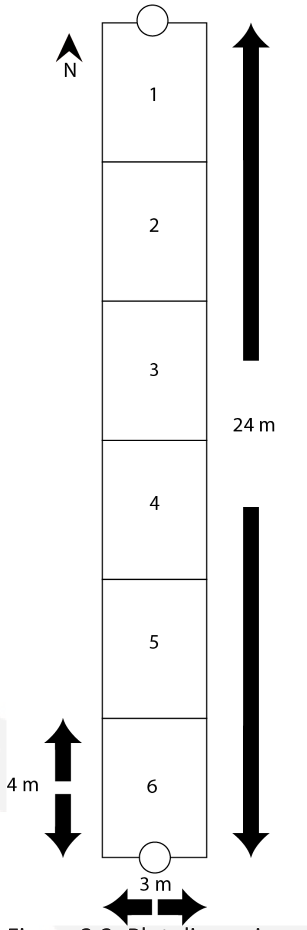


Figure 3.2: Plot dimensions

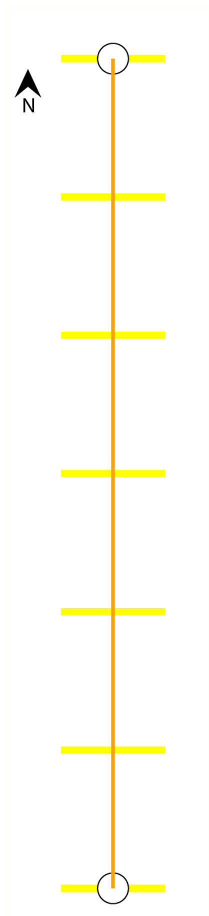


Figure 3.3: Plot in theory

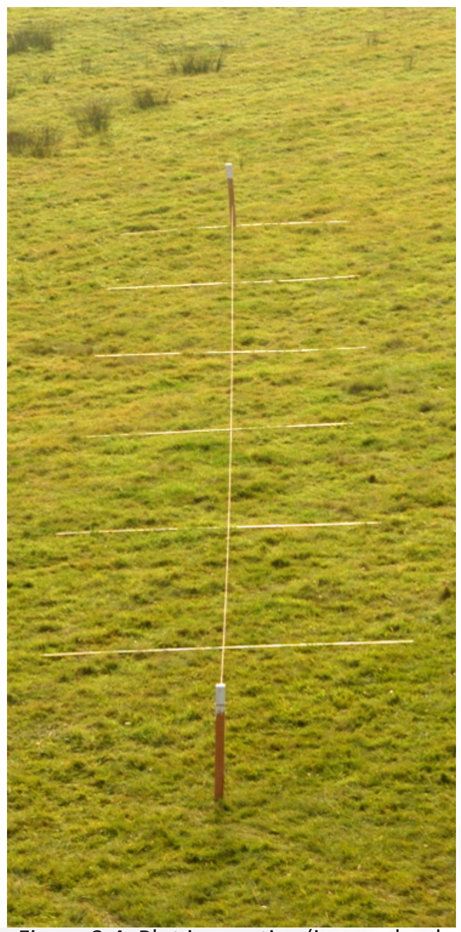


Figure 3.4: Plot in practice (in grassland for demonstration purposes

3.3.3 Appointing plot names

Each plot has an unique name in order to distinguish the plots. The names of these plots correspond with the management sections and divisions in the NP. These management sections can be found on the management map. For example if a plot is placed in management section 2E, the plot number will be called 2E. If two plots are placed in one management section a Roman numeral is added. For example “2EI” and “2EII”.
If a plot is placed inside an exclosure, instead of adding a Roman numeral the Dutch word “omrasterd” (which means exclosed) is added. In addition to the name each plot has a sequential number from 1 to 40 (see attachement 1 “Plot information).

3.4 Measurements

Data is collected both inside each subplot and outside the main plot (subplot 1 till 6). The data measured outside the main plot consist out of general measurements and surrounding factors that can influence the data that is measured in each subplot. The measurements for the browsing-, fraying- and bark stripping damage are performed inside each subplot. The description of the method for these measurements is split into 3 subparagraphs. First general (paragraph 3.4.1) and surrounding measurements (paragraph 3.4.2) will be handled and afterwards the measurements inside the subplots will be covered (paragraph 3.4.3).

3.4.1 General measurements

GPS

In this thesis a Garmin “GPSmap 62s” (Figure 3.5) is used for marking waypoints and measuring surface area.

Figure 3.5: Garmin GPSmap 62s

Waypoints

The GPS is used to mark waypoints. These waypoints mark the location of the Northern wooden post of the plots. The waypoints can be used in follow up research to find the plots.

Measuring of surface area

The GPS is used for measuring the surface area of natural or manmade gaps in the canopy and for measuring exclosures. When the surface area measurement function is activated the person carrying the GPS walks around the gap from canopy to canopy (see figure 3.6). When mapped the surface area is automatically calculated by the GPS.
The NP uses the single tree selection method (Leidekker, 2012). This can create a situation where an open forest is present. When this is the case the surface area is not measured.

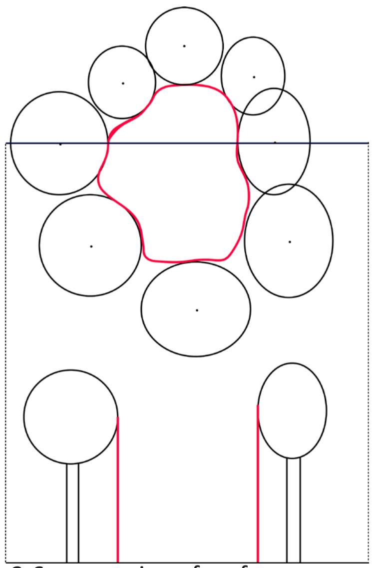


Figure 3.6: measuring of surface area

Direction plot

The direction of the plot is set out with the help of a compass (Figure 3.7). This is done every time a plot is set up to make sure that the plot is aligned exactly north to south. When this exact alignment is not possible the plot is first setup in a different alignment (for example east-west). Afterwards the compass is used to determine the degrees.

Figure 3.7: Compass

Visualization

In order to visualize the location of the plot and its surroundings there are a minimum of five pictures taken:

- one of the Northern wooden post with the name of the plot on it
- one to the north
- one to the east
- one to the south
- one to the west

The picture of the wooden post is used to identify at which plot the other pictures are taken.
The camera used in this thesis is a Pentax K100d with an 18-55 mm lens. The pictures are taken with the lens set at 18 mm and the camera mounted on a tripod. The tripod is consequently set at the maximum height so that the pictures are taken at 1,87 m. The tripod is setup above the Northern wooden post (Figure 3.8).

Figure 3.8: Camera on tripod

3.4.2 Measurements for surroundings

From the Northern wooden post a circle is measured out with a radius of 25 m (see figure 3.9). This circle has a surface area of 1.964 m^2. Inside this circle the following measurements are taken:

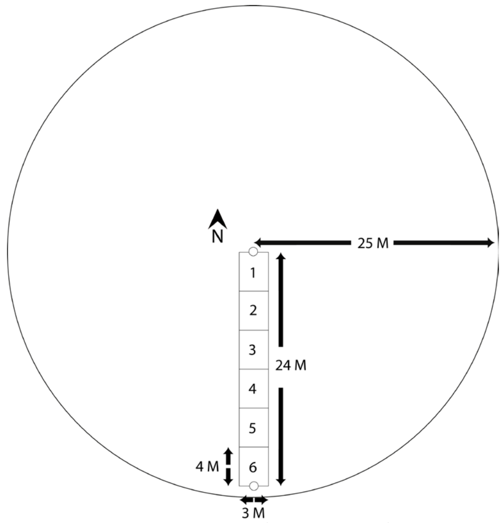


Figure 3.9: Transect with 50 m Circle

Coverage

The coverage of the canopy- and the shrub layer is estimated in percentages (20 m^2 coverage equals 1%).
The canopy layer includes all wooden plant species with a height of more than 5 meters.
The shrub layer includes all wooden plant species with a height between 10 cm and 5 meters.
The same is done for ground coverage. For 3 groups the coverage is estimated in a percentage:

- Blue/red berry
- Grass species
- Other:
  - Moss
  - Heater
  - Litter
  - Bare ground
  - Woody debris

It is possible that the total ground coverage exceeds 100% because these groups can overlay.

Dominant and sub dominant tree species

The dominant and sub-dominant tree species in the canopy layer inside the circle are noted.

Dominant tree species height

The height of one tree is measured. This tree belongs to the dominant tree species. This tree is chosen at random with an estimation on average height in mind. A clinometer is used to measure the tree height.

Anthropogenic influences

All anthropogenic influences within a radius of 100 meters around the plot are noted. Only anthropogenic influences that have a potential effect on ungulates or the forest regeneration are noted. For example: logging activities or bicycle paths.

3.4.3 Measurements inside the subplots

For each regenerated tree inside the subplots the following measurements are taken:

- Tree species
- Height class (see table 3.1 and figure 3.10)
- Top shoot browsed in 2011 (see sub paragraph 2.4.1 "Browsing damage")
- Top shoot browsed in 2012 (see sub paragraph 2.4.1 "Browsing damage")
- Fraying damage (see sub paragraph 2.4.2 "Fraying")
- Bark stripping damage (see sub paragraph 2.4.3 "Bark stripping")
- If bark stripping or fraying damage is present the begin and the end height is noted.

Height class	Height in cm
1	10 - 40
2	41 - 80
3	81 - 120
4	121 - 160
5	161 - 200
6	>200

Table 3.1: Height classes

Description of height class measuring tool

The tool for measuring tree height classes is a 2.10 m long PVC pipe.
The red part of the tool is pointed downwards and represents the 10 cm where trees are not measured.
Counting from this red part the first brown area is height class 1, the following grey area is height class 2 and so on.

Figure 3.10: Height measurement tool

Registering and processing of collected data

The registering of the measured data is done with a field form in Excel on a laptop or analogue field forms. The analogue field forms were only used if weather prevented the use of a laptop. Later on these analogue field forms were digitalized. The chance for mistakes is lower when the data is directly entered in Excel.
All the gathered data is stored into a digital database, that can be found on the DVD in the back of this rapport. Every plot has an individual folder. This folder contains:

- The measured data in the form of an excel sheet
- The 5 pictures (see sub-paragraph 3.4.1 "General measurements")
- A GIS shapefile, only if the surface area is measured (see sub-paragraph 3.4.1 "General measurements")

3.4.4 Tools used for processing

The following programs are used to process and analyze the gathered data:

- Microsoft office Excel 2010: used for making all the calculations, tables and graphs
- Esri ARC map 10: used for processing the GIS data received from the NP and for processing the GPS data
- DNRGPS version 6.0.0.15: an open source program made by the Minnesota Department of Natural Resources that can export the data from the GPS to Shapefiles usable in GIS
- Garmin basecamp version 4.0.2: a by Garmin released program used to export the data form the GPS to the computer.

3.5 Justification

All of the data collected in the field for browsing-, fraying- and bark stripping damage in the NP needs to be uniform. In other words the used method needs to be replicable so that the data collected every year forms a reliable database. Therefore the method used in the inventory of 2011 (Pronk, 2012) is also used in this thesis. To make sure that the method of 2011 was sufficient other methods were reviewed (Suchant, et al., 2011) (Kuiters, 2000) (Smit, et al., 1998) (Kolk, 1996) (Ouden, 2012) and compared with the one used in 2011. This led to changes that either supplemented the method, made the replicability of the method easier or made the field inventory easier to accomplish. The implications of these changes are the following:

Supplementing changes for the method

When looking at figure 2.1 it can be seen that more than one factor is of influence on browsing. The method that was used in 2011 did not take these factors into account. The measurements for dominant and sub-dominant tree species, anthropogenic influences and the estimations of the coverage of the canopy, shrub and ground layer were introduced into the method to account for these factors (see sub-paragraph 3.4.2 "Measurements for surroundings").

Changes to enhance replicability

In 2011, the only way in which plots were marked was by GPS coordinates. The problem with GPS is that the accuracy of a general GPS-device is about 3 meters. This inaccuracy led to a deviation from the original measuring point. To make sure that future measuring is conducted in the exact same location two wooden posts were introduced. One marking the north side of the plot that is marked with the GPS and another one at the south side so that the plot is always set up in the exact same direction.

Changes for easier field inventory

In the original method (Pronk, 2012) the plot is set up from the northeast corner. This introduced the possibility for error, namely in which side of the line was measured. In other words the east- or west side. To nullify the possibility of this error the wooden post was moved from the northeast corner to the center of the plot between the north-eastern and north-western corners. The line used for setting out the plot now runs through the middle of the plot. Nullifying the error also had other benefits. By placing the line in the middle each subplot is divided into 2 exact halves. This makes the possibility for double measurements less apparent and 2 people can measure in 1 subplot without interfering with each other.

Changes to the conditions used for locating new research areas

The conditions mentioned below were used In 2011 to find potential research areas. The explanation of changes made is written below the condition in cursive. The conditions used in this thesis are presented in paragraph 3.2 Research areas.

- **The tree regeneration is located within the borders of the NP**
  The NP also has properties outside the fence. These properties lie inside the borders of the NP but they lie outside the fence that is placed around the NP. For example the part near the village of Otterlo called "het Otterlose bos". Changes have been made to exclude these parts.

- **The tree regeneration is reachable for Roe and Red deer**
  This condition is changed to include exclosures because xclosures are also measured in this thesis. These exclosures are put in place to protect this area against ungulates.

- **The young trees present are naturally regenerated**
  This condition is completely removed. This is done because the management of the NP also works with young planted trees which are also viable for the research.

- **The site is a (small) clearcut**
- **The minimal surface area of the site is 20 x 30 meters (without full grown trees)**
  The above two conditions are completely removed because the NP is only working with (small) clear cuts since 2009 (Leidekker, 2012). Therefore there are not enough suitable research locations in clearcuts.

- **The forest regeneration present is not younger than 2 years of age**
- **The forest regeneration present is not older than 5 years of age**
  The forest regeneration is viable food for the ungulates between the following heights, 10 cm until 2 meters. Some tree species can live for many years without growing above the maximum height for browsing. Therefore the age is replaced with the minimum and maximum heights reachable for deer species.

- **Also locations, that naturally formed by windfall or snow can be used if they meet the other conditions, except clearcut.**
  This condition is covered in other conditions so it was removed.

Implementing of the changes

The changes have been implemented during the inventory of this thesis. This means that not all the data is collected in the same manner. The inventory was started before the method was completely revised. This was done because the lowering of the fence was planned in October 2012. Also, the coming autumn would have made the inventory harder. Because, broad-leaved trees would have been harder to spot and recognized without their leaves. Especially in thick groups of regenerated trees.

The first 10 plots inventoried (plot numbers 1, 2, 4, 9, 13, 23, 24, 27, 36 and 38) are inventoried using the method used in 2011 (Pronk, 2012) with the addition of the placement of 1 wooden post in the north-east corner. In these plots only browsing damage of 2012 is assessed. All the rest of the plots are inventoried using the new method described in this chapter.

Another change has been made in the marking of the plots. Plots 1, 2, 4, 6, 9, 13, 15, 17, 19, 21 to 24, 27 and 31 to 40 are marked with small wooden posts that are normally used to stack planks. These wooden posts are however easily rooted from the ground by Wild boars and will rot away easily in the forest. Therefore, thicker wooden posts were made and used to mark the other plots. The small wooden posts are to be replaced with the thicker wooden posts and set at the correct positions before the next inventory of the multiannual monitoring program.

Chapter 4 Results

This chapter presents the results of the field inventory. The data will be displayed in tables and graphs which are supported by text.
The numbers and percentages presented in this chapter are presented in the Dutch way for noticing numbers. This means a comma is used to separate decimals from whole numbers and a dot is used to separate large numbers.

4.1 Dataset

During the inventory a total of 13.211 regenerated trees have been inventoried. Those trees are divided over 40 plots which are spread over 3 sections (see paragraph 3.1 "Sections"). Table 4.1 shows the spread of the plots per section. The location of the plots are displayed in figure 4.1. A table with information about the plots and the pictures of the plots are presented in attachment 1 "Plot information".

Section	Surface area	Number of plots	Number of trees	Percentage of trees
1	536 m^2	11	3.277	25 %
2	4.198 m^2	19	6.625	50 %
3	446 m^2	10	3.309	25 %

Table 4.1: The spread of the plots over the three sections

Table 4.2 shows the unaltered dataset from the data gathered in the field inventory. Regenerated trees are either browsed in 2011 or in 2012. Some trees however are browsed in both years. To account for a double counting error when calculation the total trees browsed; the trees browsed in both 2011 and 2012 were subtracted from the total browsed per species.

	Total number of trees	Percentage of total inventoried trees	Number of trees with top shoot browsed	Percentage of top shoot browsed per species	Number of trees with top shoot browsed in 2011	Percentage of top shoot browsed in 2011 per species	Number of trees with top shoot browsed in 2012	Percentage of top shoot browsed in 2012 per species	Number of trees with top shoot browsed in both 2011 and 2012	Percentage of top shoot browsed in both 2011 and 2012 per species	Number of trees with fraying damage	Percentage of trees with fraying damage per species	Number of trees with bark stripping damage	Percentage of trees with bark stripping damage per species
Total	**13.211**	**100%**	**1.833**	**13,87%**	**1.025**	**7,76%**	**1.308**	**9,90%**	**500**	**3,78%**	**90**	**0,68%**	**1**	**0,01%**
Alder Buckthorn	303	2,29%	142	46,86%	65	21,45%	132	43,56%	55	18,15%	0	0,00%	0	0,00%
Beech	14	0,11%	1	7,14%	1	7,14%	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Birch	3.825	28,95%	482	12,60%	263	6,88%	270	7,06%	51	1,33%	30	0,78%	1	0,03%
Black cherry	150	1,14%	114	76,00%	78	52,00%	101	67,33%	65	43,33%	6	4,00%	0	0,00%
Common hornbeam	1	0,01%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Douglas fir	1.152	8,72%	4	0,35%	4	0,35%	0	0,00%	0	0,00%	2	0,17%	0	0,00%
Eastern white pine	1	0,01%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Great silver fir	213	1,61%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	6	2,82%	0	0,00%
Hairy birch	245	1,85%	126	51,43%	71	28,98%	90	36,73%	35	14,29%	2	0,82%	0	0,00%
Hemlock	540	4,09%	1	0,19%	1	0,19%	1	0,19%	1	0,19%	4	0,74%	0	0,00%
Horse-chestnut	1	0,01%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Juneberry	454	3,44%	147	32,38%	97	21,37%	83	18,28%	33	7,27%	2	0,44%	0	0,00%
Larch spec.	1.048	7,93%	4	0,38%	2	0,19%	3	0,29%	1	0,10%	6	0,57%	0	0,00%
Planted lime tree	6	0,05%	4	66,67%	0	0,00%	4	66,67%	0	0,00%	0	0,00%	0	0,00%
Mountain-ash	949	7,18%	546	57,53%	261	27,50%	472	49,74%	187	19,70%	0	0,00%	0	0,00%
Norway spruce	17	0,13%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Pedunculate oak	216	1,64%	140	64,81%	122	56,48%	71	32,87%	53	24,54%	1	0,46%	0	0,00%
Planted pedunculate oak	32	0,24%	7	21,88%	0	0,00%	7	21,88%	0	0,00%	0	0,00%	0	0,00%
Red oak	600	4,54%	89	14,83%	39	6,50%	66	11,00%	16	2,67%	1	0,17%	0	0,00%
Scots pine	3.374	25,54%	2	0,06%	2	0,06%	1	0,03%	1	0,03%	30	0,89%	0	0,00%
Sitka spruce	1	0,01%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%	0	0,00%
Sycamore maple	69	0,52%	24	34,78%	19	27,54%	7	10,14%	2	2,90%	0	0,00%	0	0,00%

Table 4.2: The unaltered data per tree species for the whole NP

4.2 Abnormalities

During the inventory a few abnormalities were found. These are explained further below.

Coppiced Red oak

The first abnormality can be found in the numbers of Red oak. 1 Red oak coppice woodland (plot number 4) and 1 plot with Red oak coppiced stems (plot number 1) were inventoried. In these plots a high number of Red oak is found. This results in an above average representation of browsing damage for Red oak in this part of the NP. To calculate the average number and browsing damage for Red oak throughout the NP the Red oak found in these plots are excluded from the calculations.

To illustrate the deviation in the calculations caused by Red oak in the plots 1 and 4 the numbers of Red oak are shown in table 4.3. The first row shows the calculations including plots 1 and 4. The second row shows the calculations excluding plots 1 and 4.

Furthermore, 1 Red oak with fraying damage is found during the inventory. This Red oak was inventoried in plot 4. It was also removed from further calculations.

	Number of Red Oak	Percentage of Red oak	Red oak browsed	Percentage of Red oak browsed	Red oak frayed	Percentage of Red oak frayed
Including plot 4 and 1	600	4,54 %	89	14,83 %	1	0,17 %
Excluding plot 4 and 1	36	0,28 %	22	61,11 %	0	0 %

Table 4.3: Difference of including or excluding Red oak from the calculations

Excluded tree species

The second abnormality is caused by the number of trees inventoried of certain tree species.

The species Common hornbeam, Eastern white pine, Horse-chestnut and Sitka spruce where excluded from the graph because only one tree was found per species. No damage was found on any of these trees. The Common hornbeam (plot number 39), Eastern white pine (plot number 37) and Sitka spruce (plot number 32) are found in section 3. The Horse-chestnut (plot number 14) is found in section 1.

Exclosures

Several exclosures are made in the NP to protect the vegetation inside these exclosures against the influence of ungulates. In this thesis 4 plots were inventoried inside exclosures (plots 15, 23, 34 and 39). There is no browsing-, fraying or bark stripping damage found inside the exclosures. Nevertheless, the plots that are located inside exclosures have not been excluded from the calculations because the differences with or without the data gathered inside exclosures is negligible in the results (see paragraph 5.2 “Results”).

Planted trees

The final abnormality is caused by planted Lime trees and planted Pedunculate oak. The only locations where planted Lime trees were found are plots 39 and 40. The planted Lime trees are excluded from the graphs because only 6 individuals were inventoried. 2 Lime trees were planted inside an exclosure. The remaining 4 trees are situated outside the exclosure. The trees outside the exclosure all have browsing damage. This resulted into an abnormal high browsing percentage of this species which is representative for that exact location but not for the whole NP.

The planted Pedunculate oak are included in the graphs because there are enough trees inventoried (32 individuals) and the trees were found on different locations in the NP. The planted Pedunculate oak were found in plot 23, 39 and 40.

Calculated trees

A total of 13.211 trees where inventoried during this thesis. Overall 564 Red oak trees were excluded. The remaining 12.647 trees where used in the calculations.

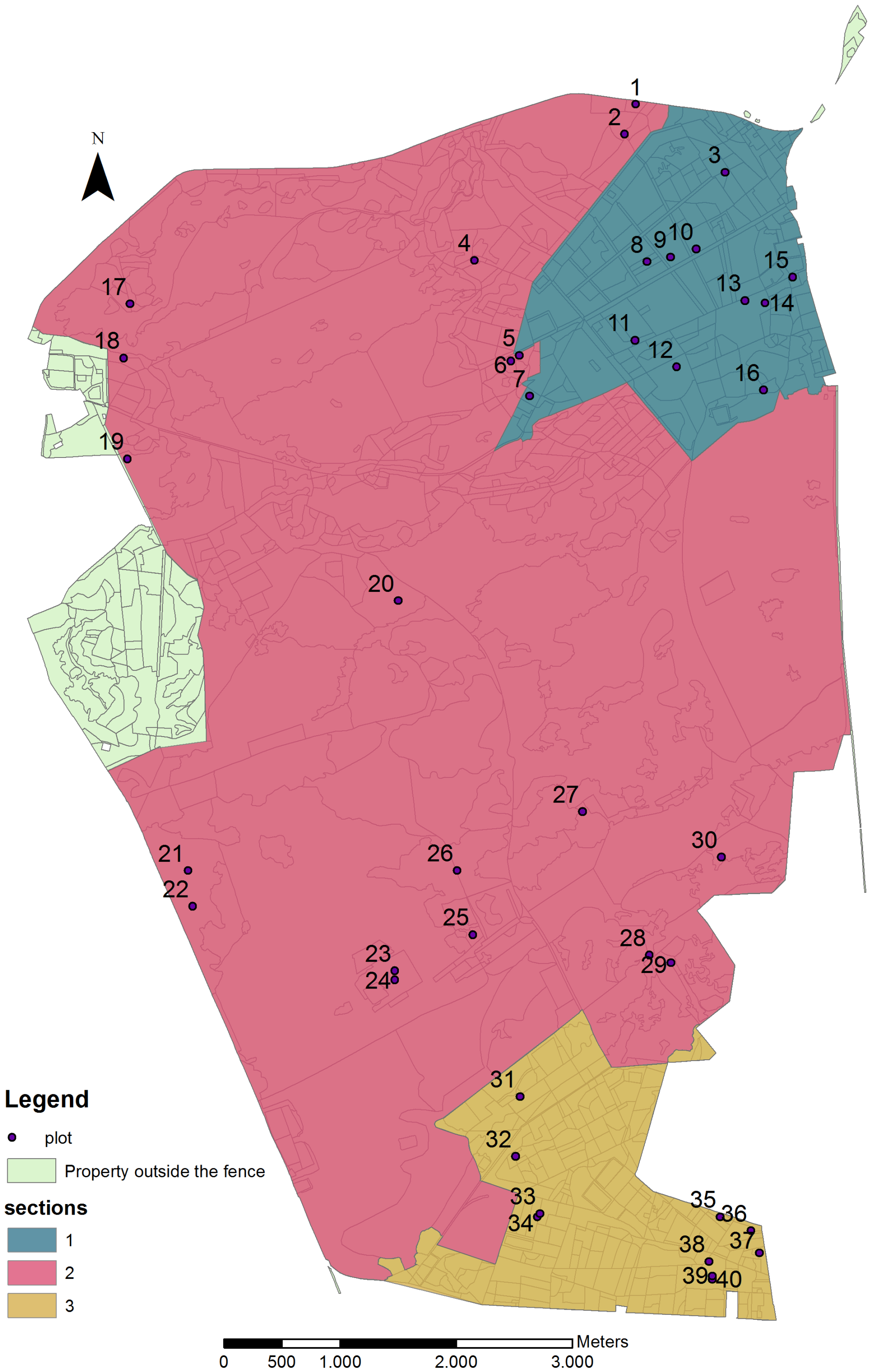


Figure 4.1: Location of the plots within the sections

4.3 Composition of regenerated trees

The composition of regenerated tree species is displayed in graph 4.1 for the whole NP and for each section. This gives an indication of which species are dominant and shows the distribution of the regenerated trees over the NP. This is presented below in a top 5 enumeration. First the top 5 of species for the whole NP is presented. Afterwards the top 5 of species per section is presented.

4.3.1 Top 5 of present species for the whole NP

6.347 coniferous species and 6.865 broad-leaved species were inventoried in this thesis. The 2 tree species that were inventoried the most are Birch and Scots pine. Together they form 56,92% of the total trees inventoried in the thesis which corresponds with the situation in the field.

The top 5 of measured tree species in the NP is:

- Birch 30,24% (with 3.825 individuals)
- Scots pine 26,68% (with 3.374 individuals)
- Douglas fir 9,11% (with 1.152 individuals)
- Larch 8,29% (with 1.048 individuals)
- Mountain-ash 7,50% (with 949 individuals)

4.3.2 Top 5 of present species for section 1

The composition of species in section 1 consists mainly out of broad-leaf species. With 2.318 individuals out of the 3.277 trees inventoried in section 1 this makes 70,74%.

The top 5 of inventoried trees in section 1 is:

- Birch 36,13% (with 1.184 individuals)
- Mountain-ash 15,41% (with 505 individuals)
- Scots pine 10,04% (with 329 individuals)
- Larch 10,01% (with 328 individuals)
- Douglas fir 7,63% (with 250 individuals)

4.3.3 Top 5 of present species for section 2

The composition of species in section 2 consists mainly out of coniferous trees. With 3.373 individuals out of the 6.061 trees inventoried in section 2 this makes 55,65%.

The top 5 of inventoried trees in section 2 is:

- Scots pine 30,03% (with 1.820 individuals)
- Birch 25,57% (with 1.550 individuals)
- Douglas fir 12,82% (with 777 individuals)
- Hemlock 7,99% (with 484 individuals)
- Mountain-ash 6,72% (with 407 individuals)

4.3.4 Top 5 of present species for section 3

The composition of species in section 3 consists mainly out of coniferous trees. With 2.014 individuals out of the 3.309 inventoried trees in section 3 this makes 60,86%.

The top 5 of inventoried trees in section 3 is:

- Scots pine 37,02% (with 1.225 individuals)
- Birch 32,97% (with 1.091 individuals)
- Larch 13,45% (with 445 individuals)
- Great silver fir 6,10% (with 202 individuals)
- Douglas fir 3,78% (with 125 individuals)

4.3.5 Analysis

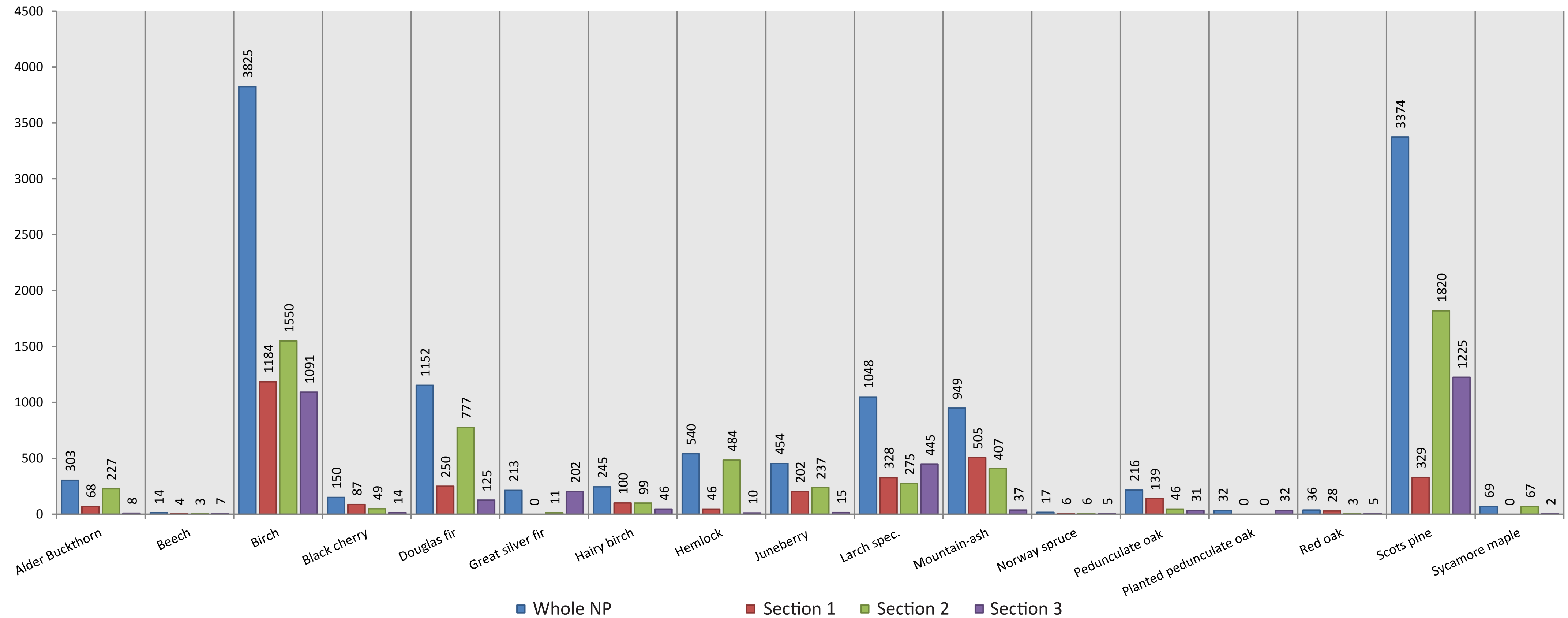
In section 1 there are more broad-leaved trees found, in percentages this is 70,74%.

In section 3 there are more coniferous trees found, in percentages this is 60,86%.

Section 1 and 3 have been exclosed for Red deer and Roe deer until 1996. (Velde, 2008) Because of this, the forest regeneration has grown without influences from Red deer and Roe deer. This was beneficial for broad-leaved species. The trees that regenerated back than, are now full grown trees. Therefore, there are more full grown broad-leaved trees in section 1. This can explain why there are more regenerated broad-leaved trees in the forest regeneration.

Section 3 contains more foreign planted coniferous trees, probably for the wood production. These foreign coniferous trees create more shade on the ground. Therefore only “shade trees” can germinate and grow out to grown trees when they stand under the coniferous trees.

In section 2 the ground is the poorest. Therefore, especially Scots pine and Birch can germinate and establish.



Graph 4.1: The composition of regenerated trees in total and per section

4.4 Browsing

In this chapter the amount of browsed trees is shown in two different ways, namely:

The number of browsed trees

This shows how many trees of a species are browsed. This can be used to see which tree species ungulates eat the most. The number of browsed trees is measured during the inventory and is shown in graph 4.2. The total number of trees of each species can be found in table 4.2.

Browsing percentage

The browsing percentage is calculated by deviding the number of browsed trees per species by the total number of inventoried trees of that species. The browsing percentage allows comparison of browsing between tree species. The number of browsed trees can be the same for 2 species but the percentage of browsing can be different. The browsing percentage per species is given in a top 5 for the whole NP and for each section.

4.4.1 The whole NP

The number of browsed trees

Graph 4.2 shows that the species with the highest number of browsed trees in the NP is Mountain-ash with 546 individuals browsed. The second most browsed tree species is Birch with 482 browsed individuals.

Browsing percentage

The following enumeration shows the top 5 of species with the highest browsing percentage in the whole NP. Here can be seen that Black cherry has the highest browsing percentage.

- Black cherry with 76,00% (114 devided by 150 inventoried)
- Pedunculate oak with 64,81% (140 devided by 216 inventoried)
- Red oak with 61,11% (22 devided by 32 inventoried)
- Mountain-ash with 57,53% (546 devided by 949 inventoried)
- Hairy birch with 51,43% (126 devided by 245 inventoried)

4.4.2 Browsing per section

The number of browsed trees

Graph 4.2 shows that there are fewer number of browsed trees in section 3 than in section 1 and 2. The graph also shows that section 2 has the most browsed trees (817) with section 1 not far behind (809).

Browsing percentage

The following enumeration shows the browsing percentage per section. Here can be seen that the highest browsing percentage is found in section 1. Also can be seen that the lowest browsing percentage is found in section 3.

- Section 1 has a browsing percentage of 24,66% (808 devided by 3.277 inventoried)
- Section 2 has a browsing percentage of 13,48% (817 devided by 6.061 inventoried)
- Section 3 has a browsing percentage of 4,62% (153 devided by 3.309 inventoried)

4.4.3 Section 1

The number of browsed trees

Graph 4.2 shows that the species with the highest number of browsed trees in section 1 are Mountain-ash (261) and Juneberry (103).

Browsing percentage

The following enumeration shows the top 5 species with the highest browsing percentage in section 1. Here can be seen that Black cherry has the highest browsing percentage.

- Black cherry with 88,51% (77 devided by 87 inventoried)
- Alder buckthorn with 79,50% (54 devided by 68 inventoried)
- Pedunculate oak with 70,00% (98 devided by 139 inventoried)
- Red oak with 64,29% (18 devided by 28 inventoried)
- Hairy birch with 56,00% (56 devided by 100 inventoried)

4.4.4 Section 2

The number of browsed trees

Graph 4.2 shows that the species with the highest number of browsed trees in section 2 is Birch with 281 browsed individuals. The second most browsed tree species is Mountain-ash with 255 browsed individuals.

Browsing percentage

The following enumeration shows the top 5 species with browsing damage in section 2. Here can be seen that Pedunculate oak has the most browsing damage with 86,96% of the trees browsed.

- Pedunculate oak with 86,96% (40 browsed out of 46 inventoried)
- Black cherry with 69,39% (34 browsed out of 49 inventoried)
- Red oak with 66,67% (2 browsed out of 3 inventoried)
- Mountain-ash with 62,65% (255 browsed out of 407 inventoried)
- Hairy birch with 57,58% (57 browsed out of 99 inventoried)

4.4.5 Section 3

The number of browsed trees

Graph 4.2 shows that the species with the highest number of browsed trees in section 3 is Birch with 61 browsed individuals. The second most browsed tree is Mountain-ash with 30 browsed individuals.

Browsing percentage

The following enumeration shows the top 5 species with browsing damage in the whole NP. Here can be seen that Mountain-ash has the most browsing damage with 81,08% of the trees browsed.

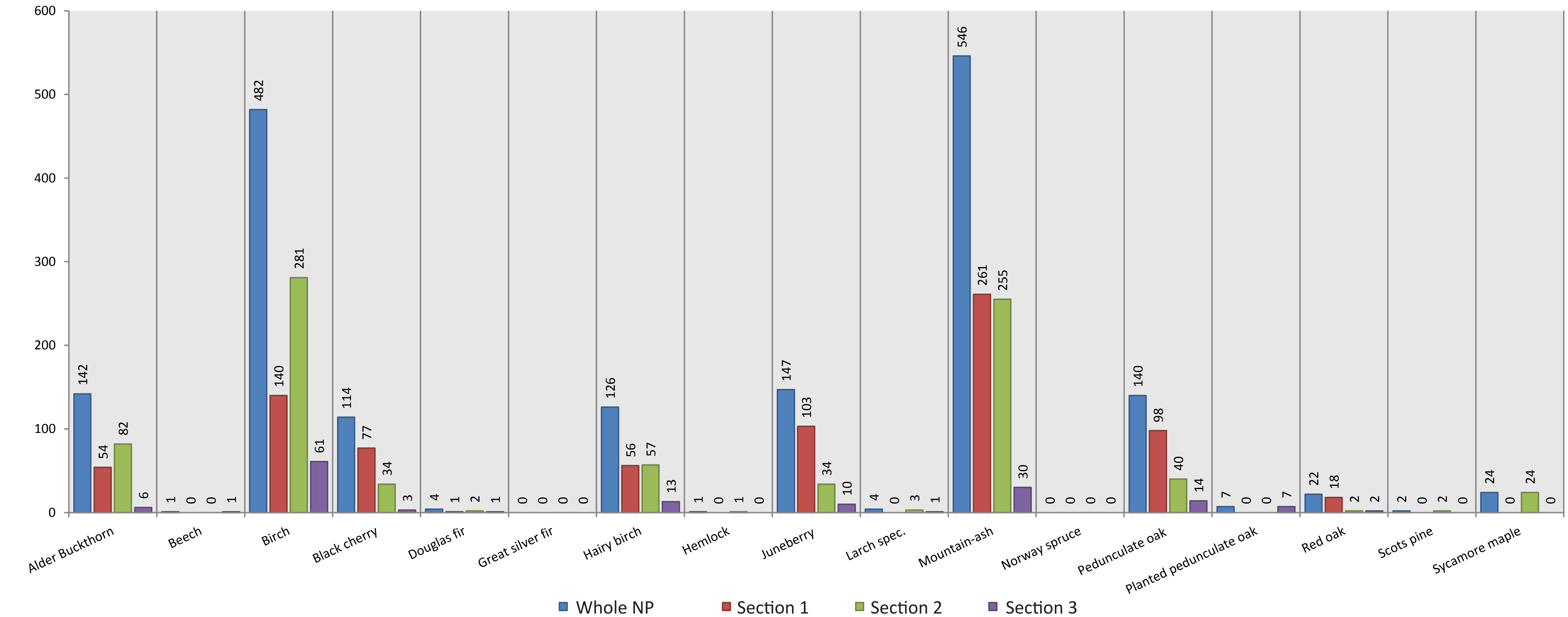
- Mountain-ash with (81,08%) (30 browsed out of 37 inventoried)
- Alder buckthorn with (75,00%) (6 browsed out of 8 inventoried)
- Juneberry with (66,67%) (10 browsed out of 15 inventoried)
- Pedunculate oak with (45,16%) (14 browsed out of 32 inventoried)
- Red oak with (40,00%) (2 browsed out of 5 inventoried)

4.4.6 Analysis

In section 3 there is less browsing than in the other sections.

Mountain-ash and Birch are browsed the most in numbers, because there are many individuals of these species present. Therefore, when a deer species browses on a tree the change that it is a Moutain-ash or Birch is high. Black cherry and Pedunculate oak have the highest browsing percentage. The leaves and buts of Black cherry contain a high value of proteins in spring (Buysse, 2012).

Almost exclusively broad-leaved trees are browsed. This because the coniferous tree species contains terpenoids. These terpenoids are to protect the tree against browsing. These terpenoids make that the deer species do not like coniferous trees.



Graph 4.2: Number of browsed trees of the whole NP and per section

4.5 Fraying and bark stripping

In this chapter the amount of fraying is shown in two different ways, namely:

The number of frayed trees

This shows how many trees of a species are frayed. This can be used to see what tree species ungulates fray the most. The frayed trees that are measured during the inventory and is shown in graph 4.3. The total number inventoried of each species can be found in table 4.2.

Fraying percentage

The fraying percentage is calculated by deviding the number of frayed trees per species by the total number of inventoried trees of that species. The fraying percentage allows comparison of fraying between tree species. The number of frayed trees can be the same for 2 species but the percentage of fraying can be different. The fraying percentage per species is given in a top 5 for the whole NP and for each section.

Bark stripping

Bark stripping is not shown in the graph because only 1 Birch with bark stripping damage is found during the inventory. This Birch is found in section 2 (plot number 5).

4.5.1 The whole NP

The number of frayed trees

Graph 4.3 shows that the species with the highest number of frayed trees in the NP are Scots pine and Birch. Both with 30 individuals frayed.

Fraying percentage

The following enumeration shows the top 5 species with fraying damage in the whole NP. Here can be seen that Black cherry has the most fraying damage with 4% of the trees frayed.

- Black cherry with 4,00% (6 out of 150 inventoried)
- Great silver fir with 2,82% (6 out of 213 inventoried)
- Scots pine with 0,89% (30 out of 3.374 inventoried)
- Hairy birch with 0,82% (2 out of 245 inventoried)
- Birch with 0,78% (30 out of 3.825 inventoried)

4.5.2 Fraying per sections

The number of frayed trees

Graph 4.3 shows that the number of frayed trees is almost the same in section 1 (33 frayed trees) and section 2 (34 frayed trees). Section 3 has 22 frayed trees.

Fraying percentage

The following enumeration shows the calculated fraying damage per section. Here can be seen that the most fraying damage is found in section 1 (1,03%). Also can be seen that the fraying damage in section 2 (0,56%) and section 3 (0,66%) lie close to each other.

- Section 1 with 1,03% (33 frayed trees out of the total 3.277 inventoried)
- Section 2 with 0,56% (34 frayed trees out of the total 6.061 inventoried)
- Section 3 with 0,66% (22 frayed trees out of the total 3.309 inventoried)

4.5.3 Section 1

The number of frayed trees

Graph 4.3 shows that the species with the highest number of frayed trees in section 1 is Birch with 15 frayed trees. After Birch, Black cherry is the most frayed with 5 frayed trees.

Fraying percentage

The following enumeration shows the top 5 species with fraying damage in section 1. Here can be seen that Hemlock has the most fraying damage with 8,70% of the trees frayed.

- Hemlock with 8,70% (4 out of the 46 inventoried)
- Black cherry with 5,75% (5 out of the 87 inventoried)
- Hairy birch with 2,00% (2 out of the 100 inventoried)
- Birch with 1,27% (15 out of the 1.184 inventoried)
- Juneberry with 0,99% (2 out of the 202 inventoried)

4.5.4 Section 2

The number of frayed trees

Graph 4.3 shows that the species with the highest number of frayed trees in section 2 is Scots pine with 17 frayed trees. The second most frayed species is birch with 13 frayed trees.

Fraying percentage

The following enumeration shows the top 5 species with fraying damage in section 2. Here can be seen that Black cherry has the most fraying damage with 2,04% of the trees frayed.

- Black cherry with 2,04% (1 out of the 49 inventoried)
- Larch with 1,09% (3 out of the 275 inventoried)
- Scots pine with 0,93% (17 out of the 1.820 inventoried)
- Birch with 0,84% (13 out of the 1.150 inventoried)
- No other tree species was frayed in section 2

4.5.5 Section 3

The number of frayed trees

Graph 4.3 shows that the species with the highest number of frayed trees in section 3 is Scots pine with 12 frayed trees. The second most frayed species is Great silver fir with 6 frayed trees.

Fraying percentage

The following enumeration shows the top 5 species with fraying damage in section 3. Here can be seen that Great silver fir has the most fraying damage with 2,97% of the trees frayed.

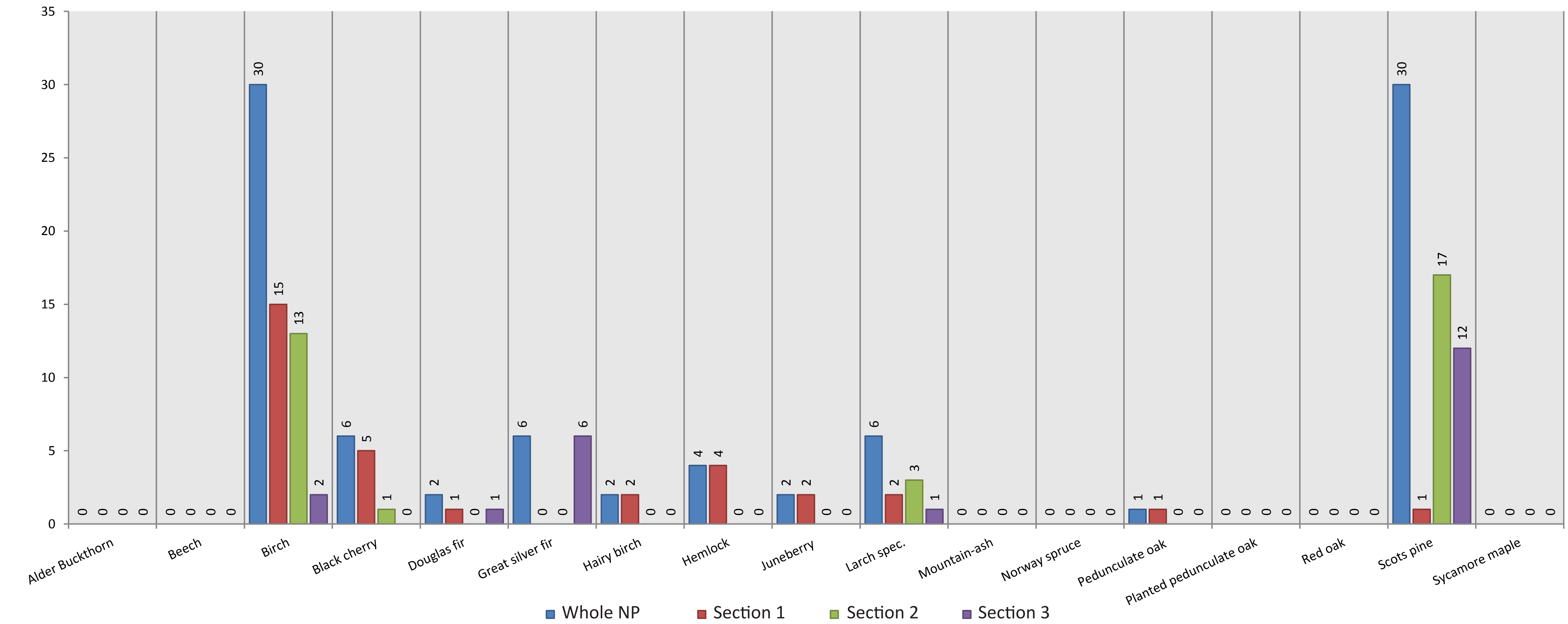
- Great silver fir with 2,97% (6 out of the 202 inventoried)
- Scots Pine with 0,98% (12 out of the 1.225 inventoried)
- Douglas fir with 0,80% (1 out of the 125 inventoried)
- Larch with 0,22% (1 out of the 445 inventoried)
- Birch with 0,18% (2 out of the 1.091 inventoried)

4.5.6 Analysis

Black cherry and Great silver fir have the highest fraying percentage because they smell nice for Red deer and Roe deer (Wensink, 2012).

Birch and Scots pine are frayed the most. This is probably because these are the tree species that are present the most. Therefore, when a deer species frays a tree the change that it is a Birch or Scots pine is high.

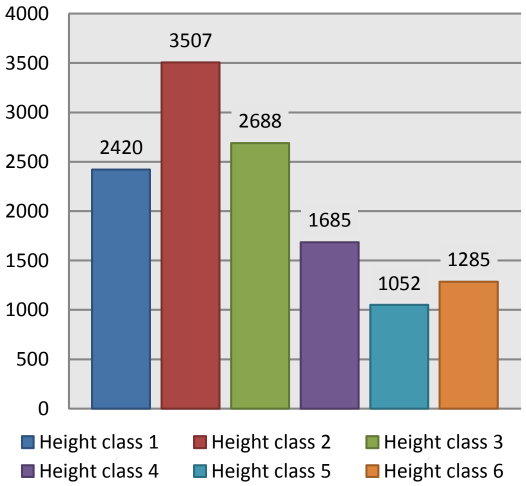
The highest fraying percentage is in section 1. This is because a large population of male Red deer live close by (see figure 4.3).



Graph 4.3: The number of frayed trees per species for the whole NP and per section

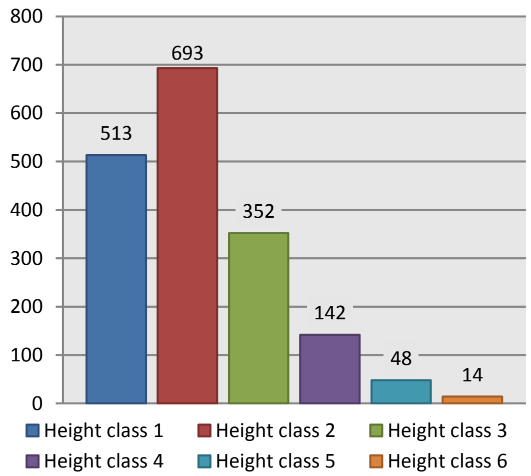
4.6 Results per height class
In this paragraph the following data is shown per height class:
- Number of trees (graph 4.4)
- Number of trees per species (graph 4.9)
- Number of browsed trees (graph 4.5)
- Browsing percentage (graph 4.6)
- Number of browsed trees per species (graph 4.10)
- Number of frayed trees (graph 4.7)
- Fraying percentage (graph 4.8)
- Number of frayed trees per species (graph 4.11)

4.6.1 Total number of inventoried trees per height class
In graph 4.4 the total number of inventoried trees is shown per height class. The majority of inventoried trees is found in height class 2 with 3.507 trees (27,75%) followed by height class 3 with 2.688 trees (21,27%).
In graph 4.9 the number of inventoried trees per species is presented divided over the height classes.
Derived from this graph the top 5 of inventoried tree species in height class 2 is:
- Birch with 1.114 trees (31,77%)
- Scots pine with 772 trees (22,01%)
- Larch spec. with 340 trees (9,69%)
- Mountain-ash with 318 trees (9,07%)
- Douglas fir with 264 trees (7,53%)

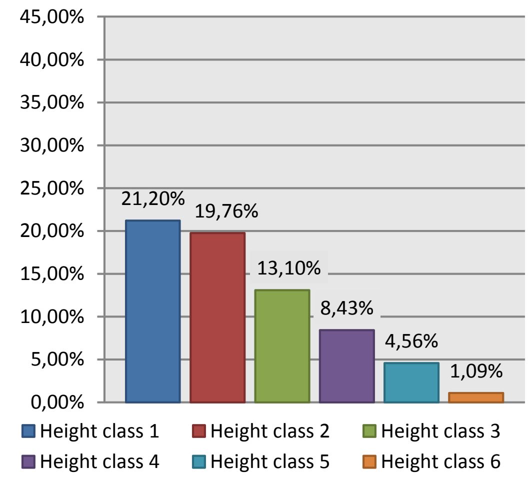


Graph 4.4: Number of trees per height class

4.6.2 Number of browsed trees per height class
In graph 4.5 the number of browsed trees is shown per height class. There can be seen that the majority of the browsed trees is found in height class 2 with 693 browsed trees (39,33%). Followed by height class 1 with 513 browsed trees (29,11%).
Graph 4.6 shows the percentage of browsed trees per height class. This shows that the biggest percentage of browsed trees is found in height class 1 (21,20%) followed by height class 2 (19,67%).
Graph 4.10 presents the number of inventoried browsed trees per species divided over the height classes. Derived from this graph the top 5 of browsed tree species in height class 1 is:
- Mountain-ash with 217 trees (33,96%)
- Hairy birch with 63 trees (9,86%)
- Birch with 58 trees (9,08%)
- Pedunculate oak with 53 trees (8,29%)
- Alder buckthorn with 42 trees (6,57%)

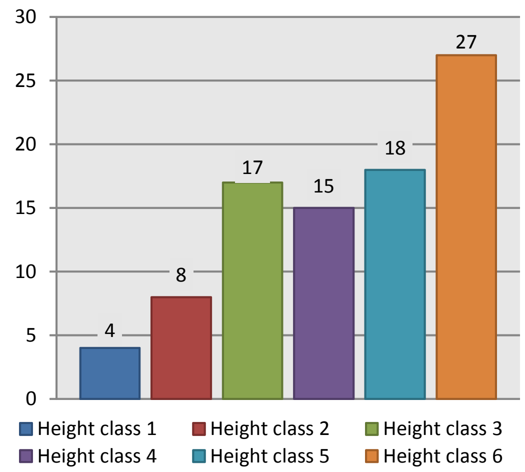


Graph 4.5: Number of browsed trees per height class

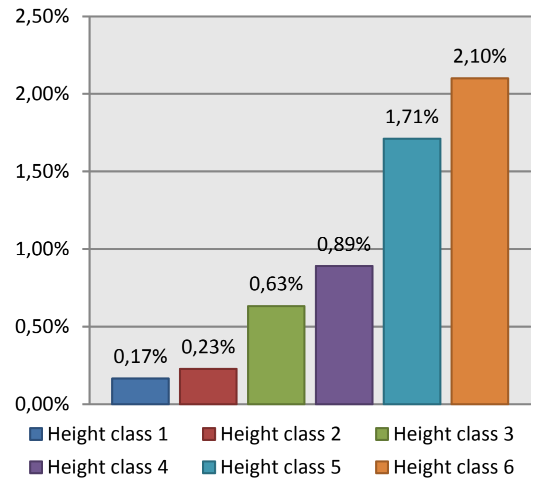


Graph 4.6: Browsing damage in percentage per height class

4.6.3 Number of frayed trees per height class
In graph 4.7 the number of frayed trees per height class is shown. Here can be seen that the majority of the frayed trees falls in height class 6 with 27 frayed trees (30,34%) followed by height class 5 with 18 frayed trees (20,22%).
Graph 4.8 shows the fraying damage per height class in a percentage. In this graph can be seen that the percentage of fraying increases with the height class with the highest percentage in height class 6 (2,10%).
Graph 4.11 presents the number of inventoried frayed trees per species divided over the height classes. Derived from this graph the top 5 of frayed tree species in height class 6 is:
- Scots pine with 13 trees (50,00%)
- Birch with 8 trees (30,77%)
- Hemlock with 2 trees (7,69%)
- Larch spec. with 2 trees (7,69%)
- Black cherry with 1 tree (3,85%)

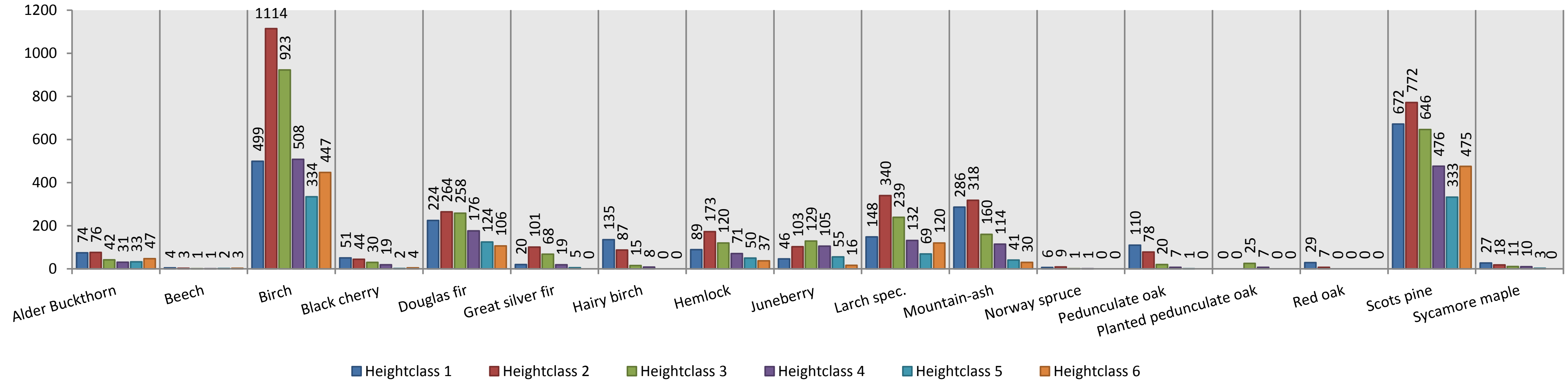


Graph 4.7: Number of frayed trees per height class

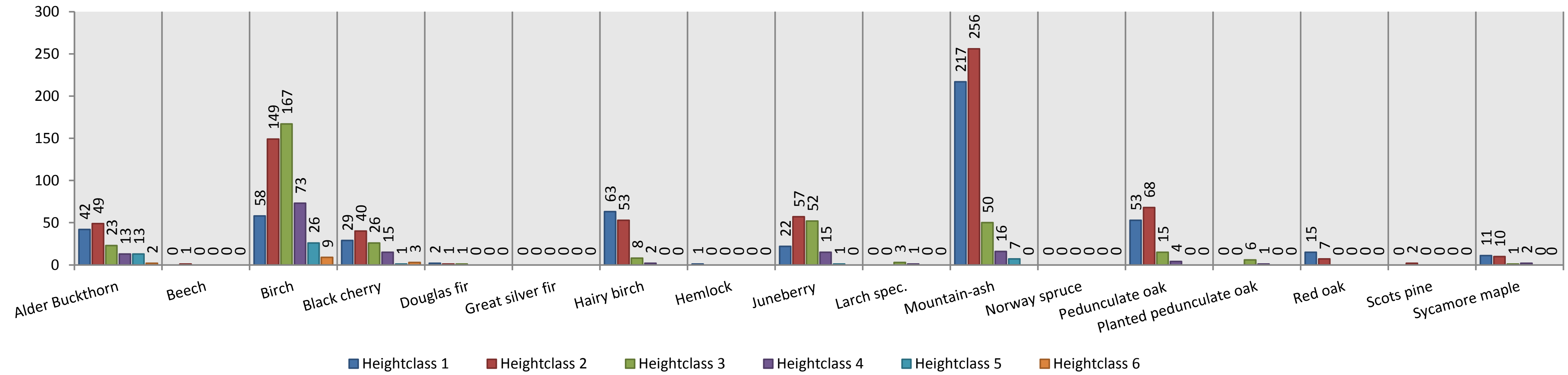


Graph 4.8: Fraying damage in percentage per height class

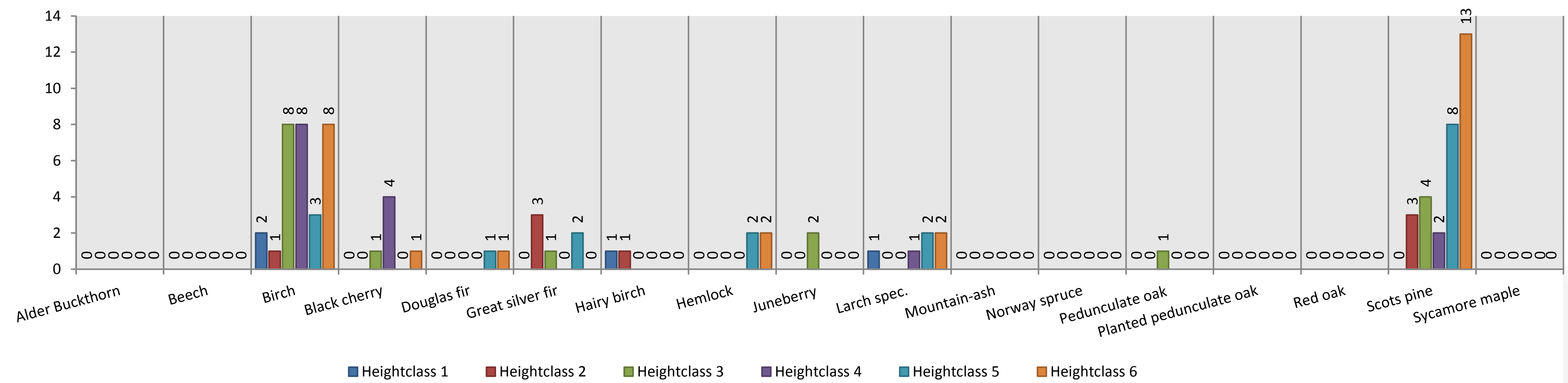
4.6.4 Analysis
It can be seen that with lower height classes the browsing increases. This can be explained by the method used in this thesis. This method is focused on top shoot browsing and not (side) shoot browsing. The top shoots of trees in the lower height classes are easier reached by the deer species.
Furthermore can be seen that with higher height classes the fraying increases. This can be explained by the preference of deer species to fray thicker trees, because these are more resilient (Wensink, 2012).



Graph 4.9: Number of trees per species and per height class



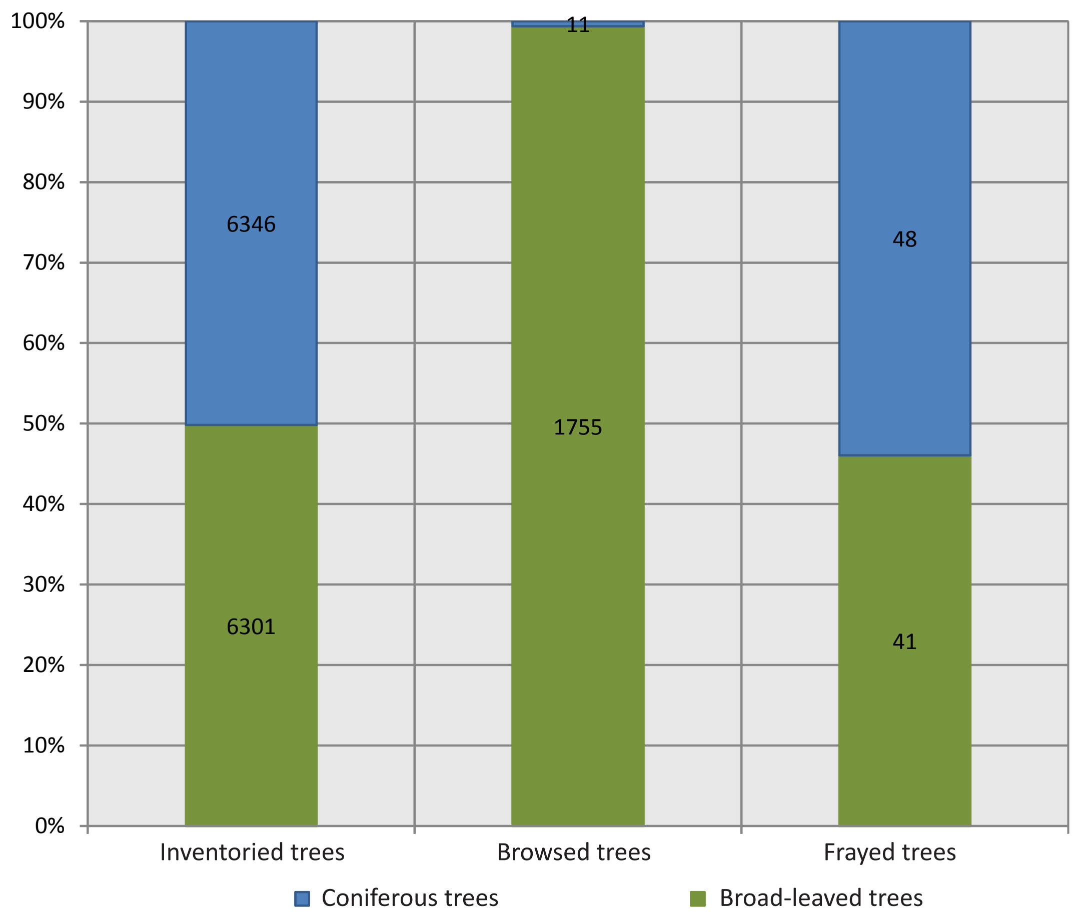
Graph 4.10: Number of browsed trees per species and per height class



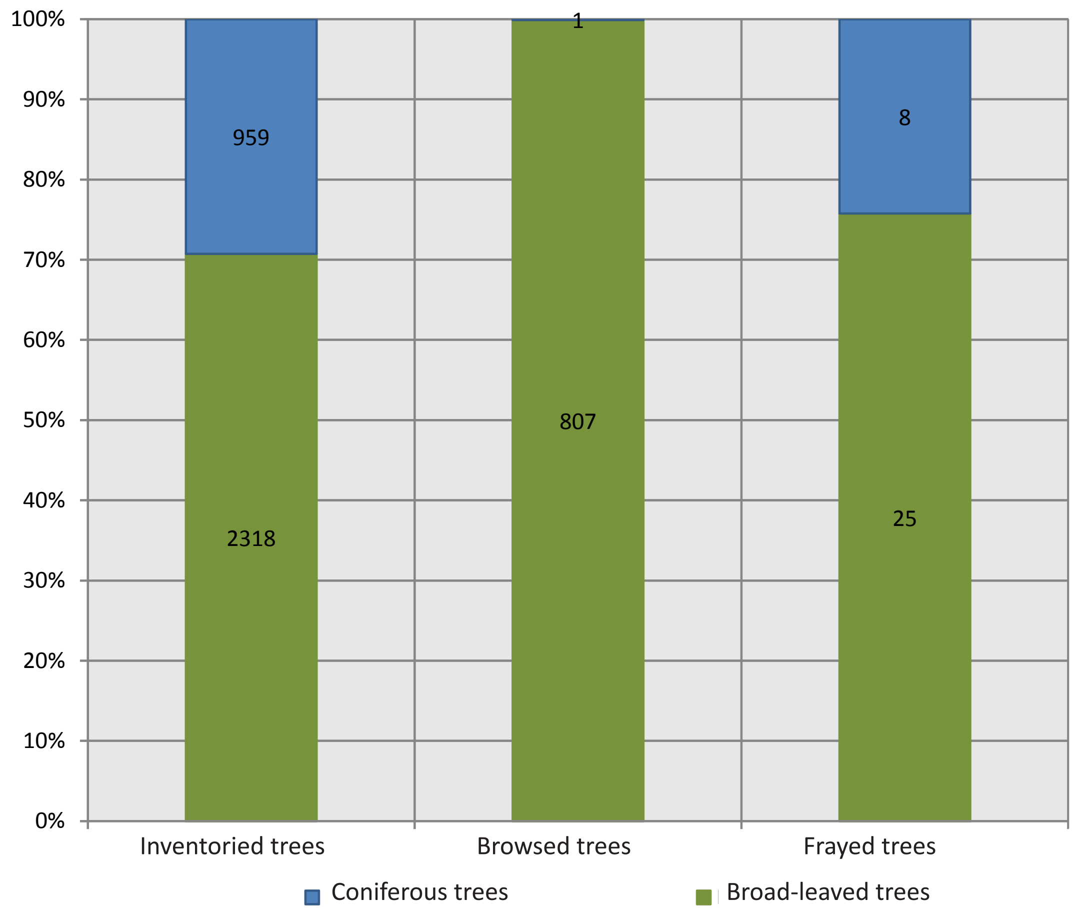
Graph 4.11: Number of frayed trees per species and per height class

4.7 Differences between coniferous and broad-leaved trees

Graph 4.12 presents the amount of trees, the amount of browsed trees and the amount of frayed trees. These amounts are presented in the graph as a number and as a percentage.



Graph 4.12: The difference between coniferous and broad-leaved trees for the whole NP



Graph 4.13: The difference between coniferous and broad-leaved trees for section 1

12.647 inventoried trees are used in the calculations. 6.301 of them are broad-leaved trees (49,82%) and 6.346 are coniferous trees (50,18%).

1.766 browsed trees were inventoried.
1.755 of the browsed trees are broad-leaved trees (99,38%). Only 11 of the browsed trees are coniferous trees (0,62%).

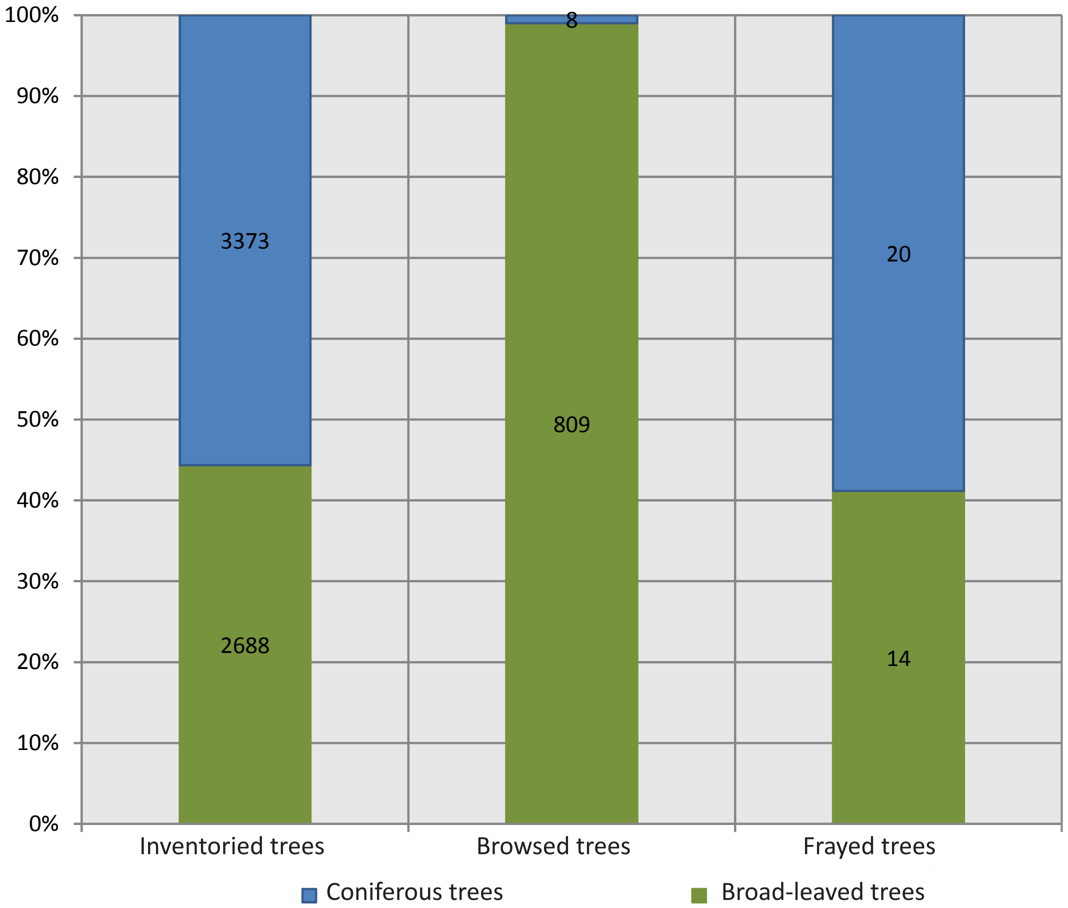
89 frayed trees were inventoried.
41 of the frayed trees are broad-leaved species (46%) and 48 coniferous species (54%)

Graph 4.13 shows the composition of coniferous and broad-leaved trees in section 1. Also the amount of browsing and the amount of fraying is shown. This is also shown for section 2 in graph 4.14 and section 3 is shown in graph 4.15

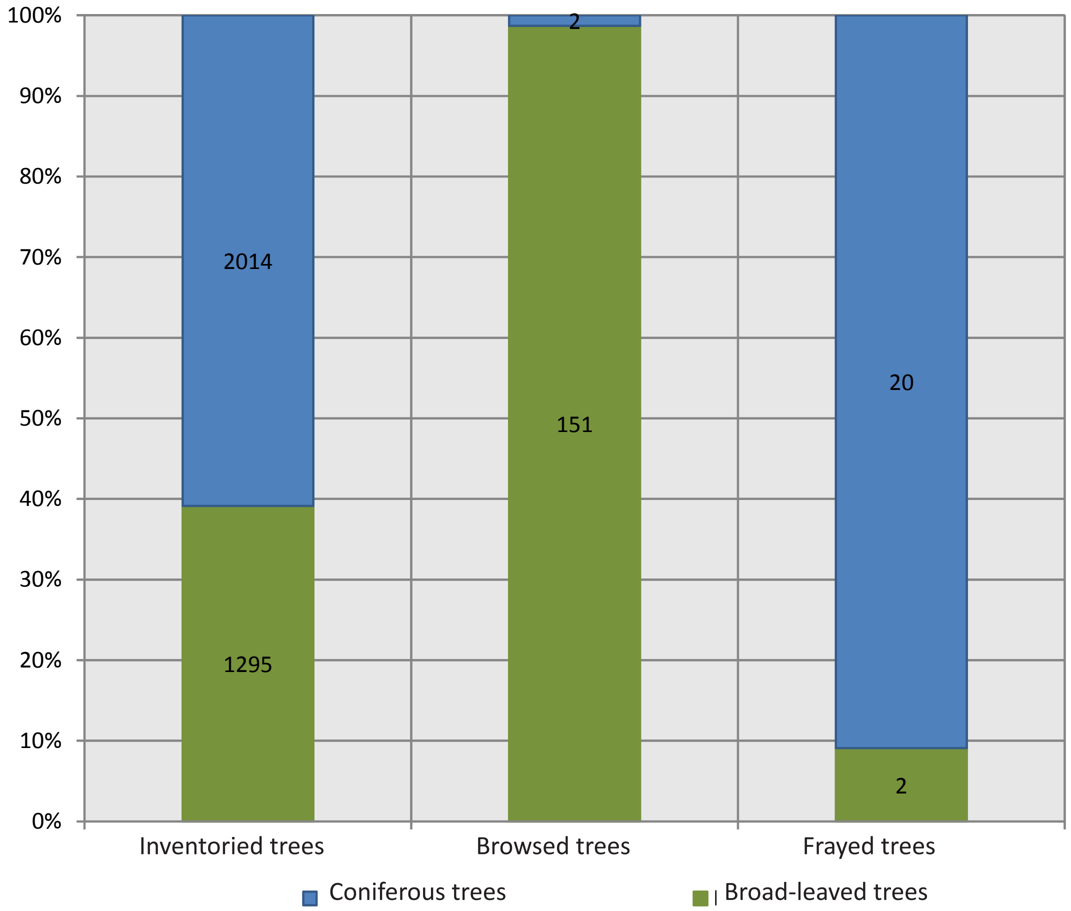
Analysis

There are some differences that stand out, namely:

- Compared with section 2 and 3, section 1 has nearly 30% more broad-leaved trees than coniferous trees.
- Compared with section 1 and 3 a higher number of coniferous trees is browsed in section 2.
- In section 1 more broad-leaved trees than coniferous trees are frayed. The opposite is true for section 3 where more coniferous trees than broad-leaved trees are frayed. In section 2 this difference is not that apparent.



Graph 4.14: The difference between coniferous and broad-leaved trees for section 2



Graph 4.15: The difference between coniferous and broad-leaved trees for section 3

4.8 Differences between inside and outside an animal retreat zone

In this paragraph the data collected inside and outside the animal retreat zones is compared. The plots that are located inside the animal retreat zones are: 11, 12, 23, 24, 25, 30, 31, 35, 36, 37. The animal retreat zones that are presented in figure 4.2 are from the year 2012.
First the composition of tree species inside the animal retreat zones will be compared with the composition of tree species outside the animal retreat zones. Then the percentage of browsed trees inside the animal retreat zones will be compared with the percentage of browsed trees outside the animal retreat zones.
The plots 15, 23, 34 and 39 are located inside exclosures. In the previous paragraphs the data of these plots was included in all calculations because the differences with or without this data is negligible in the results. In this paragraph a higher accuracy is required so the data from the plots inside exclosures is excluded from the calculations in this paragraph. This is done because the data from inside the exclosures would lead to obvious aberrations in the results. The data from the plots in the exclosures would cause a lower browsing percentage outside the animal retreat zones. This would be incorrect.
Inside the animal retreat zones there are 2.472 trees inventoried (21,1% of the total inventoried trees). Outside the animal retreat zones there are 9.253 trees inventoried (78,9%).

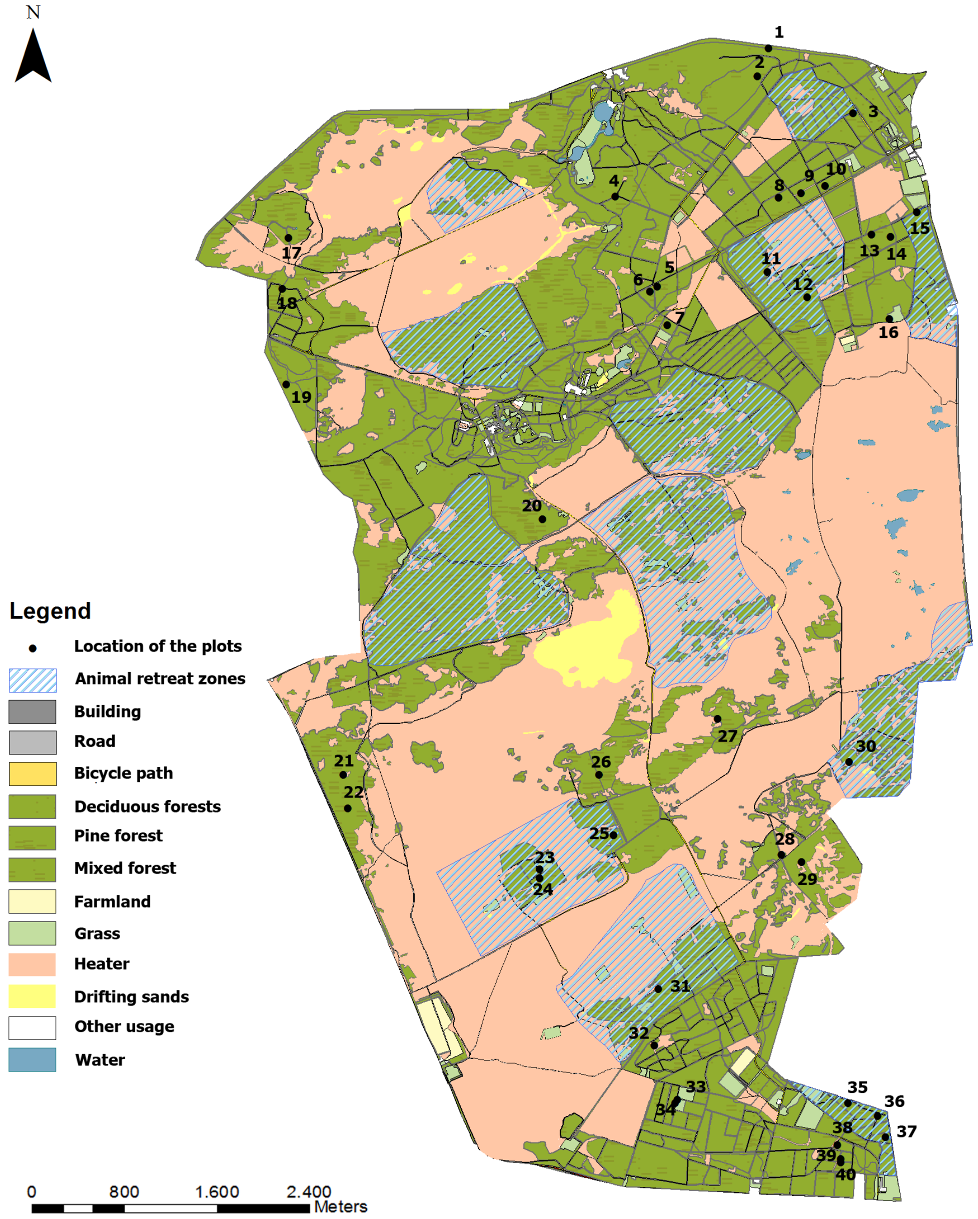


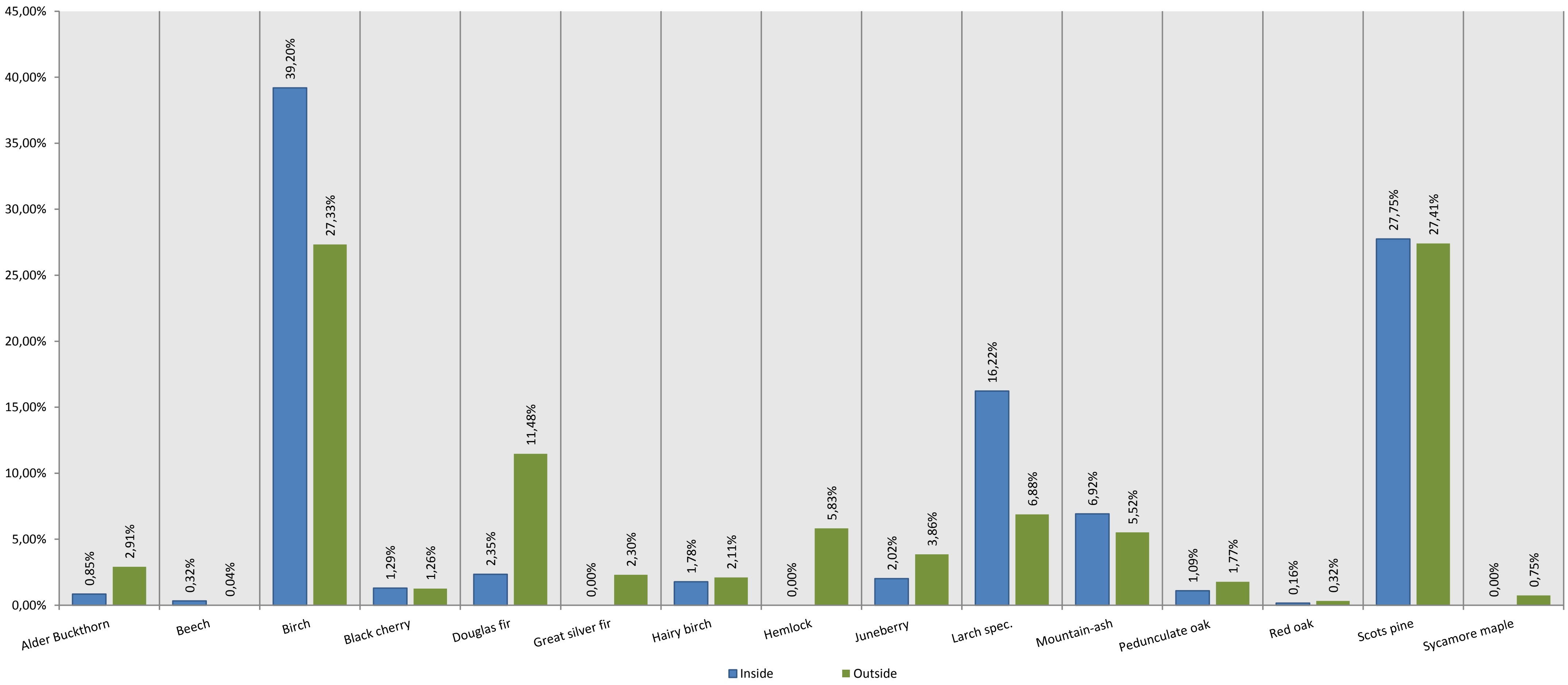
Figure 4.2: Location of the plots and the animal retreat zones

4.8.1 Composition of tree species

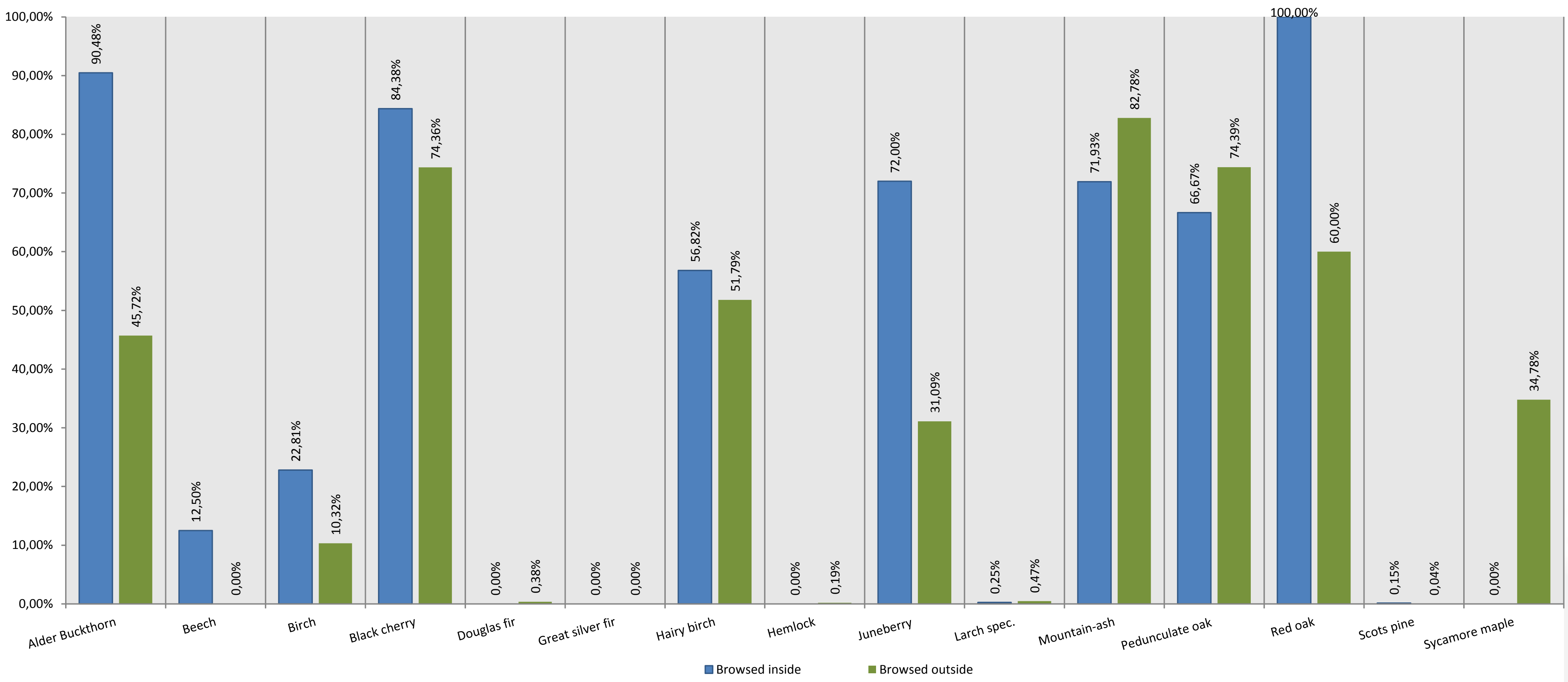
Graph 4.16 shows the composition of tree species inside and outside the animal retreat zones. The composition is presented in percentages because of the difference in number of trees inside and outside the animal retreat zones.
In the graph 4.16 can be seen that Birch and Scots pine are inventoried the most both inside and outside the animal retreat zones. Also can be seen that Alder buckthorn, Douglas fir and Juneberry are inventoried more outside than inside the animal retreat zones. Hemlock, Great silver fir and Sycamore maple were not found inside the animal retreat zones. Birch, Larch and Mountain-ash are inventoried more inside the animal retreat zones than outside.
Furthermore the amount of Scots pine is almost the same inside and outside the animal retreat zones.

4.8.2 Browsing

Graph 4.17 shows the difference in browsing percentage inside and outside the animal retreat zones. Here can be seen that the Red oak inside the animal retreat zones is browsed 100%. This is because only 2 Red oak were inventoried inside the animal retreat zones and both trees were browsed. Moreover, can be seen that Alder buckthorn, Black cherry, Hairy birch and Juneberry are browsed more inside than outside the animal retreat zones.
Of the total 2.472 trees inventoried inside the animal retreat zones there are 304 trees browsed. This gives a browsing percentage of 19,3%.
Of the total 9.253 trees inventoried outside the animal retreat zones there are 697 trees browsed. This gives a browsing percentage of 13,9%.
This means that 5,4% more browsing can be found inside than outside the animal retreat zones.



Graph 4.16: The difference in tree composition between inside and outside the animal retreat zones



Graph 4.17: The difference in browsing percentage between inside and outside the animal retreat zones

4.9 Exclosures

In this thesis there are 4 plots inventoried inside exclosures (plot numbers 15, 23, 34, 39). At 3 of these exclosures (plot numbers 23, 34, 39) there is also a plot placed next to the exclosure. This is done to compare the forest regeneration with and without the influence of ungulates.

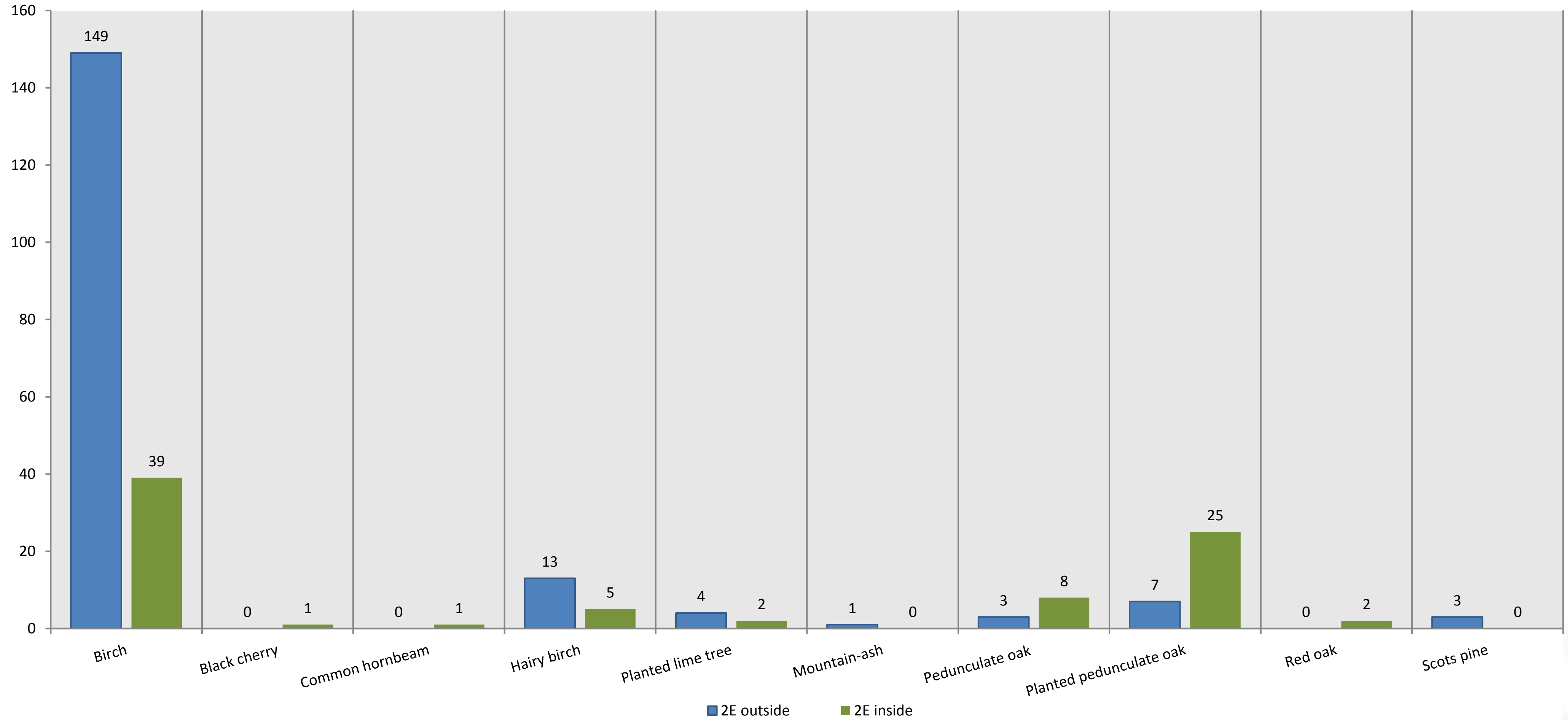
There is not enough data gathered to compare the forest development inside and outside the exclosures. No conclusions on forest development can be made because the differences between inside and outside an exclosure vary from one exclosure to another. This variation in differences can be explained by the age of the exclosures and the preparations for forest regeneration done inside.

- The exclosure where plots 39 and 40 are located is only a few years old. Furthermore Lime trees and Pedunculate oaks are planted inside and outside the exclosure in 2011.
- The exclosure where plots 33 and 34 are located is about 10 years old. Furthermore is experimented in this exclosure with different types of damages to the ground.
- The exclosure where plots 23 and 24 are located is about 10-15 years old. Furthermore these plots are located inside an animal retreat zone. Therefore the plot placed outside the exclosure is subjected to an abnormal high number of Red deer. Also the plot placed outside the exclosure (plot 23) is located under forest canopy, the plot inside the exclosure (plot 24) is located in a gap in the canopy. Furthermore there are Pedunculate oaks planted inside the exclosure and not outside.

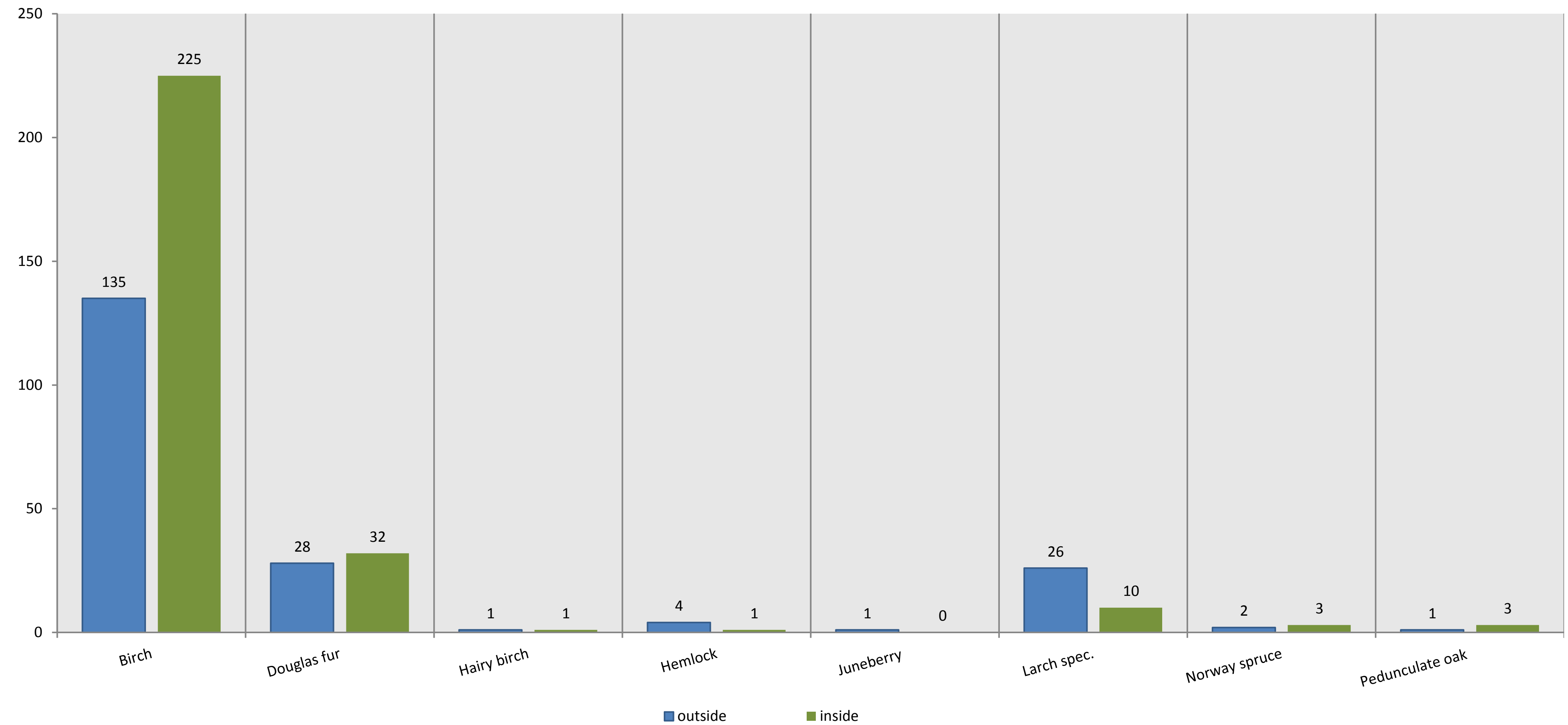
The composition of trees between inside and outside the exclosures are presented in the following graphs:

- Graph 4.18 shows the difference between plot number 39 (inside) and 40 (outside)
- Graph 4.19 shows the difference between plot number 34 (inside) and 33 (outside)
- Graph 4.20 shows the difference between plot number 23 (inside) and 24 (outside)

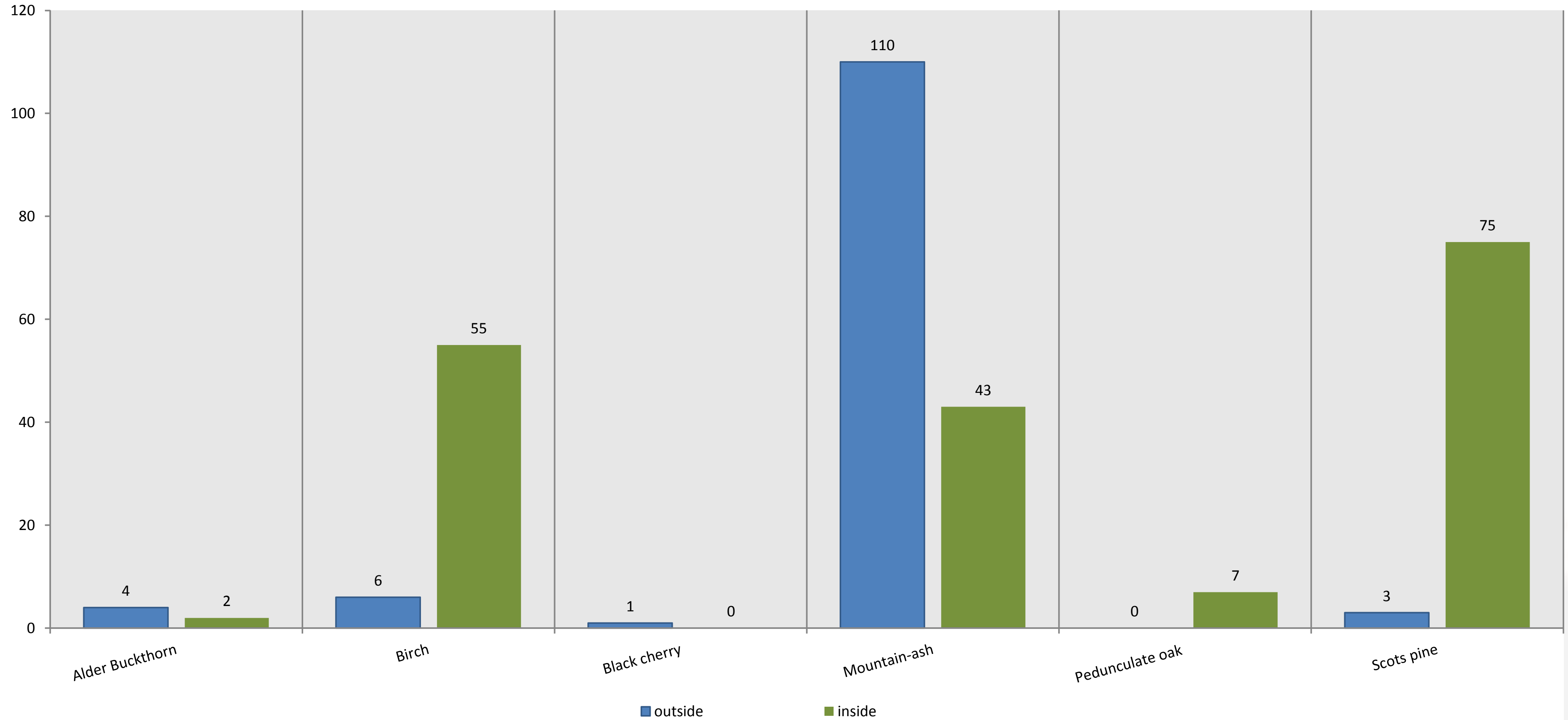
Here can be seen that the composition of trees is different each comparison. Furthermore can be seen that by the 2 older exclosures (plots 33, 34, 23 and 24) the amount of birch is higher inside than outside. By the younger exclosure this is the other way around (plots 39 and 40).



Graph 4.18: The difference in tree composition for inside and outside the exclosure in stand 2E (plot numbers 39 and 40)



Graph 4.19: The difference in tree composition for inside and outside the exclosure in stand 7J (plot numbers 34 and 33)



Graph 4.20: The difference in tree composition for inside and outside the exclosure in stand 26H1 (plot numbers 23 and 24)

4.10 Comparison of deer density with the amount of browsing and fraying

This paragraph presents the current density of Red deer and Roe deer and the inventoried amount of browsing and fraying damage.

Red Deer

Figure 4.4 shows the distribution of Red deer for the NP. The number of animals that are displayed in the pie charts in figure 4.4 can be found in table 4.3. The figure shows an average of the calculated spring counting of the last 3 year. Because, 3 years ago the locations of the animal retreat zones were changed and therefore also the local deer (Wensink, 2012).

Red deer is counted using 2 different methods, performed at the same time. The first method involves 2 people that count every Red deer they see on a so called "counting spot". The locations of these counting spots correspond with the location of the pie charts in figure 4.4. The second method involves 3 vehicles that drive through the NP, each in their own section. The "scouting areas" are shown in figure 4.4. The countings are performed 2 times each year in March, with a few days in between. The second counting is performed because not every deer is spotted during the first counting. Every Red deer that is encountered is recorded.

Figure 4.4 also shows the foraging routes of Red deer, estimated by game keeper Johan Wensink. Red deer needs to eat "juice food" (for example herbs) and "high fibre food" (for example top shoots). Red deer migrates from their resting areas to the areas where they can find juice food and along the way they will eat high fibre food (Lieftink, 2012; Wensink, 2012; Krul, 2012).

Roe deer

Figure 4.3 shows the distribution of Roe deer of the year 2012. The Roe deer are counted in the months February and March. "Mobile counting" in vehicles is performed and every Roe deer that is spotted is marked on a map. It is assumed that every deer seen and marked on the map is inside its own territory. No foraging routes are shown in the figure because Roe deer will only forage inside, or near, its own territory.

Amount of browsing and fraying

There is a relation between the present deer species and the damage they cause to regenerated trees. No deer, no damage to regenerated trees caused by deer. This relation is a fact (Leidekker, 2012). Figure 4.5 present the amount of browsing and fraying per plot. The size of the pie charts shows where the most damage is found. The bigger the pie chart; the bigger the number of browsed trees. Here can be seen that the majority of the browsed trees is in the north-east corner of the NP.

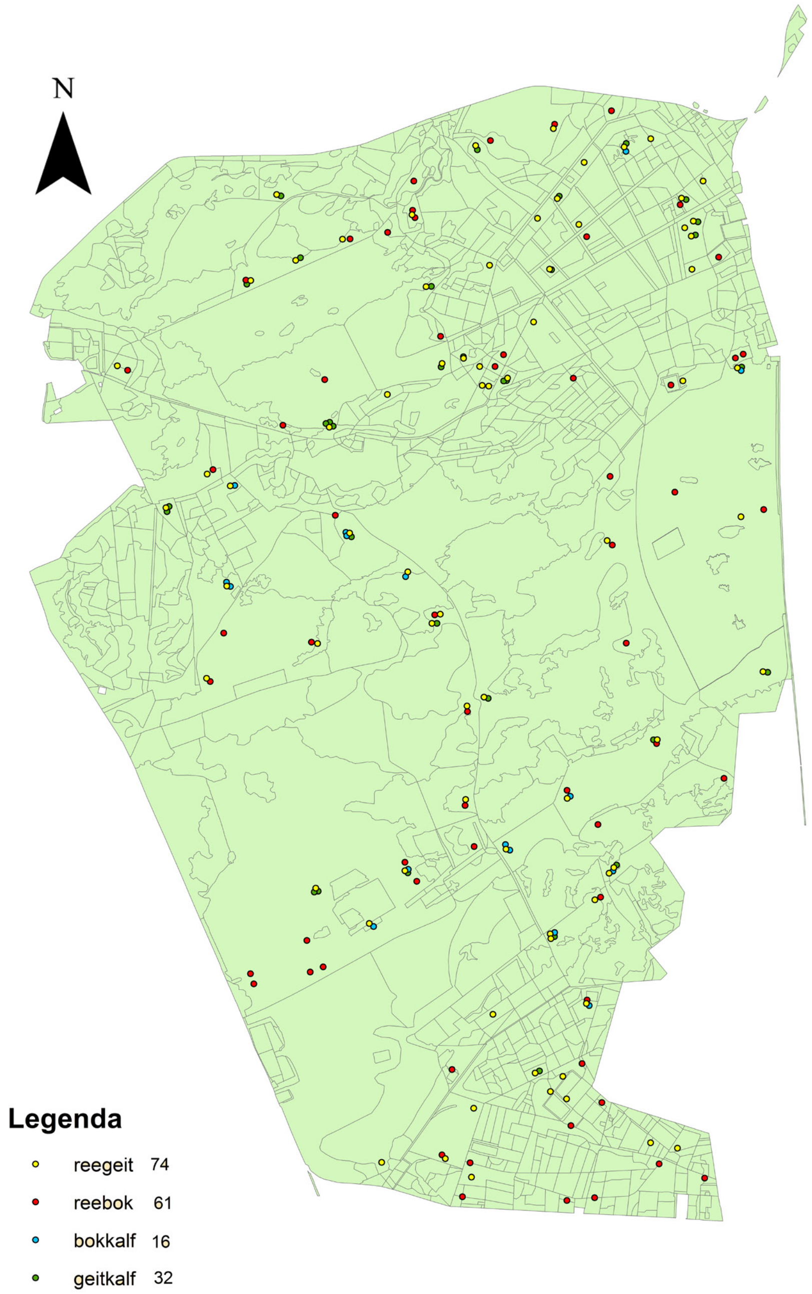


Figure 4.3: Distribution of Roe deer.

Comparison between deer density and the local amount of browsing and fraying

At first no clear conclusion can be drawn between the deer density and the amount of browsing and fraying. The most browsing and fraying seems to be in the north-east corner of the NP. Roe deer seems to be spread equally over the NP. The distribution of Red deer does not clearly correspond with the location of the most browsing and fraying. Red deer migrates between foraging areas and resting areas. With a little fantasy the foraging routes (shown in figure 4.4) lead to places with high density of browsing and fraying. These conclusions are very vague. No firm statements on the comparison between the local deer density and the local amount of browsing and fraying can be made, because:

- The distribution of deer shown in the figures 4.4 and 4.3 is an approximation of the truth. The distribution of the deer is based on the spring coutings and on the knowledge of the gamekeepers. It is possible to do some calculations but this is not useful, because the data is not accurate enough.
- For a correct comparison between the local deer density and the local amount of browsing and fraying, the density of Red deer and Roe deer must be combined into 1 unit per section or per plot location. However, the deer species have different browsing and fraying behavior. Therefore the spread of browsing and fraying is different for the deer species and they cannot be combined. This because both deer species can browse in the section or the plot location and a comparison with just one species would give a distorted outcome of the comparison.
- The only comparison between the local deer density and the local amount of browsing and fraying can be made for the whole NP, not per section or per plot location.

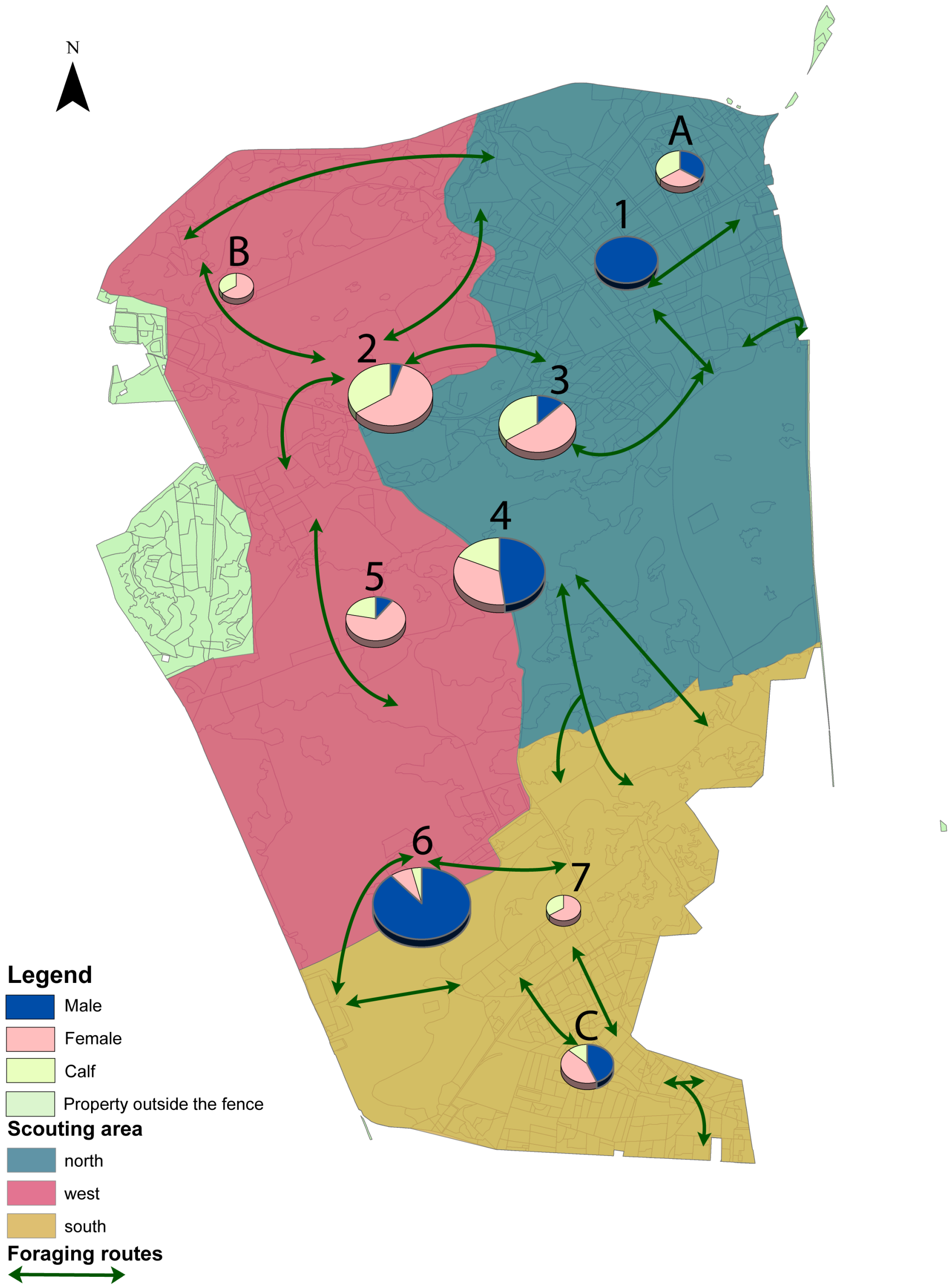


Figure 4.4: Distribution of Red deer, with foraging routes

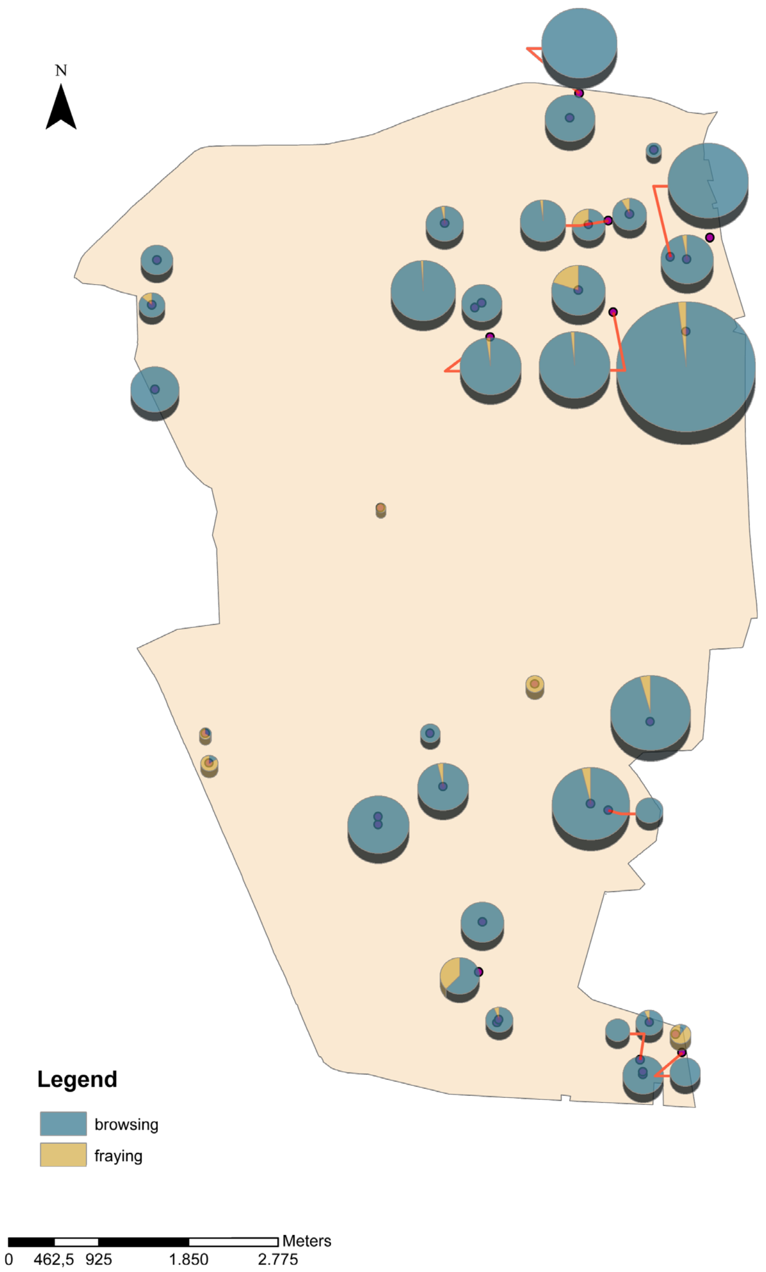


Figure 4.5: Amount of browsing and fraying per plot

Location	Name	Male	Female	Calf	Total
A	Scouting area north	2	2	2	6
B	Scouting area west	0	2	1	3
C	Scouting area south	3	3	1	7
Location	**Name**	**Male**	**Female**	**Calf**	**Total**
1	Zwarte veld	10	0	0	10
2	Schuilkelder	1	11	6	18
3	Koeverbos	2	8	5	15
4	Lijkweg	10	7	4	21
5	Plijmen	1	6	2	9
6	Staf	21	2	1	24
7	Kompagnieberg	0	2	1	3

Table 4.4: Numbers of Red deer distributed across the NP

Chapter 5 Discussion

This chapter presents the discussions concerning the method and the results.

5.1 Method

Choice of method

The method used in this thesis is not the only method that can be used for this research. More methods are available to inventory browsing-, fraying and bark stripping damage on (regenerated) trees. It can be argued that another method would have been easier to perform or could have given more accurate results. However, the multiannual monitoring program does not tolerate a big deviation from the method used in 2011 (Pronk, 2012). Because the data collected over the years needs to be collected in the same manner. If deviated too much the data would become incomparable.

Fraying and bark stripping

The method used is in this thesis is primarily focused on top shoot browsing damage. Therefore the inventory is focused on regenerated trees that are useful as research subjects for top shoot browsing. The conditions needed to accurately inventory fraying and bark stripping are different from the conditions of top shoot browsing. The most prominent difference is that of the denseness of trees. For the measuring of top shoot browsing dense sites are preferred. But in these sites fraying will less likely occur (Pronk 2012). The trees that are inventoried on average in this thesis are too small in diameter for bark stripping (Wensink, 2012).

Knowledge on browsing, fraying and stripping damage

All our knowledge on how to recognise the damage done to regenerated trees is gathered during this thesis. Literature and the gamekeepers of the NP provided the required knowledge to identify the damage. Therefore, it is possible that the data from the first inventoried plots is not as accurate as the data from the plots inventoried later.

Plot placement

Every plot is placed deliberately and any element of randomness is discarded. This is done because the goal of the thesis is to measure the changes in damage to forest regeneration over the coming years not the chance of tree damage. Therefore the amount of trees measured is important.

Completeness of the inventory

Because the changes are made during the inventory not all the data on the plots is complete. The database does contain all the data on browsing-, fraying- and bark stripping damage for every plot, but the data on the surroundings is incomplete. The missing data is not crucial for the multiannual monitoring program. The data is used to give an indication of what environment the inventoried trees grow in. This data can easily be added to the database at any time, as long as the same method is used.

Usage of environmental data

The data gathered on the environmental factors (described in sub-paragraph 3.4.2. "Measurements for surroundings") is not used in this thesis. The goal of the environmental data is to give an insight into the influences of the environment on the regenerated trees. The data was initially gathered to explain strange results found during the inventory. This proved to be unnecessary. However, the data is available for future research.

Changes to the method

Changes have been made to the method used in 2011 (Pronk, 2012) as mentioned in paragraph 3.5 "Justification". These changes have been put into practice during the inventory of this thesis. The implications these changes have are discussed below.

- Because only one wooden post is used in the first 10 plots it is possible that the measuring direction of these plots will be different in future inventories.
- 14 plots are marked with small wooden post. There is a chance that these markings are rotted or rooted by Wild boar. The plot locations are still retraceable with GPS but this will be less accurate.
- For the first 10 plots only browsing for the year 2012 is assessed. Therefore the data on browsing 2011 is incomplete. However, the data on browsing 2012 is usable without the data of 2011. This means that when data of 2011 is used it should be treated as a separate inventory.

5.2 Results

Usage of data collected in the research of 2011 for the multiannual research project

The plots inventoried in 2011 (Pronk, 2012) were only marked with GPS coordinates. The accuracy of most general GPS devices is at most several meters. Therefore, it is impossible to say if the plots that were re-inventoried in this thesis are in the exact same location and data on the same trees was gathered.
Furthermore, a large difference in browsing damage to coniferous trees has been found in the results of 2011 and in the result of this thesis. In 2011, 17 browsed Scots pines were inventoried in 1 plot (in stand 28R). While in this thesis only 2 browsed Scots pines were inventoried over the whole NP. Scots pine is susceptible to fungi and parasitic infections. This can result in dieback of branches and newly formed shoot (see figure 5.1). It is possible that dieback has been mistaken for browsing damage. Research location 28R has not been re-inventoried in the exact same location as in 2011 because the plot was divided over 3 separated locations and was found to be unsuitable for the multiannual research program. Therefore, the choice was made to relocate the whole plot to a better location in the same stand (plot 20).Because the plot was relocated no real explanation can be given for the difference in browsing.

Comparison inventory results 2011 and 2012

A comparison between results from the inventory of 2011 (Pronk, 2012) and the inventory of 2012 has no added value for this study. It is possible to compare the results, but with the many changes in the method and the deviation from the location of the plots it can be argued that the data gathered in 2011 is not fully comparable with the data gathered in 2012.
The work of Stefan Pronk has been very useful to develop a method for the NP, and the new series of plots measured in this thesis.

Figure 5.1: Dieback on a shoot of a Austrian pine

Red oak

As stated in paragraph 4.1 "Abnormalities" Red oak is excluded from the calculations. One Red oak coppice woodland (plot number 4) and one plot with Red oak coppiced stems (plot number 1) were inventoried. The Red oak inventoried in these plots are excluded from the calculations because these plots are not representative for Red oak in the NP.
If the Red oaks in the plots where included in the calculations they would give a greater amount of Red oak than there are on average in the NP. Also these plots give a lower amount of browsed Red oak in the NP. Furthermore these Red oaks will be coppiced after a few years. The accurate measurement of browsing- and fraying damage, which is the goal of the multiannual research, will be disturbed after the Red oak stems are coppiced.

Exclosures

The exclosures that are inventoried are not excluded from the calculations unless mentioned otherwise. This is done because it is hard to exclude this data from the dataset. The difference between including or excluding the data from the exclosures is negligible. There is a slight aberration in the results. Afterwards, the data from inside the exclosures should have been excluded from the calculations and the results. Furthermore, there is no difference found in the composition inside and outside the exclosures. The only difference that is found is between inside and outside an exclosure is that there is no browsing or fraying found in the exclosures.

Number of ungulates and distribution

The number of ungulates given in this thesis are the corrected spring counting's. These numbers are the minimum of ungulates present in spring. During the summer more animals are born which means that at the moment of the inventory more ungulates where present in the NP than the numbers show.

The distribution of animals given in this thesis is an approximation of the truth and should be treated as such. The distribution and foraging routes of the animals is based on the knowledge of the gamekeepers of the NP.

Bark stripping

Only 1 tree was found with bark stripping damage. This can indicate that the ungulates do not need the minerals that are present within the bark of trees. However, the inventory was performed in October while bark stripping is mostly done in winter when the amount of certain minerals is scarce. This could be an explanation for the low amount of bark stripping found in the NP.

Chapter 6 Scenarios

After the fence of the NP is lowered at the 2 connections free migration of ungulates is possible between the NP and the surrounding areas. This chapter presents scenarios that give a theoretical insight into the potential effects that free migration can have. These scenarios are based on the data inventoried in this thesis, data gathered from literature and data gathered on the populations of the “Planken Wambuis” and the “Deelerwoud”. A large part of the information presented in the paragraphs 2.1 “Ecology of deer species” and 2.2 “Population size” is used to substantiate the statements presented in this chapter.

6.1 Introduction of the scenarios

A scenario is a description of a possible future situation. Many scenarios can be thought of but the scenarios discussed in this chapter were found to be the most plausible scenarios. Based on literature and interviews with experts the following scenarios are well-considered, but they seem unlikely to happen. In the following enumeration a few of these scenarios are presented and substantiated.

- **The wildlife crossings are not used by the ungulates**
  Based on experiences with similar wildlife crossings it is very likely that the ungulates will make use of the crossings (Belle, 2006). "It is like the ungulates are standing in line waiting to cross as soon as the fence is lowered" (Wensink, 2012; Leidekker, 2012).
- **Deer species will exit the NP and no deer species will enter the NP**
  The NP contains enough food for the deer species. Also enough tranquillity can be found in the animal retreat zones in the NP. These are the 2 aspects a deer needs in a habitat (Leidekker, 2012; Wensink, 2012).
  The population sizes of the deer species are larger in the Deelerwoud and the Planken Wambuis in comparison with the population sizes of the NP (see figure 2.2 and table 2.2). This means there is more competition for food and rest outside the NP than inside.
  A 700 hectare big animal retreat zone is present in the Planken Wambuis where deer can find rest, but food is scarcer in comparison with the NP.
  There are fewer visitors in the Deelerwoud than in the NP, this means that there is less disturbances for the ungulates. Food does not seem to be an issue in the Deelerwoud. However, the population sizes are much bigger in the Deelerwoud. This means there is more competition between ungulates.
  A preliminary estimation shows that the habitat suitability for deer species is better in the NP than the habitat suitability in the Planken Wambuis and the Deelerwoud. With this statement should be mentioned that the ungulates are able to migrate from the Planken Wambuis and the Deelerwoud to further areas.
  Above mentioned in mind, it seems unlikely that the population sizes in the NP will decrease. It seems more likely that they will increase.
- **More than the half of the deer species from the Deelerwoud and the Planken Wambuis will migrate to the NP**
  The base population sizes will be kept on the level the managers of the NP have decided. Even if a lot of ungulates will migrate to the NP. This will only mean that more ungulates will be hunted and the browsing pressure on the vegetation will not increase permanently.

Possible scenarios

In total 3 scenarios have been compiled about the population size, the population composition and the foraging of the deer species. Any changes in deer populations can have effects on other animals, habitats and the management of the NP. Examples for managment are changes in hunting and forestry. The goal of the scenarios is to present the possible theoretical effects free migration can have on deer populations and tree regeneration.

The 3 scenarios implemented in this chapter are:

1. Fallow deer from Deelerwoud migrate into the NP and more Red deer are hunted
2. Red deer is resting in the Planken Wambuis and is foraging in the NP
3. The sizes of the deer base populations are increased

These scenarios are written within the conditions set by the managers of the NP. For example, the managers of the NP want to keep the browsing pressure by deer species on the same level as it was before free migration has started. This means that the base population sizes are kept in mind in the scenarios.

6.2 Scenario 1: Fallow deer migrates from the Deelerwoud to the NP

Scenario description

After the fence is lowered at the Delenseweg (N804) Fallow deer will migrate from the Deelerwoud to the NP. First males (Belle, 2006) and after a longer period females will also follow. The managers of the NP have not decided the numbers of Fallow deer they will allow in the NP. In this scenario 100 Fallow deer have entered the NP.

No specific timetable is given for when this scenario is achieved. This scenario might develop over several years.

In table 6.1 an overview of scenario 1 is given.

Ungulate	Increase	Stable	Decrease
Red deer			X
Fallow deer	X		
Roe deer			X

Table 6.1: Overview scenario 1

Scenario justification

- The density of the deer species in the Deelerwoud is much higher than the density of deer species in the NP and the Planken Wambuis
- No Fallow deer are currently present in the NP and the Planken Wambuis
- Fallow deer are curious animals and they will explore new areas if they have the opportunity (Hoorn, 2006). This mostly concerns young male animals. Fallow deer are quite home-loving, especially females and old males (Belle, 2006). With these facts in mind it seems likely Fallow deer will enter the NP from the Deelerwoud
- As noticed in the experiment Deelerwoud the migration of Fallow deer is a slow process (Belle, 2006). It might take a while before Fallow deer have populated the NP (Krul, 2012)
- Fallow deer are welcome to enter the NP (Leidekker, 2012)

Effect on ungulates

Red deer and Fallow deer are both intermediate feeders (Wieren, 1997). The food consumption of 2 Fallow deer is equal to 1 Red deer (Vereniging het Edelhert, 2011). Based on the browsing pressure on the vegetation the managers of the NP have decided to keep a base population size of 200 Red deer. The managers of the NP do not want the browsing pressure to increase after the free migration of ungulates is possible. This means that for every 2 Fallow deer that enters the NP 1 Red deer must leave (by hunting or on own initiative) (Leidekker, 2012). In order to keep the browsing pressure on the vegetation on the same level when 100 Fallow deer have entered the NP the population size of Red deer must be set back from 200 to 150 Red deer. In this scenario no Red deer leaves the park on own initiative. This means that more Red deer must be hunted.

The growth of intermediate feeders to 250 animals (both Red and Fallow deer) will have an effect on Roe deer. Because Roe deer is sensitive for stress and disturbance by other ungulates the population size of Roe deer might decrease (Wensink, 2012). It is hard to say how big this decrease will be.

Effect on regenerated trees and forest development

When 100 Fallow deer have entered the NP and the population size of Red deer is set back to 150 animals, the numbers of intermediate feeders has grown to 250 animals. Because the food consumption of 2 Fallow deer is equal to 1 Red deer the food consumption will remain the same as before the change in size and composition of the populations. A Fallow deer is a bit more off a grazer compared to Red deer (Borst, 2008). Because the number of deer increases in the NP the Roe deer will have more stress. This because there are more encounters with other deer. When there is enough stress the health of the Roe deer will decrease and they will become susceptible to infections and parasites. Eventually the Roe deer population will decrease in numbers.

The above means that the browsing pressure on regenerated trees will decrease and the browsing pressure on grass- and herb species will increase. The deer species prefer to browse Black cherry, Pedunculate oak, Red oak, Mountain ash, Hairy birch and Alder buckthorn. The browsing percentage on these species will either stay at the same level or decrease with a small amount. The browsing on the species Birch and Beech and all coniferous species will either reduce or be absent. This means that with the current management the effects on forest regeneration and development will be minimal.

Other effects

- The Fallow deer is less frightened by antrophogenic disturbances (Hoorn, 2006). Also the number of deer has increased. Therefore, it is expected that the wildlife visibility will increase. However, the experiment of the Deelerwoud (Huysentruyt,2011) shows that the visibillity of deer species does not automatically increase when the population sizes increase.
- The changes in the deer populations might cause changes in the use of the area for resting and feeding.

6.3 Scenario 2: foraging of Red deer

Scenario description

In this scenario about 50 Red deer from the NP migrate to the Planken Wambuis to find rest during daytime. At night these 50 Red deer and another 50 Red deer from the Planken Wambuis will come to the NP to forage. This migration happens every day, except for the rut period.
No specific time is given for when this scenario is achieved. This scenario might develop in less than a year.
In table 6.2 an overview of scenario 2 is given.

Ungulate	Increase	Stable	Decrease
Red deer	X		
Fallow deer		X	
Roe deer		X	

Table 6.2: Overview scenario 2

Scenario justification

- The number of Red deer in the Planken Wambuis is almost twice as high as the number of Red deer in the NP. The numbers of Roe deer are about the same
- In the Planken Wambuis a 700 hectare animal retreat zone is present, connected to the wildlife crossing. “Deer can find all the rest they want here” (Lieftink, 2012)
- There are fewer visitors in the Planken Wambuis than in the NP (Lieftink, 2012)
- The amount of available food is scarce in the Planken Wambuis. (Concluded after a visit to the Planken Wambuis)
- Enough food is available in the NP but deer are bound to the animal retreat zones during daytime because of the visitorsof the NP
- Red deer are not territorial (Borst, 2010) and the daily usage of the same migration route is a common behaviour (Lieftink, 2012)

Effect on ungulates

During the day the number of Red deer has decreased in the NP by 50. At night the number of Red deer in the NP increased by a 100. These numbers are a years average. The numbers will fluctuate throughout the year.
Red deer will find permanent foraging areas in the NP. Where these permanent foraging areas will be located cannot be said. This might be close to the crossing between the Planken Wambuis and the NP because traveling short distances saves energy.
Roe deer is territorial and will not show the same migration behaviour as the Red deer. During the day Roe deer will find less competition of Red deer. Roe deer has been given more space by Red deer. However, during the day Roe deer is also hindered to forage freely because of the disturbance caused by the people present in the NP. At night Roe deer will encounter more competition from Red deer. Only a part of the Roe deer population in the NP will be hindered by the competition with Red deer because the foraging area of Red deer will be concentrated in a part of the NP. Roe deer is very spread-out over the NP (see figure 4.4).
In this scenario Fallow deer has not migrated to the NP and is therefore disregarded.

Effect on regenerated trees and forest development

50 Red deer will migrate to the Planken Wambuis in order to find rest during the day and a 100 Red deer will come to the NP in order to feed at night. This means the browsing pressure on regenerated trees has increased by 50 intermediate feeders compared to the situation before free migration was realized. The amount of food consumed during the day in the Planken Wambuis does not outweigh the amount of food consumed in the NP at night.

The above means that the browsing pressure on regenerated trees will increase. The deer species prefer to browse Black cherry, Pedunculate oak, Red oak, Mountain ash, Hairy birch and Alder buckthorn. The browsing percentage on these species will increase. The browsing on the species Birch and Beech and all coniferous species will increase.
Based on the “Deelerwoud experiment” (Belle,2006) the increase in the number of Red deer will not prevent broad-leaved tree species from regenerating.
This means that with the current management less of the preferred broad-leaved species grow above browsing height and become full grown trees. The browsing on coniferous species will not affect the forest development.

Other effects

- The visibility of deer species for the parks visitors will decrease
- The locations in the NP where damage to the vegetation occur will change

6.4 Scenario 3: Population sizes of Red deer and Fallow deer increase

Scenario description

In this scenario more Red and Fallow deer will migrate to the NP. The population sizes are increased to:

- 400 Red deer, which are 8 Red deer per 100 hectares
- 100 Fallow deer, which are 2 Fallow deer per 100 hectares
- 100 Roe deer, which are 2 Roe deer per 100 hectares

This makes 450 intermediate feeders and 100 browsers. Before the free migration was possible 7,6 deer per 100 hectares are present in the NP. In this scenario the number has increased to 12 deer per 100 hectares. Compared to the Deelerwoud, with 45,5 deer per 100 hectares, the amount of deer species in the NP is still small.
This scenario will develop over several years.
In table 6.3 an overview is given of scenario 3.

Ungulate	Increased	Stable	Decreased
Red deer	X		
Fallow deer	X		
Roe deer			X

Table 6.3: Overview scenario 3

Scenario justification

- Red deer will migrate from the Planken Wambuis and from the Deelerwoud to the NP
- Fallow deer migrates from the Deelerwoud to the NP
- Besides the deer that enter the NP from neighbouring areas deer are also born in the NP

- The population of Roe deer suffers under the consequences of competition with the other deer species
- The increase of the intended population sizes in the NP could be an experiment or could be a maintained policy. The motives are disregarded in this report because these motives will not play a part in the effects of the increased population sizes
- The increase in the population sizes is not a recommendation, it is only theoretical

Effect on ungulates

The birth of new Red deer and Fallow deer will decrease with reference to the normal population growth. This is because the population sizes have grown and there is more competition between the deer species and between the individual animals.
Roe deer suffers more hardships from competition by Red and Fallow deer. Therefore the numbers of Roe deer will decrease. In this scenario the population has decreased from 183 (Stichting Het Nationale Park De Hoge Veluwe, 2012[b]) to 100 animals.

Effect on regenerated trees and forest development

The population size of Red and Fallow deer has increased. But from an ecological point of view the maximum amount of deer species that are able to live in the NP is not reached by far. The vegetation can bear much more browsing pressure. Yet, this is not the wish from the managers of the NP.
Forestry is not the main goal in the NP but the managers of the NP want to keep the possibility of harvesting a reasonable quality and quantity of wood from the NP's forests. "Not only now, but also in the following decades" (Leidekker, 2012).
The effect of the increased populations of intermediate feeders on forest regeneration is that the browsing pressure on the vegetation will increase. Regenerated broad-leaved tree species will decline in number, but they will not disappear completely from the forest (Belle, 2006). Regenerated broad-leaved tree species will not grow above browsing height under the influence of the browsing pressure. Especially Black cherry and Pedunculate oak will be browsed and will decline the most. Mountain-ash is present in high numbers. Therefore the browsing pressure must be very high before Mountain-ash will disappear, the same can be said for Birch.
Not only broad-leaved but also coniferous tree species go through the effects of the increased deer populations. Especially Larch, Douglas-fir and Hemlock will be browsed. Scots pine will experience browsing too but this species is present in such high numbers that the effect will barely be noticed.

More (regenerated) trees are frayed. How much the amount of frayed trees has increased depends on the composition in gender of the deer populations. The more male deer present the more frayed trees can be found.

Chapter 7: Conclusion

In this chapter an answer is given to the main research question. In order to answer the main question the sub-questions are discussed first.

7.1 Conclusion of each sub-question

7.1.1 Sub-question 1

"What additions and changes can be made to the method used in 2011?"

The enumeration below is a short summary of the additions and changes made.

- The division of the NP into 3 sections is maintained, but the section borders have been changed to correspond with clearly recognizable landmarks
- The measurements for factors that can influence the amount of damage to regenerated trees by deer species are added to the method used in this thesis
- Besides noting the coordinates, wooden posts are places to mark the plots location in the field
- Changes have been made to the conditions of a plot location
- Changes have been made to the way a plot is set up

For further detail see paragraph 3.5 "Justification".

7.1.2 Sub-question 2

"How much browsing-, fraying- and bark stripping damage to regenerated trees caused by ungulates is there currently in the NP?"

Browsing

- 13,9% (1.833) of all inventoried trees (13.211) are browsed
- 99,4% of all the browsed trees are broad-leaved species
- In numbers Mountain-ash (546) and Birch (482) are browsed the most. Proportional Black cherry (76%) and Pedunculate oak (65%) are browsed the most
- Striking is that Black cherry is browsed so much, this is against expectations

Fraying

- 0,7% (90) of all inventoried trees (13.211) are frayed
- In numbers Birch (30) and Scotch pine (30) are frayed the most. Proportional Black cherry (4%) and Great silver fir (3%) are frayed the most
- The higher the trees, the more fraying damage is found. The highest number and the highest proportion of frayed trees are found in height class 6 (above 2 meters)

Bark stripping

- Only 1 regenerated tree with a stripped bark is found.

For further detail see chapter 4 "Results".

7.1.3 Sub-question 3

"What is the relation between the current browsing-, fraying- and bark stripping damage and the density of deer species in the NP?"

There is a relation between the present deer species and the damage they cause to regenerated trees. No deer, no damage to regenerated trees caused by deer. This relation is a fact (see figure 2.1).

When the inventory was preformed 196 Red deer and 183 Roe deer were present in the NP. With these numbers the total browsing damage to all inventoried regenerated trees was 13,9%.

With the current number of male deer the total fraying damage to all inventoried regenerated trees was 0,7%.

The amount of bark stripping damage on regenerated trees is negligible with the current number of deer in the NP.

When the population sizes of the deer species increases or decreases the amount of browsed-, frayed- and stripped regenerated trees also increases or decreases along with the deer populations.

For further detail see paragraph 4.10 "Comparison of deer density with the amount of browsing and fraying".

7.1.4 Sub-question 4

"What effects can free migration of ungulates have on the population size and/or composition of deer species in the NP?"

Free migration can be seen as the "guiding factor" and management can be seen as the "deciding factor" in what changes will occur in population size and/or species composition. This means that free migration can result into changes, but the managers of the NP will decide what changes will be allowed. Therefore, no effects on the population size and/or composition can be determined.

The above mentioned cannot be said for the gender composition of the populations, because gender composition cannot be managed by population management. For examples see chapter 6 "Scenarios"

7.1.5 Sub-question 5

"What are the effects on the forest development if the population size and/or composition of deer species changes?"

Changes in population size and composition of deer species can have the following effects:

- **More browsing**
  More coniferous species will be browsed, especially Hemlock and Douglas fir. However, the majority of browsed trees will still be broad-leaved species. Especially Black cherry and Pedunculate oak will suffer under the overall increased deer population sizes. The browsing damage on Mountain-ash and Birch will increase too, but these species are present in high numbers and therefore the decline in numbers will be unnoticeable. See paragraph 4.4 "Browsing".

- **Less browsing**
  The browsing pressure on less preferred tree species will decrease. These are the coniferous species and the broad-leaved species Beech and Birch.
  The browsing pressure on the preferred tree species will remain on the same level or will decline. These are the species Black cherry, Mountain-ash, Hairy birch and Alder Buckthorn. The browsing pressure on the other trees inventoried in this thesis are somewhere in between. These are the species Juneberry and Sycamore maple. See paragraph 4.4 "Browsing".

- **More fraying**
  Male deer have a preference to fray Black cherry and Great silver fir. Especially these species will be frayed more. Fraying damage on the other tree species will increase too, but the amount of fraying damage to these other tree species will not increase as much as the amount of fraying damage to Black cherry and Great silver fir.
  Mostly bigger regenerated trees are frayed. See paragraph 4.5 "Fraying and bark stripping".

- **Less fraying**
  Fraying damage on all regenerated tree species will decrease. The preferred tree species Black cherry and Great silver fir will still be frayed more than the other species. See paragraph 4.5 "Fraying and bark stripping".

- **Bark stripping**
  No conclusions on bark stripping can be made based on the data gathered in this thesis. See paragraph 5.1 "Method".

- **Change in height of damage**
  Each deer species has a different maximum height they can reach to cause damage. With a change in species composition the height that regenerated trees will be browsed can increase or decrease. This depends on what deer species increases or decreases. See paragraph 2.4 "Traces of browsing, fraying and bark stripping".

7.2 Conclusion of the main research question

What are the effects of free migration of ungulates on the forest development in "Het Nationale Park De Hoge Veluwe"?

Depending on what effect free migration is going to have on the deer population sizes, the composition of deer species and the composition in gender will have the following effects on regenerated trees:

- **Browsing damage on regenerated trees increases**
  Especially preferred species like Black cherry and Pedunculate oak will become scarce. These species will seldom grow out to full grown trees. Species that deer do not prefer like Birch, Beech and coniferous trees will be browsed more.

- **Browsing damage on regenerated trees decreases**
  Preferred species like Black cherry and Pedunculate oak are browsed in the same amount or the browsing will decline. The browsing on less preferred tree species like Birch, Beech and coniferous species will decline or even end.

- **Fraying damage on regenerated trees increases**
  The current amount of fraying damage to regenerated trees is negligible. If the amount of fraying damage increases, the forest development will barely suffer under the influence of a higher number of frayed trees. Most trees are still able to grow after they are frayed. The increase of fraying will only have an effect on forestry: less regenerated trees are able to grow into quality trees for wood production.

- **Fraying damage on regenerated trees decreases**
  The current amount of fraying damage to regenerated trees is negligible and therefore the effect of fraying on the forest development is also negligible.

- **Bark stripping damage on regenerated trees increases**
  The current amount of bark stripping damage to regenerated trees is negligible. If the amount of bark stripping damage increases, the forest development will barely suffer under the influence of a higher number of bark stripped trees. Most trees are still able to grow after their bark has been stripped. The increase of bark stripping will only have an effect on the forestry: less regenerated trees are able to grow into quality trees for wood production.

- **Bark stripping damage on regenerated trees decreases**
  The current amount of bark stripping damage to regenerated trees is negligible and therefore the effect of bark stripping on the forest development is also negligible.

The influences of Moeflon and Wild boar present in the NP are negligible. For further details see paragraph 1.7 "Assumptions".

Chapter 8: Recommendations

Recommendations for future research on the subjects of this thesis are two-part. Namely recommendations for:

- The inventory for the multiannual monitoring program
- Research on the perspective on forest regeneration with changes in wildlife migration.

8.1 The inventory

- All of the materials needed to set up the plots and perform the inventory are available at the NP. It is recommended to use the same materials to perform the inventory. This way the inventory is done the same as in this thesis
- The use of fixed borders for the subplots is recommended in order to tell if a tree grows inside the plot or not. An eye-catching colored string or a PVC pipe can be used to mark the borders. These borders are placed on the ground at the base of the regenerated trees. Therefore, the borders can be easier seen during the inventory. In order to measure a trend it is important to inventory the exact same locations every year. This means the borders of the plot should be placed and marked with great accuracy
- It is recommended that the string that is used to set out the plot remains on its place during the inventory. This string splits the subplots in half (See sub-paragraph 3.3.2 "Setup and orientation of the plot"). This makes it possible to inventory with two persons without interfering each other. When inventorying with only one person the string can be used to keep a better overview of which trees are inventoried
- It is recommended that the inventory is performed by at least 2 persons. 1 person can perform the measurements, while the other person records the measurements immediately on a laptop. It is difficult to perform the inventory alone and it is inefficient
- It is recommended to perform the inventory before falls sets in and the leaves have not yet fallen off the trees. The leaves make it easier to identify the species. It also makes the spotting of small regenerated broad-leaved tree species in dense regeneration easier
- As mentioned in paragraph 3.5 "Justification" all the data collected in the field for the whole multiannual monitoring program needs to be uniform. It is therefore recommended that coming inventories will be performed in the months September and October

8.2 The perspective on forest regeneration

The data presented in this thesis gives a rough estimation on where the animals live and forage. To give a better indication on the effects of wildlife migration on the damage to regenerated trees it is recommended to:

- Perform a more thoroughgoing habitat- and vegetation research. The found data can be used to better predict where and in what amount browsing damage will occur
- Tranquillity of the habitat should be taken into account as a factor when this research is performed. This because the browsing behavior of ungulates is mainly influenced by available food and tranquillity
- Replicate the inventory on habitat and vegetation in the Planken Wambuis and the Deelerwoud. With this data the habitat suitability of the areas can be compared. The data can be used to give a better estimation on what the ungulates are likely to do when free migration is possible
- Use the data gathered with the cameras which are set up near the wildlife crossings to monitor the passage of ungulates. When analyzed it give an indication of ungulate migration

8.3 Dataset

With the dataset created by means of the inventory it is possible to answer other questions than discussed in this thesis. The subjects below can be used as inspiration for further research questions.

- Relation between browsing damage assessed in this thesis of 2011 and 2012
- Relation between browsing-, fraying- and bark stripping damage and anthropogenic influences, like roads
- Relation between browsing-, fraying- and bark stripping damage and supplies, like game meadows and mineral licks
- The effects of the density of regenerated tree

8.4 Additional

The multiannual monitoring program can be used as a tool to check if the intended population sizes are on the desirable level. The managers of the NP want to keep the amount of damage on regenerated trees at the same level as before free migration was possible. With the results of the multiannual monitoring program can be seen when the amount of damage is increasing or decreasing. This can be used to evaluate and correct the intended population size or the number of animals that must be shot.

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Attachments

Attachment 1: - Plot information
- Location of the plots
- Pictures of the plots

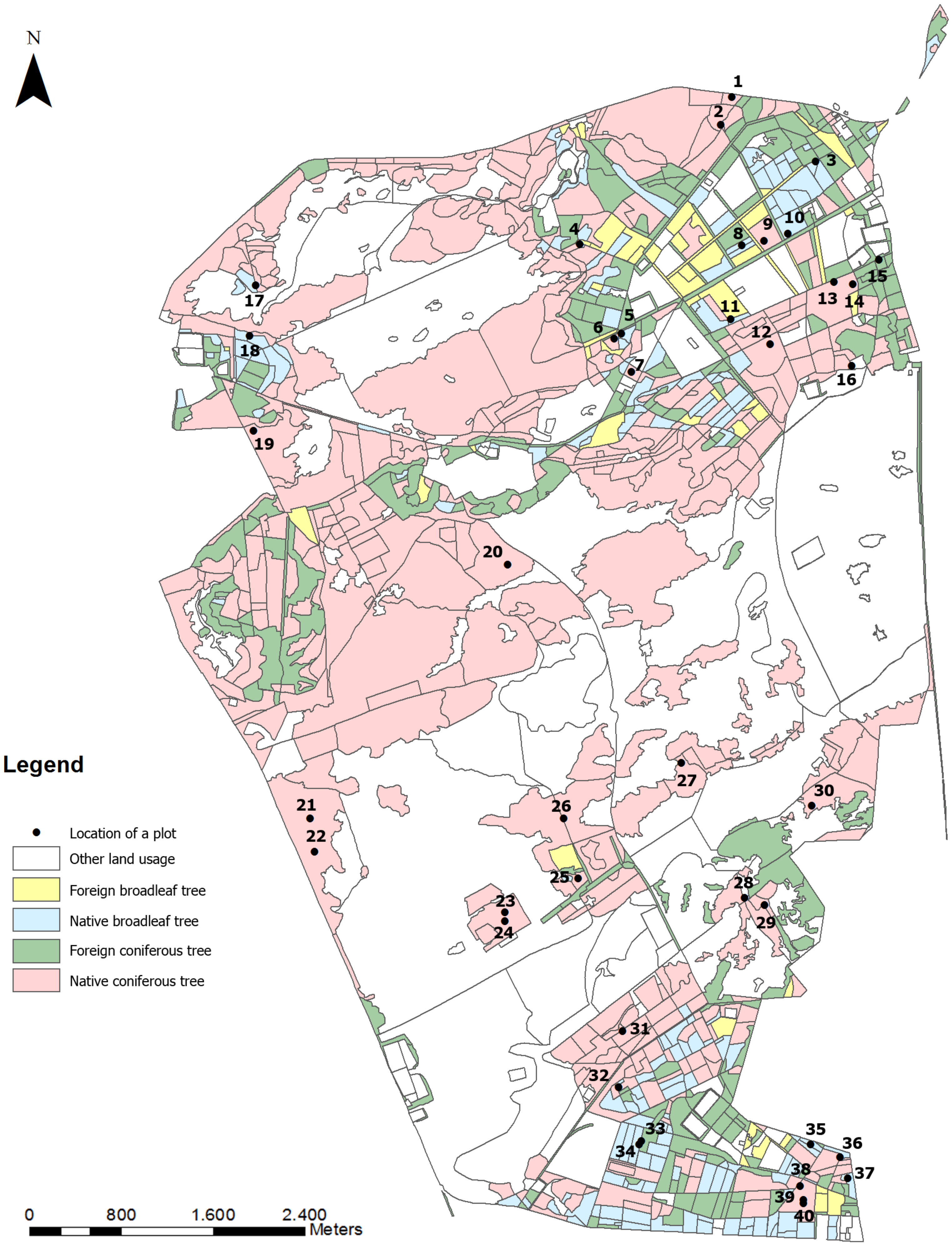
Attachment 2: Definition of used terms

Attachment 3: List of used tree species

Attachment 4: DVD with data

Attachment 1: Plot information

Plot number	Stand	Number of measured trees	Number of broad-leaved trees	Number of coniferous trees	Number of browsed trees (total)	Number of frayed trees	Number of stripped trees	Animal retreat zone	Exclosure	Dominant tree species	Dominant tree height	Sub-dominant tree species	Coverage canopy	Coverage shrub layer	Coverage ground layer: Blue berry	Coverage ground layer: Grass	Coverage ground layer: Other	Remarks
Total:		**13.211**	**6.865**	**6.346**	**1.833**	**90**	**1**	**10**	**4**									
1	84N	453	378	75	116	0	0											Red oak coppice stems
2	95E	557	531	26	51	0	0											
3	81L	434	6	428	5	0	0			Douglas fir	30	Silver Fir	65%	45	1	10	95	
4	91K	581	525	56	28	1	0			Red oak		Birch	40%	55	1	3	96	Red oak coppice woodland
5	78C	705	51	654	33	0	1			Hemlock	25	Silver Fir	55%	50	1	3	99	
6	77N	419	309	110	85	1	0			Scots pine		Larch spec.	25%	80	5	30	65	
7	77A	254	213	41	75	2	0			Scots pine	16	Birch	20%	55	0	80	95	
8	80C2	519	23	496	17	6	0			Douglas fir		Larch spec.	60%	25	4	10	95	
9	80A	235	194	41	41	1	0											
10	81E	303	148	155	22	2	0			Douglas fir	21	Scots pine	60%	60	1	7	95	
11	48A	183	174	9	47	12	0	X		Silver birch	16	Eastern white pine	5%	30	0	95	40	
12	42A	314	307	7	102	2	0	X		Scots pine	16	Birch	8%	60	10	60	40	
13	43A	340	324	16	133	0	0			Scots pine		-						
14	43A	612	384	228	55	2	0			Scots pine	13	Birch	15%	65	10	25	65	
15	44J1	305	299	6	0	0	0		X	Larch spec.		Beech	2%	40	20	40	40	
16	33B	465	465	0	391	8	0			Scots pine		Pedunculant oak	40%	30	10	60	25	
17	68D1	113	25	88	21	0	0			Scots pine		-	25%	45	0	50	50	
18	67G	423	15	408	12	2	0			Scots pine	18	Douglas fir	50%	55	4	15	90	
19	61L	274	75	199	48	0	0			Scots pine		-	45%	45	1	60	40	
20	28R	210	0	210	0	2	0			Scots pine	15	-	3%	30	3	75	75	
21	26J	117	1	116	1	2	0			Scots pine		Corsican Pine	15%	35	0	40	40	
22	26J	153	1	152	1	5	0			Scots pine		-	45%	20	2	49	49	
23	26H1	182	107	75	0	0	0	X	X	Scots pine		-						
24	26H1	124	121	3	78	0	0	X		Scots pine		-						
25	26E	220	145	75	51	2	0	X		Scots pine	23	Birch	22%	25	3	60	85	
26	28G	282	7	275	8	0	0			Scots pine	10	-	6%	17	0	70	90	Busy bicycle path very close by
27	29J	163	0	163	0	7	0											
28	24T1	537	505	32	119	5	0			Scots pine	21	Birch	6%	25	1	80	80	
29	24C	180	27	153	15	0	0			Scots pine	15	-	70%	50	0	40	95	
30	24H	246	211	35	126	6	0	X		Scots pine	18	Birch	20%	20	2	97	25	
31	21B	270	44	226	38	0	0	X		Scots pine		-	20%	40	1	85	80	
32	19M1	632	128	504	20	12	0			Silver fir		Scots pine	50%	65	2	20	90	
33	7J	327	138	189	14	1	0			Birch	12	Douglas fir	17%	45	5	70	28	
34	7J	353	229	124	0	0	0		X	Birch	12	Douglas fir	20%	70	3	20	70	
35	11S	521	73	448	14	1	0	X		Larch spec	20	Pedunculant oak	15%	30	0	50	60	
36	10H1	388	61	327	1	8	0	X		Scots pine		-						
37	10A	206	190	16	19	0	0	X		Corsican pine	15	Birch	40%	20	5	85	70	
38	2E	349	172	177	12	0	0											
39	2E	83	83	0	0	0	0		X	Scots pine	13	Birch	20%	35	0	70	50	
40	2E	179	176	3	34	0	0			Scots pine	13	Birch	5%	30	5	70	60	


N
1
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27
28
29
30
31
32
33
34
35
36
37
38
39
40
Legend
Location of a plot
Other land usage
Foreign broadleaf tree
Native broadleaf tree
Foreign coniferous tree
Native coniferous tree
0
800
1.600
2.400
Meters

Plot number: 1
Stand: 84N


North


East


South


West

Plot number: 2
Stand: 95E


North


East


South


West

Plot number: 3
Stand: 81L


North


East


South


West

Plot number: 4
Stand: 91K


North


East


South


West

Plot number: 5
Stand: 78C


North


East


South


West

Plot number: 6
Stand: 77N


North


East


South


West

Plot number: 7
Stand: 77A


North


East


South


West

Plot number: 8
Stand: 80C2


North


East


South


West

Plot number: 9
Stand: 80A


North


East


South


West

Plot number: 10
Stand: 81E


North


East


South


West

Plot number: 11
Stand: 48A


North


East


South


West

Plot number: 12
Stand: 42A


North


East


South


West

Plot number: 13
Stand: 43A


North


East


South


West

Plot number: 14
Stand: 43A


North


East


South


West

Plot number: 15
Stand: 44J1


North


East

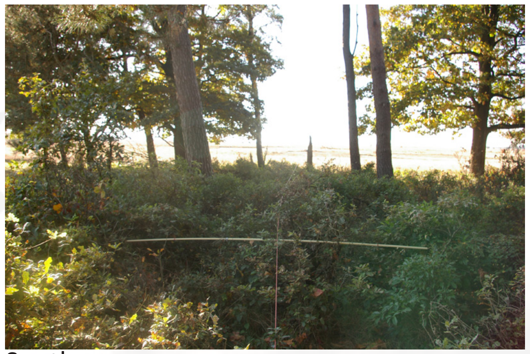

South


West

Plot number: 16
Stand: 33B


North


East


South


West

Plot number: 17
Stand: 68D1


North


East


South


West

Plot number: 18
Stand: 67G


North


East


South


West

Plot number: 19
Stand: 61L


North


East


South


West

Plot number: 20
Stand: 28R


North

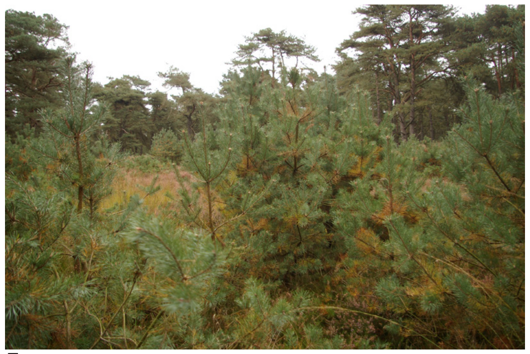

East


South


West

Plot number: 21
Stand: 26J


North


East


South


West

Plot number: 22
Stand: 26J


North


East


South


West

Plot number: 23
Stand: 26H1


North


East


South


West

Plot number: 24
Stand: 26H1


North


East


South


West

Plot number: 25
Stand: 26E


North


East


South


West

Plot number: 26
Stand: 28G


North


East


South


West

Plot number: 27
Stand: 29J

No photos are taken

Plot number: 28
Stand: 24T1


North


East


South


West

Plot number: 29
Stand: 24C


North


East


South


West

Plot number: 30
Stand: 24H


North


East


South


West

Plot number: 31
Stand: 21B


North


East


South


West

Plot number: 32
Stand: 19M1


North


East


South


West

Plot number: 33
Stand: 7J


North


East


South


West

Plot number: 34
Stand: 7J


North


East


South


West

Plot number: 35
Stand: 11S


North


East


South


West

Plot number: 36
Stand: 10H1


North


East


South


West

Plot number: 37
Stand: 10A


North


East


South


West

Plot number: 38
Stand: 2E


North


East


South


West

Plot number: 39
Stand: 2E


North


East


South


West

Plot number: 40
Stand: 2E


North


East


South


West

Attachment 2: Definition of used terms

Animal retreat zone
Some areas in the NP are off-limits for visitors. These areas serve as a retreat for the animals. In this areas the animals can find rest from visitors during the day.

Bark stripping
Deer species are able to eat the bark of tree trunks or branches by using the incisors in their lower jaw. This is called “bark stripping” in this project. Deer species do this when they have a mineral shortage to get the minerals inside the bark.

Browsing
In this project “browsing” refers to the feeding/gnawing by ungulates on buds, foliage and twigs to the top shoot of regenerated trees.

Damage
When browsing, fraying and bark stripping by ungulates has an impact on the regenerated trees it is often described as damage. Whether this should be called damage or not depends on the purpose of these trees and the opinion of the manager. There is no unequivocal answer. If the ‘damaged’ trees are meant to produce long straight wood to sell, the ungulates might hinder the straight growth of these trees and lower their value. This can be considered (financial) damage. For every trace/sign of browsing, fraying and bark stripping the word damage is used in this research. This is done because in the field of study the traces are mostly called damage.

Fraying
“Fraying” is the act of rubbing antlers to a tree trunk or branch by a male deer in order to remove ‘velvet’ from his new antlers or to mark territories. Sometimes deer species can fray trees because they are bored waiting for the people to leave the NP (Wensink, 2012).

Top shoot
The top shoot is the dominant, vertical, on-going shoot of the tree. The top shoot is not always the strait on-going shoot of the tree.

Tree regeneration
Forest regeneration forms the changeover of generations in a forest. Old trees make place for new ones. This can happen naturally or artificial (Ouden, et al., 2010). Both natural and artificial regeneration is inventoried in this project.

Attachment 3: List of tree species

English full name	Scientific name	Dutch full name	Dutch acronym
Alder Buckthorn	*Rhamnus frangula*	Vuilboom/Sporkehout	Vb
Beech	*Fagus sylvatica*	Beuk	Bu
Birch	*Betula pendula*	Berk	Be
Black cherry	*Prunus serotina*	Amerikaanse vogelkers	Pr
Common hornbeam	*Carpinus betulus*	Haagbeuk	Hb
Douglas fur	*Pseudotsuga menziesii*	Douglasspar	Dg
Eastern white pine	*Pinus strobus*	Weymouthden	Wd
Great silver fir	*Abies grandis*	Grote zilverspar	Ag
Hairy birch	*Betula pubescens*	Zachte berk	Zbe
Hemlock	*Tsuga spec.*	Hemlockspar	Hl
Holly	*Ilex aquifolium*	Hulst	Hs
Horse-chestnut	*Aesculus hippocastanum*	Witte paardenkastanje	Pk
Juneberry	*Amelanchier lamarckii*	Amerikaans Krenten-boompje	Ak
Larch spc.	*Larix spec.*	Larix of lork	Jl
Lime tree	*Tilia spec.*	Linde	Li
planted Lime tree	*Tilia spec.*	Geplante Linde	P li
Mountain-ash	*Sorbus aucuparia*	Wilde lijsterbes	Lb
Norway spruce	*Picea abies*	Fijnspar	Fs
Pedunculate oak	*Quercus petraea & -robur*	Inlandse eik	Ei
planted Pedunculate oak	*Quercus petraea & -robur*	Geplante Inlandse eik	P ei
Red oak	*Quercus rubra*	Amerikaanse Eik	Ae
Scots pine	*Pinus sylvestris*	Grove den	Gd
Sitka spruce	*Picea sitchensis*	Sitkaspar	Ss
Sycamore maple	*Acer pseudoplatanus*	Gewone esdoorn	Ge