Tree establishment under high browsing pressure in Eriksberg Wildlife Park, Sweden

Pēteris Vīrs
Supervisors: Mats Niklasson
Marcin Churski

Swedish University of Agricultural Sciences
Master Thesis no. 279
Southern Swedish Forest Research Centre
Alnarp 2017

Tree establishment under high browsing pressure in Eriksberg Wildlife Park, Sweden

Pēteris Vīrs

Supervisors: Mats Niklasson, SLU Southern Swedish Forest Research Centre
Marcin Churski, Polish Academy of Sciences, Mammal Research Institute
Examiner: Eric Agestam, SLU Southern Swedish Forest Research Centre

Swedish University of Agricultural Sciences
Master Thesis no. 279
Southern Swedish Forest Research Centre
Alnarp 2017

Master thesis in Forest Management,
Advanced Level (A2E), SLU course code EX0630, 30 ECTS

Abstract

The aim of the study was to investigate under which conditions (in terms of topography, amount of rocks, presence of thorny bushes, visibility, etc.) temperate trees can establish under very high browsing pressure. The study was conducted in Eriksberg Wildlife Park (EWP), Blekinge, Sweden. EWP is a 915 ha fenced area with c 1600 game animals being managed mainly for hunting reasons. The following species are present: European bison (55), red deer (350), mouflon (200) and fallow deer (750). Strong browsing and grazing by wild animals has been going on since the fence was erected in the 1940s in a smaller part and since 1976 in the whole fence.

Seedlings of trees (4-300 cm) and two bush species (*Sambucus* and *Rosa*) were searched for in 37 transects of 250 m length and 10 m width, a total area of 11.5 ha was covered. Tree establishment was evaluated in ten habitat types: previous agriculture field, big solitary rock, cliff, fallen tree, flat area, juniper stands, road, rocky area, thorny bush and wet area.

In total, 253 seedlings were found over the surveyed 11.5 ha. Seedling density was the highest on big rocks and cliffs with 222.37 and 109.17 seedlings*ha^{-1}, respectively. In flat area seedling density was 2.9 seedlings*ha^{-1}. As a control, tree density was surveyed in one exclosure, where it was found 2320 seedlings*ha^{-1}. No seedlings were found on agriculture fields. 62% of the seedlings were lower than 50 cm. Mean height (+/- SE) of all seedlings was 63.5 cm (+/- 4.7) cm The highest seedlings were found in thorny bushes: 112.0 cm (+/- 18.9), on cliffs: 97.9 cm (+/- 9.9) and on the top of big rocks: 88.2 cm (+/- 16.2) cm. On the flat area the average height was the lowest: 10.7 (+/- 1.5) cm.

Seedlings appear almost only in habitat types with some kind of protection features as fallen tree, big rock, thorny bushes, junipers stand or cliff, but in comparison with exclosures tree establishment is sparse.

Key words: Browsing, seedling protection, forest regeneration Eriksberg Wildlife Park.

1 Introduction

1.1 Background

Animal browsing has been an important driving factor to change ecosystems all over the world for a long time (Bond 2005, Gordon et al. 2004, Bradshaw et al. 2003). Bond (2005) emphasizes that vast areas are not in equilibrium with climate, and as one of the factors he mentions is the animals which control ecosystems. Animals can change tree species composition and vegetation structure, also affecting protected areas, where animals are a part of ecosystem (Gordon et al. 2004, Putman et al.1998). Browsers can be considered as a tool to manage biodiversity, but also as a factor which can change landscape (Gordon et al. 2004).

The forestry sector struggles with wild herbivores (Metslaid et al. 2013; Ezebiloet al. 2012). Therefore more unpalatable tree species are chosen for forest regeneration. That is one of the reasons, why most forest owners in Sweden, Estonia and Latvia choose spruce instead of other tree species (Metslaid et al. 2013).

1.2 Driving factor of dense animal populations

Food availability and predators are two main driving factors for animal population dynamics. An example is when moose populations increased when the clearcutting system was introduced in Northern Europe. It ensured higher share of young stands and more available nourishment (Gordon et al. 2004).

In spite of the large impact large herbivores may have on managed ecosystems, animals may be artificially kept in dense populations for hunting reasons, because they provide goods and revenues (Gordon et al. 2004). The goods animals provide are diverse: meat, furs, trophies and they also meet recreation purposes. Hunters often focus on harvesting males and save fertile females in a population (Morellet et al. 2007).

There is a general lack of examples how very dense browser populations affect ecosystems, tree species composition and their ability to regenerate (Fornara 2007; Smit 2011). Animals cause economic loss for forestry, but the impact is often overestimated (Putman et al. 1998). Putman (1998) writes that forest ability of recovery in most cases is not considered, when damage assessment is done. Dale (2000) suggested that ecologists should help to work out scientifically based management plans and make decisions based on facts.

1.3 Browsing and grazing impact on ecosystems

Grazing can increase the share of browse tolerant or unpalatable plants (Crawley et al.1997). At the same time animals may avoid places where mostly unpalatable plants are growing (Palmeret al. 2003). This can change the spatial distribution of animals over the time (Putman et al. 1998). Grazing can also create unique niches for other plants and can

increase biodiversity if the abundance of animals is intermediate. In this case, however, the term "intermediate" is unclear. Today it seems that populations of herbivores in many areas of Europe are denser than "intermediate" and cause changes in spatial distribution of habitats (Putman et al. 1998). Tree regeneration studies using establishment in and outside exclosures may display the role of herbivores on species composition and often emphasizes that many ecosystems are not in equilibrium with its climatic optimum (Gordon et al. 2004, Kuijper 2011, Kuijper et al. 2010b).

Goheen (2004) indicates that large herbivores have an indirect effect on seedling establishment of Acacia seedlings in African savannas by decreasing seed predators. It has been shown that seed predators like rodents are less frequent outside of the exclosures where big animals are present.

1.4 Protection structures

In natural ecosystems, trees can escape browsing when animals are less abundant because of epidemic diseases or high carnivore populations (Kuijper 2011). Also nursery and protection structures as thorny bushes, rocky areas, fallen trees etc. can create a time lag for trees to escape (Smit et al. 2005; Smit et al. 2011). Smit (2011) considers thorny bushes not only as mechanical protection against herbivores, but also emphasizes that unpalatable plants and thorny bushes create better microhabitat for tree establishment like higher pH level and moisture content of soil. Herbivores do not eat thorny bushes by big bites, but after some small bites they will go further and look for some easier food (Charles-Dominique et al. 2016). Trees have different survival strategies to cope with browsing. Browsed seedlings have been found to have higher height growth and more extensive tree branching (Forana et al. 2007). More browsed trees also may have denser thorn cover to protect themselves from browsers. Unpalatable vascular plants are important as nursery plants. Animals try to avoid sites, where the probability to find nourishment is lower (Smit et al. 2005, Smit et al. 2011).

Crowns of fallen tree can create protection where seedlings can establish. On the other hand, a fallen tree also may attract animals because they use twigs and bark of trees as nourishment. Browsers also may hesitate to stay in places with fallen trees. This has been explained with fear from carnivores which can hide in such places (Kuijper 2011). Herbivores prefer places with good visibility.

.

1.5 Aim of the study

This study is relevant because there is a general lack of knowledge about tree regeneration under heavy browsing pressure (Bond 2005; Smit et al. 2005) and worldwide there are only some examples of high browsing pressure to tree regeneration (Putman et al. 1998; Cutini et al. 2011). The aim of this study was to investigate if and where trees can regenerate under very high browsing pressure. The detailed goal of this study was to evaluate tree regeneration success by estimating density and seedling height in different habitats with different properties from a browsers point of view.

2 Materials and methods

2.1 Study site

The study was done in Eriksberg Wildlife Park (EWP), South East Sweden (56°10’ N, 14°59’ E) a 915 ha fenced area (fig. 1). The climate of the area is described as warm temperate humid climate. The annual precipitation is 563 mm (Climate-data 2017) with rather mild winters and a long vegetation period by Swedish standards: from 190 to 210 days (SMHI 2015). Mean annual temperature in Ronneby is 7.8 °C. In January mean temp is -0.4°C and July 16.9 °C (Climate-data 2017).

Fig. 1 The area of Eriksberg Wildlife Park and distribution of transects

2.2 Land types and tree species composition in EWP

In general, in Eriksberg the dominant tree species are pine *(Pinus sylvestris)* oak *(Quercus robur)*, beech *(Fagus sylvatica)* and hornbeam *(Carpinus betulus)* but no exact data exists on the distribution and relative share of tree species. According to the management plan (MP) of the reserve, pine was present in 16% of the total area, beech, oak and hornbeam was present in 48% of the area. Juniper *(Juniperus communis)*, grows mainly on rocky outcrops and covers 15% of the area (fig 2 and appendix 1). The Eriksberg reserve is made up from several land and forest types with a high variation, although forest is dominating, open fields make up some 8% of total land area.

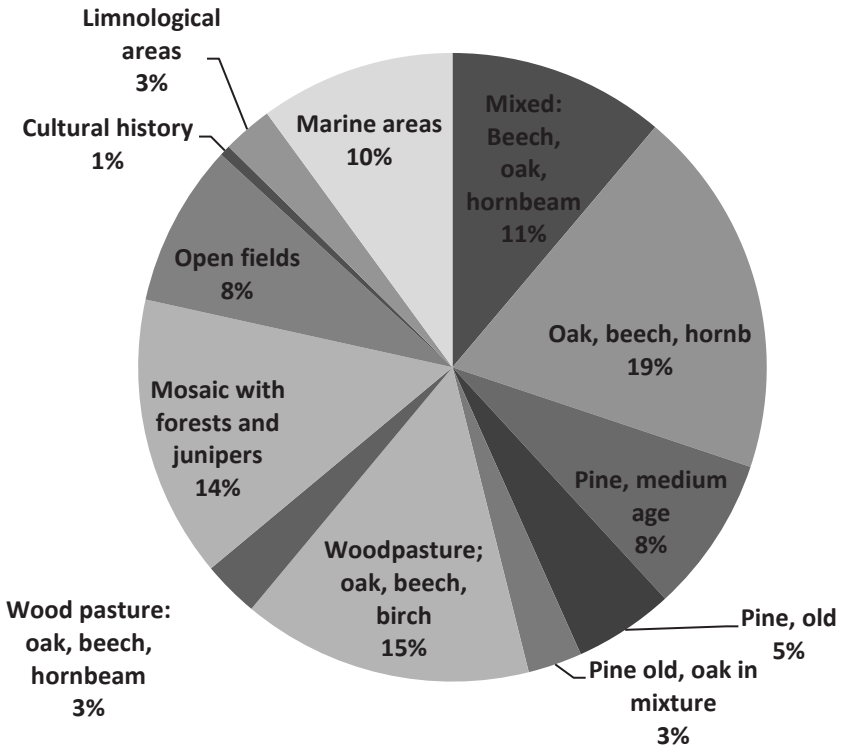


Fig. 2. Forests and land types in Eriksberg Wildlife Park according to management plan (MP)

2.3 Wildlife management

Animal density of all species is controlled by hunting lasting from 1st of October to 15th of February, but still animal numbers are kept artificially high. Inside the area are found approximately 750 - 800 fallow deer, 350 - 400 red deer, 200 mouflon and 55 European bison (table 1) , which is almost 180 animals per ha when hunting season begins. On average, 567 animals are hunted annually. Inside the fence are no big predators which can control the amount of animals.

Table 1 Number of animals in Eriksberg wildlife park

Species	**Population before hunting, (n)**	**Share in community (%)**	**Density of animals (n*100 ha^{-1})**	**Number of animals hunted annually, (n)**
Fallow deer *(Dama dama)*	750	45%	82.0	300
Red deer *(Cervus elaphus)*	350	21%	38.3	80
Wild boar *(Sus scrofa)*	300	18%	32.8	175
Mufflon *(Ovis orientalis)*	200	12%	21.9	10
European bison *(Bison bonasus)*	55	3%	6.0	2
Total	**1655**	1	180.9	**567**

Supplementary feeding is done in winter, because otherwise the nourishment of the area is not enough to sustain the population all year round. The amount of fodder fed to animals annually in total is up to 1700 tons: 1300 tons carrots, potatoes and sugar beets, 300 tons of silage and 100 tons of oats is approximately fed annually. In spring and autumn pellets with deworming substances are fed to reduce parasite load. Mating season for red deer lasts from September to October. During this time red deer is consuming very little nourishment. Extra feeding for deer is started after mating season in November. After mating season animals are wasted. If supplementary feeding is not done animals may strip the bark of mature trees. Grains for wild boars are provided during summertime to reduce digging in pastures and hay fields.

2.4 Data collection

Data were gathered at four occasions in the period between 18th of March and 14th of May 2016. The first three days were spent to test methodology, protocols and recognize habitat types we had not considered before and to get familiar with conditions specific for the area.

In the tests, it was found that seedlings were rare and difficult to find which rendered the first idea to do a whole area inventory impossible. Seedlings were small and difficult to see from distance longer than 5m. Therefore it was decided to only record seedlings from 4 cm to 300 cm high, and to do this survey in 5+5 m wide transects.

37 transects were made randomly distributed to cover all habitat types. Each transect was 250 m long and 10 m wide. For the habitat types thorny bushes, cliff, junipers stands the recorded area was extended outside the transect. In total transects covered 11.47 ha or 1.25% of total area.

The start and end point of each transect was marked with a GPS. Distances between each habitat type in the transect were measured by GPS and were used to calculate the relative share of habitat type. For the habitat type thorny bushes and fallen tree, also seedlings of bush species were recorded. Easiness for the animal to penetrate was estimated. For habitat type big rock the height of the rock and seedling root access to the soil was estimated.

2.5 Habitat types

Ten habitat types were distinguished with presumed different protection effects from browsing.

1. Agriculture land is flat land formerly used for agriculture purposes. Agriculture land does not have any obvious protection against browsing animals, every spot is well visible and accessible. Agriculture lands are mostly located in valleys.
2. Big rocks are rocks big enough to permit seedling establishment, often covered by mosses. In this habitat type only rocks higher than deer head level were included, which could provide protection from browsing.
3. Cliff is a habitat type with steep or vertical slope with height more than 1.5 m.
4. Fallen trees. Their crown structure was evaluated in three categories in relation to how easy animals were estimated to penetrate it. By category "1" recently fallen trees were marked where animals cannot penetrate, with category "2" - fallen trees with only coarse branches left and "3" characterize trees which consists only of stem.
5. Flat area differs from agriculture land by former usage. Flat land has not been used as agriculture land and it could consist of bedrock, it can be covered by trees or without them, usually it was forest covered. Single stones could be present. This is simply the “normal” ground in the forest.
6. Juniper habitat is an area dominated by juniper *(Juniperus communis)* stands, usually on very xeric rock dominated areas.
7. Road are consideratet as the areas along the roads within 5 m from the edge of the road.
8. Rocky area is an area covered by different sized rocks, lower than deer head level.
9. Thorny bushes are mostly blackthorn *(Prunus spinosa)* and hawthorn. (*Crataegus sp*.). Thorny bushes have been shown to provide tree regeneration in highly browsed areas (Smit 2011).
10. Wet area was distinguished because we noticed that bushes and palatable vascular plants were not browsed if animals need to stand in water to reach the seedling (appendix 2).

All the seedlings were recorded and measurements of height, diameter, total and number of browsed shoots were recorded. Visibility and accessibility were estimated. A photo of each seedling was taken.

2.6 Exclosure in EWP

The exclosure was erected in 1979 in EWP and was located on flat area. The area of exclosure was 0.75 ha. As a control and comparison for the influence of browsing on seedling establishment five circular sample plots (radius = 5.62 m) with a total area 500 m^2 were surveyed in the exclosure. In these sample plots density per area unit (number of seedlings*ha^{-1}) were calculated.

2.7 Density and browsing intensity of seedlings

The density of seedlings in each habitat type were calculated as total number of seedlings divided with total area of particular habitat type.

The number of shoots in total and browsed shoots was recorded for each seedling. Seedlings with no browsed shoots were counted as unbrowsed. All the rest were counted as browsed.

2.8 Tree species performance

The Shannon index of diversity was used to compare tree species distribution and richness among habitat types. Higher Shannon index indicates higher diversity of tree species in the habitat. When only one species occurs, Shannon index, H, is zero. (Shannon, 1963)

Shannon index was calculated as:

$$H = -\sum p_i \times \ln(p_i)$$

where

- H - Shannon index
- p_i - Share of one tree specie

2.9 Accessibility

Accessibility of each seedling was estimated from 0 (inaccessible) to 3 (easy to access). Seedlings on cliffs and on top of big rocks where it is apparently impossible to reach or jump for animals were classified as "0". Class "1" was assigned to seedlings being difficult to reach for animals, but still possible. For example, on cliffs with a height of 2 m, on big rocks possible to jump, among thorny bushes which protect seedling and hesitate animals to reach it, inside dense fallen tree. Class "2" was for seedlings with some obstacle to reach it, like rocky area, fallen tree, thorny bushes or wet area. Class 3 was given for seedlings which were estimated to be easy to access. These were typically seedlings growing on a flat area, next to fallen trees, if there were no twigs anymore etc.

2.10 Visibility

Visibility was evaluated in a similar way; “0”: seedlings totally hidden by something, like dense thorny bushes or fallen tree, in wet areas it sometimes could be unpalatable vascular plants. "1": seedlings hidden from two or more sides. Mostly seedlings among rocks, bare fallen trees or bushes as well as seedlings growing on big rocks and cliffs higher than eye level. “2": seedlings possible to see from almost every side. These were seedlings in open juniper stands, seedlings next to a rock etc. and with "3": seedlings visible from every angle.

2.11 Data processing

The data were analyzed in R environment (R Core Team 2015). A statistical problem was the generally rare seedling occurrence. Because of that some of the figures published below are not statistically strong. In these cases the number of observation is written in brackets.

ANOVA One-way tests and General Linear Models (GLM) were used to compare the reliability of results. P values were used to compare significant differences of results between habitat types, species and browsing intensity.

3 Results

In total 253 observations seedling were found in the survey. Seedlings were found in all habitat types except habitat types road and agriculture land. However large differences were found in different habitat types.

3.1 Density of seedlings per habitat type

The density of seedlings differed significantly between the habitat types. The highest density of seedlings were found in the habitat types big rock, cliff, and fallen tree; 222.4; 109.2 and 94.6 seedlings*ha^{-1}, respectively. Seedling density on flat area was 2.9 seedlings*ha^{-1} (fig. 3). In the exclosure seedling density was much higher: 2300 seedlings*ha^{-1}.

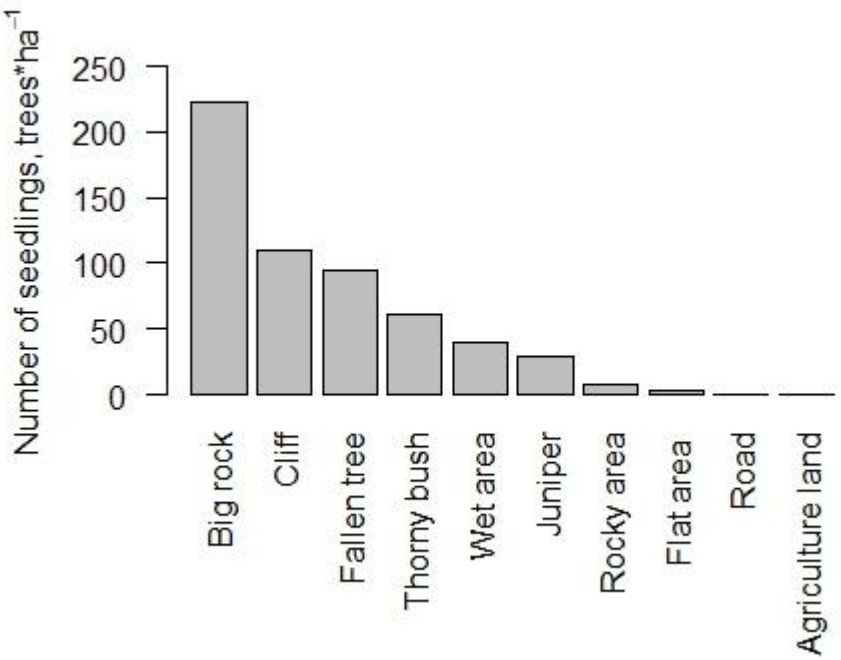


Fig. 3. Density of seedlings per habitat type

The tree species differed greatly in success of establishment. Rowan was overall the most common species with highest density on big rocks (104.2 seedlings*ha^{-1}), cliffs (52.4 seedlings*ha^{-1}) and fallen trees (40,0 seedlings*ha^{-1}) as well as on average in the whole study area (25.4 seedlings*ha^{-1}). Pine was the second most common tree species with mean density 14.2 seedlings*ha^{-1}. It was most common in juniper stands (41.7 seedlings*ha^{-1}) and cliffs (25.3 seedlings*ha^{-1}). The rest of the tree species were only rarely occurring, all having less than 27 seedlings in the surveyed transects (table 3).

Table 2. Seedling density per ha and absolute numbers, seedlings*ha^{-1} (n)

	Area	Alder	Beech	Birch	Hornbeam	Maple	Oak	Pine	Rose	Rowan	Elder	Spruce	Crab Apple
Agriculture land	0.58	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Big rock	0.14	0 (0)	0 (0)	41.7 (6)	6.9 (1)	13.9 (2)	0 (0)	41.7 (6)	0 (0)	104.2 (15)	0 (0)	13.9 (3)	0 (0)
Cliff	0.63	0 (0)	0 (0)	15.8 (10)	7.9 (5)	1.6 (1)	7.9 (5)	25.3 (16)	0 (0)	52.2 (33)	0 (0)	1.6 (1)	0 (0)
Fallen tree	0.27	0 (0)	14.5 (4)	3.6 (1)	3.6 (1)	0 (0)	3.6 (1)	10.9 (3)	0 (0)	40.0 (11)	0 (0)	14.5 (4)	0 (0)
Flat area	4.06	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.2 (1)	0 (0)	0.5 (2)	0 (0)	1.5 (6)	0 (0)
Juniper	1.72	0 (0)	0 (0)	0.6 (1)	0 (0)	0 (0)	0 (0)	26.2 (45)	0 (0)	1.7 (3)	0 (0)	0.6 (1)	0 (0)
Road	0.08	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Rocky area	3.03	0 (0)	2.3 (7)	0.3 (1)	1 (3)	0 (0)	0 (0)	0.7 (2)	0 (0)	0.7 (2)	0 (0)	2.3 (7)	0 (0)
Thorny bush	0.48	6.3 (3)	4.2 (2)	0 (0)	12.6 (6)	2.1 (1)	0 (0)	0 (0)	12.6 (6)	4.2 (2)	8.4 (4)	0 (0)	2.1 (1)
Wet area	0.48	0 (0)	2.1 (1)	6.2 (3)	22.8 (11)	0 (0)	0 (0)	8.3 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Average:		0.8	2.9	8.5	6.9	2.2	1.4	14.2	1.6	25.4	1.1	4.3	0.3

3.2 Tree species performance

The Shannon index of diversity varies from 0.33 to 1.89 depending on habitat type. Shannon index including all habitat types is 1.92. In total 12 species were found with greatest abundance in thorny bushes (8 species; Shannon index - 1.89). The smallest number of tree species was found in flat area (3 species; Shannon index - 0.85), juniper stands (4 species; Shannon index - 0.33) and wet area (4 species; Shannon index - 1.09) (table 4).

Table 3. Characteristics of EWP

Habitat	Surveyed area, ha	% of total area surveyed	Number of observations of this habitat type	Total number of seedlings	Share of seedlings, %	Shannon index
Agriculture land	0.58	5%	5	0	0%	-
Big rock	0.14	1%	40	32	13%	1.44
Cliff	0.63	6%	26	71	28%	1.46
Fallen tree	0.27	2%	73	25	10%	1.59
Flat area	4.06	35%	93	9	4%	0.85
Junipers	1.72	15%	7	50	20%	0.33
Road	0.08	1%	2	0	0%	-
Rocky area	3.03	26%	53	22	9%	1.58
Thorny bush	0.48	4%	27	25	10%	1.89
Wet area	0.48	4%	6	19	8%	1.09
Total	11.4	100%		253	100%	

3.3 Height of the seedlings

More than half of the surveyed seedlings, (159; 62%) are found in height class up to 50 cm (fig. 5). Mean height of all seedlings was 63.5 cm.

The height of seedlings differed significantly between the habitat types. The highest mean height were in thorny bushes (112.0 cm), on cliffs (97.9 cm) and on the top of big rocks (88.2 cm). On flat area the average height was the lowest (10.7cm) (fig. 6).

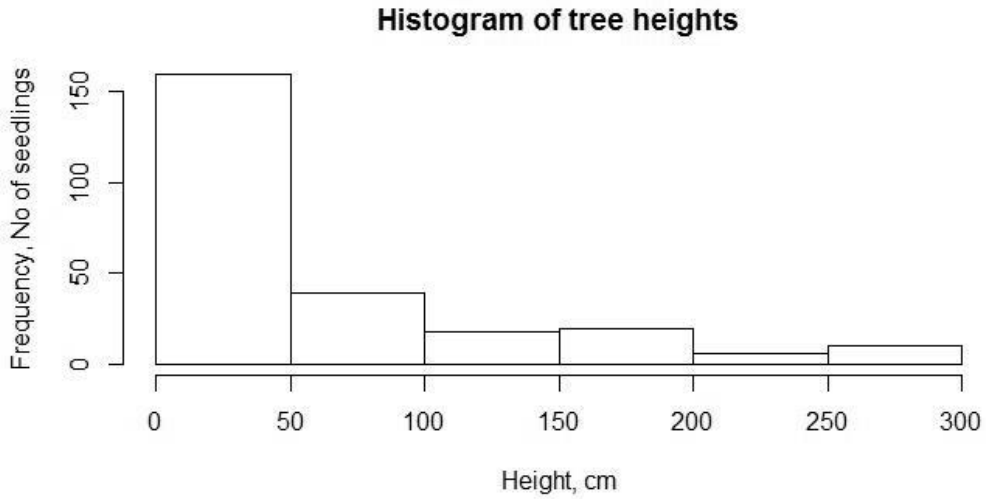


Fig. 4. Histogram of all seedling heights.

There was a general difference in height between unbrowsed seedlings and browsed ones, respectively 84.3 and 45.6 cm.

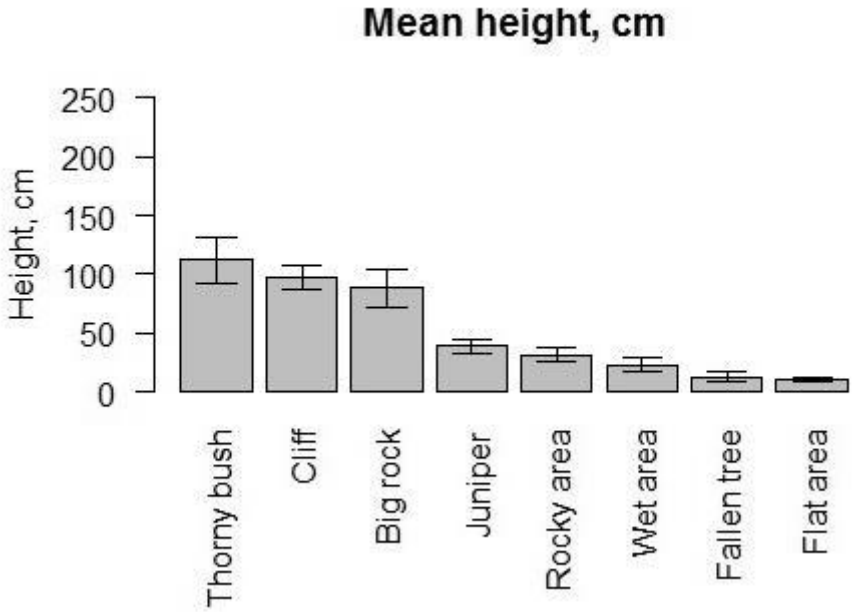


Fig. 5. Mean height of seedlings in habitat types (+/- SE).

Height of seedlings differed significantly between the tree species. The highest was birch (93.2) , followed by rowan (86.5), alder (64.0), maple (63.3) and pine (50.5).

Due to small number of observation standard error for height of rose and elder is big. The mean height of these species was 210.8 cm and 190.0 cm (fig. 7).

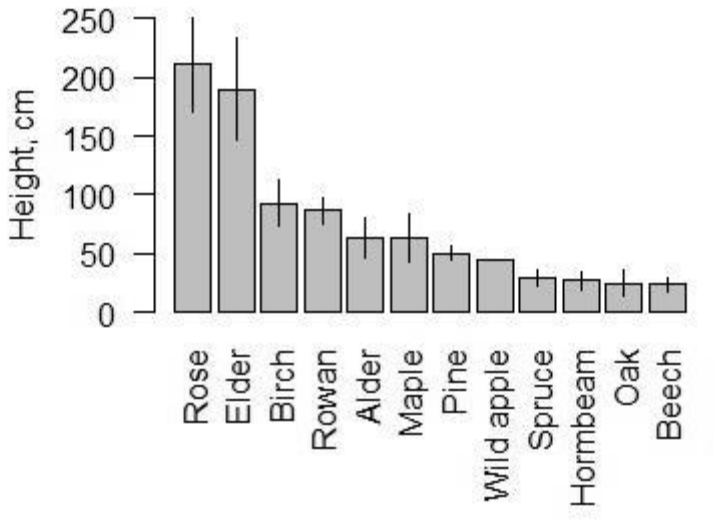


Fig. 6. Mean height of tree species (+/- SE).

3.4 Browsing intensity

The least browsed seedlings were in the habitat types big rock and cliff where more than 70% of seedlings were not browsed. The biggest share of browsed seedlings was in juniper stands and in rocky area where less than 10% of seedlings were not browsed. In total 51% of the seedlings were browsed. (table 5). In the habitat types fallen tree, thorny bushes flat area and wet area browsing intensity varied from 40% to 54%.

Table 4 Numbers and share of browsed and unbrowsed seedlings per habitat type

	Browsed		Unbrowsed		Total
Agriculture land	0	-	0	-	0
Big rock	7	22%	25	78%	32
Cliff	20	28%	51	72%	71
Fallen tree	10	40%	15	60%	25
Flat area	4	44%	5	56%	9
Junipers	48	96%	2	4%	50
Road	0	-	0	-	0
Rocky area	21	95%	1	5%	22
Thorny bush	14	56%	11	44%	25
Wet area	8	42%	11	58%	19
Total	132	52%	121	48%	253

In juniper habitat most seedlings are pines which are heavily browsed and result in small height and big diameters and bushy appearance (fig. 8). The highest seedlings were recorded on cliff and big rock, also thorny bushes provide similar conditions but in many cases, but not always (observations outside the transects), seedlings cannot escape out of thorny bushes and are browsed until bush level (fig. 9).

Fig. 7. Repeatedly browsed pine in juniper habitat.

Repeatedly browsed pine in juniper habitat.

Fig. 8. Rose seedling in thorny bush. Rose is browsed up until the edge of more protective bushes (*Prunus spinosa* and *Crataegus sp.*)

3.5 Accessibility and visibility

The estimated accessibility correlated with proportion of browsed seedlings; more accessible seedlings were more browsed. Only 6% of seedlings were browsed in places estimated as inaccessible. Accessibility marked with "0" was only in habitat types big rock, cliff and thorny bushes. 72% were browsed in places estimated totally accessible (marked with "3") (fig 10). Classification of visibility did not show any clear result, with no clear trends in browsing levels with increasing visibility (Fig. 10. Visibility per habitat typefig. 11).

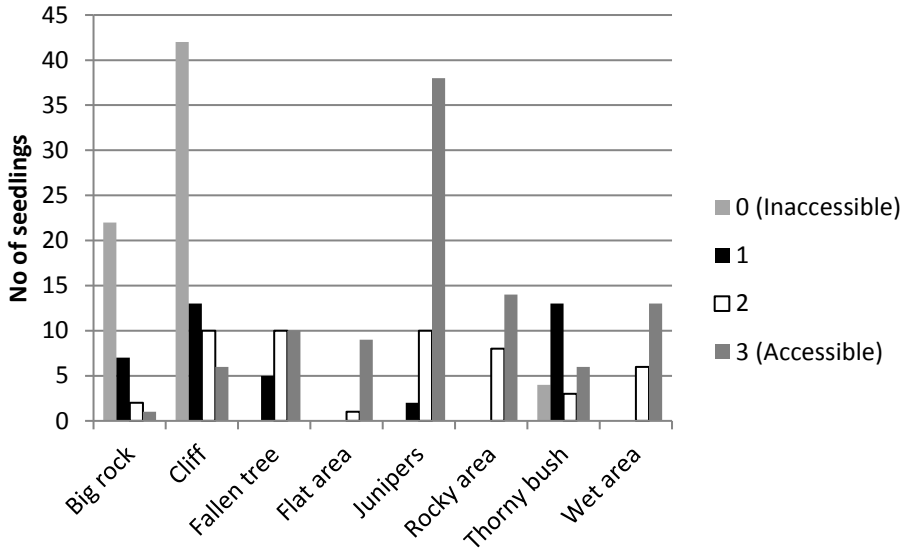


Fig. 9. Accessibility per habitat types

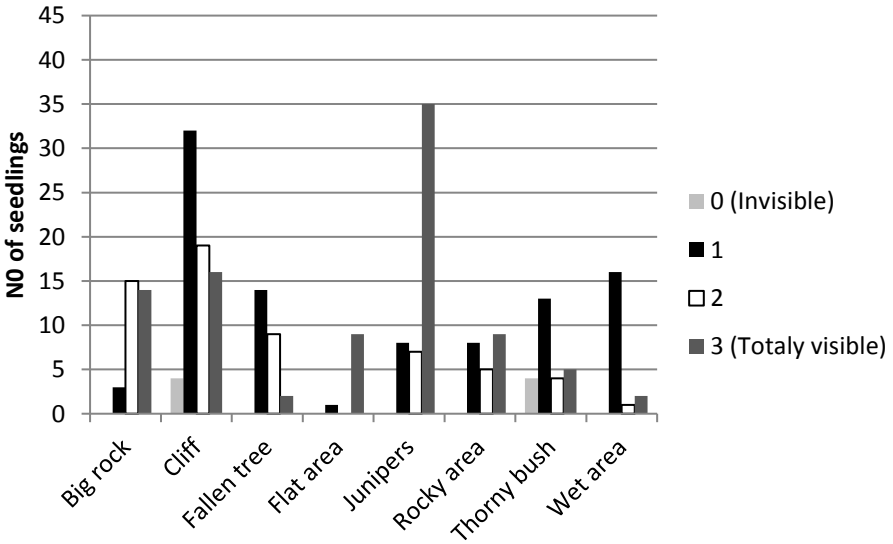


Fig. 10. Visibility per habitat type

4 Discussion

The number of seedlings observed was very small (253 over 11.47 ha, 22 seedlings per ha at average). This low number also strongly reduced the statistical strength of this study. However, for practical reasons more area could not be surveyed in this study. Nevertheless, the low seedling density is one of the reasons why the EWP area is of interest to study in the light of a very high animal density. As a comparison of animal density the numbers for Sweden as a whole is from 300 000 to 400 000 moose, 300 000 – 1 000 000 roe deer in Sweden (Skogssverige et al. 2016). This equals 1-3 animals*km^{-2} at a national level. In EWP the total density is 180 animals*km^{-2} which is 60 - 180 times more.

4.1 Seedling establishment in different habitats

My study showed that seedlings can occur under a very high browsing pressure if there are protection features like big rocks, cliffs, thorny bushes or fallen trees, although occurrence is rare (fig. 3). Protection features have different effect on the animals: Thorny bushes ensure mechanical protection against grazers, on big rocks seedlings are inaccessible. Fallen trees reduce accessibility as well as visibility. Seedlings do not appear, or is extremely rare, in habitat types lacking protection features like agriculture lands, or flat areas.

On big rock, cliffs and in thorny bushes establishment of seedling is the relatively most successful. These three habitat types were the only habitats where accessibility for some seedlings was evaluated as totally unaccessible (fig. 10). On big rocks, however, I found many dead seedlings on the tops. Apparentely, in the summer this habitat easily dries out and probably can not ensure enough water for seedlings. In only 4 cases out of 37 it was estimated that roots had access to soil on big rocks. Thus, it can be expected that the majority of seedlings on big rocks without access to soil will eventually die because of lack of moisture or nutrients since I did not see any mature trees on big rocks.

Thorny bushes can facilitate tree establishment (Charles-Dominique et al. 2016, Smit et al. 2011) and my results confirm this. Reduction of visibility, mechanical protection, better growing conditions or interaction of all three factors play a significant role for seedling occurance in thorny bushes.

In the study area we observed that palatable bushes and trees are not browsed if animals must stand in water. Perhaps this is because soft bottom or unwillingness to get legs wet. There is no clear explanation why animals frequently swim to get to the large Dragsö island in the area, where heavy browsing was observed, but on the other hand do not step in shallow water to browse trees and bushes there (appendix 2). The situation on the Dragsö island in the study area was not further investigated, but it could be a relevant comparison how seedlings suffer from browsers on islands.

Roads were also considered as possible protection features, but no seedlings were found in this habitat inside the randomly located transects but three seedlings

were found next to the road when we looked for them especially, outside transects. Within transects were less than 1% of area of habitat type road. The area recorded as road is perhaps underestimated. There could appear more seedlings if all the roads in EWP were separately investigated, but there was not time for such special investigation. However, our visual observation along all roads shows that this habitat is likely not very significant as protection feature. Frequent car transport on the roads obviously had little scaring effect (own observations). The Eriksberg staff also informed that tractors, which carry food for animals, attract animals closer to roads.

Although tree crowns of fallen trees soon had lost most branches, fallen trees anyway seem to result in higher density of seedlings compared with flat area. Probably, fallen tree protects seedling in the first years, when the crown is still dense enough to hinder herbivores, provided that seedlings occur simultaneously. Later, fallen trees do not provide such good protection when only some main branches are left. In total, 73 fallen trees were recorded in the transect surveys (29 pines, 18 spruces, 12 oaks, 5 beeches, 4 aspens, 2 ashes, 2 hornbeams and 1 juniper, data not presented). Only 12 (16%) of these trees were classified to ensure good protection, being hard to penetrate (class "1", fig 12). The rest of the recorded trees just seem to reduce visibility.

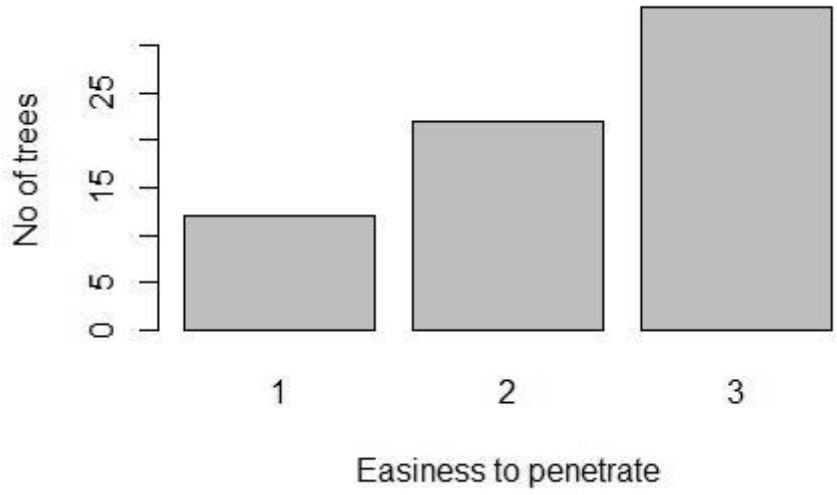


Fig. 11. Classification of the possibility for animals to penetrate crowns of fallen trees

4.2 Seedling and browsing height

Smit (2011) considered that safe browsing height (above which trees survive and continue growing upwards) was 1.5 m in an area browsed by Icelandic horses and cattle. In EWP the 'safe height' is probably higher, because of European bison and red deer which are larger animals. Most of surveyed seedlings did not exceed the height of 50 cm, and only 15.3% is higher than 1.5 m, the tallest seedlings are only found in the

more protective habitats like big rock and cliff. There are big differences between habitats in this sense. For the habitats with worse protective features like flat area or juniper stand very few seedlings exceeded 50 cm in height. Most seedlings in flat area and junipers are heavily suppressed and browsed several times, especially in juniper stands (table 5 and fig. 8).

.

4.3 Tree species performance

Rowan was the most common seedling in general and most of them were found in the habitats fallen trees, cliffs and big rocks (table 3). Rowan seeds are distributed by birds and it easily appears in places where birds can land (Raspe et al. 2000).

Pine is the second most successful species and occurs in high numbers in juniper stands. In juniper habitat high browsing intensity (table 5), in combination with light-open conditions create bush-type pine trees with very low height and probably great age. The height/diameter relation is lower for browsed seedlings and this is very notable in juniper habitat. Rowans and pines have good seed distribution. Rowan seeds can be distributed on cliffs and big rocks by birds where herbivores have problems to reach them. Pine seeds can germinate in xeric habitats like juniper stands. These factors combined make pine and rowan to be more competitive in EWP.

Spruce seedlings were present in all habitats except thorny bushes and wet area, but the number of spruce seedlings is small. Spruce is less drought tolerant and requires more nutrients compared with pine and this probably make spruce less competitive in EWP.

Oak was unexpectedly rare considering it being one of the dominant trees in EWP. Oak seedlings were found only in cliff and fallen tree habitats. 48% of the EWP area is classified as mature oaks and beech in the management plan (fig. 2) which should ensure a good seed production. Seed predation of oaks and beeches affect the amount of oak and beech seeds and seedlings. The impact of rodents as seed predators is unknown. Wild boars are large consumers of oak and beech seeds, wild boars prefer acorns and beech nuts and this could be an important limiting factor for oak and beech establishment in EWP, it was observed wild boar grouting in most parts of EWP.

4.4 Accessibility and visibility

Accessibility and visibility probably play an important role in protecting seedlings from browsing. Animals do not browse seedlings which are difficult to access, but according to my results, visibility does not play as important role as accessibility. In the case of junipers stands visibility was reduced, although seedlings were easily visible and accessible at short distance. Probably, the fear factor (Kuijpers 2011) can play an important role in this habitat forcing animals to spend shorter time in junipers stand. This factor has been shown to be important in areas where large predators like wolves and lynxes are present (Kuijpers 2011). Herbivores avoid such

areas or stay there for a short time. However, big predators have not been present in EWP in many decades and fear from them could be expected to disappear, unless this is an inherent behavior. Thus, juniper stands could contribute to tree development also in the wild.

In contrast, agriculture lands are totally accessible and seedlings there well notable. Nothing hinders herbivores to spend much time and graze in this habitat. Furthermore, in summertime there is more palatable plants which attract herbivores. This, and of course if mowing occurs at times (not known for the EWP) explains why we did not find almost any seedling on agriculture land.

Seedling establishment was much higher in exclosures, about 100 times higher than in the transects. During the data were collected we did not observe previous year wilted grass anywhere in the EWP area, except inside the exclosures. This is another indication of high browsing pressure outside exclosures.

4.5 EWP in future

The EWP differs from most other ecosystems in the region due to the high browsing pressure. The landscape is almost without trees younger than c. 30 years (assessed age of pines by counting branch whorls at a few occasions). It is expected that the area will become more and more open due to rare regeneration in combination with mortality of big trees. Although openings appear in the forest by fallen trees, the regeneration is extremely limited. Establishment of seedlings is successful only in habitats of low accessibility and visibility or in fenced exclosures.

It was observed many first year seedlings in the end of May during the field work, in many habitats. This indicates that the bank of seedlings is large and germination is not limited by soil or light factors in general. It could be interesting to investigate how these seedlings are removed by herbivores.

Acknowledgments

I would like to express my greatest thanks to my supervisors Mats Niklasson for leading research and helping with methodology during all research and Marcin Churski for work with data analysis. Next to that, I am grateful to Emma Holmström who helped me with data processing in R studio computer program. Thanks to EWP for contribution and accommodation, especially Per-Arne Olsson who provided me with information about Eriksberg. This Master thesis is supported financially with IKEA scholarship.

References

Bakker, E. S., H., Olff, et al., 2004. Ecological anachronisms in the recruitment of temperate light-demanding tree species in wooded pastures. Journal of Applied Ecology 41(3): 571-582.

Bond, W. J., 2005. Large parts of the world are brown or black: A different view on the 'Green World' hypothesis. Journal of Vegetation Science 16(3): 261-266.

Bradshaw, R. H. W., G. E. Hannon, et al., 2003. A long-term perspective on ungulate-vegetation interactions. Forest Ecology and Management.

Charles-Dominique, T., T. J. Davies, et al., 2016. Spiny plants, mammal browsers, and the origin of African savannas. National Academy of Sciences of the United States of America 113(38): E5572-E5579.

Climate data, 2017. Available: https://en.climate-data.org/location/8770/

Crawley, M.J., 1997. Plant Ecology, 2nd edn. Blackwell Science, Oxford, UK. (chapter 13, Plant–Herbivore Dynamics (pages 401–474)).

Cutini A., Bongi P., Chianucci F.,Grignolio S., Amorini E., Apollonio M., 2011. Roe deer (Capreolus capreolus L.) browsing effects and use of chestnut and Turkey oak coppiced areas. Annals of Forest Science 68:667–674 DOI 10.1007/s13595-011-0072-4

Dale V. H, Haeuber, R. A., 2000. Applying Ecological Principles to Land Management. Springer.

Ezebilo E., Sandström C., Ericsson G., 2012. Browsing damage by moose in Swedish forests: assessments by hunters and foresters Eugene, Scandinavian Journal of Forest Research Volume 27, 2012 - Issue 7

Fornara, D. A., J. T. Du Toit., 2007. Browsing lawns? Responses of Acacia nigrescens to ungulate browsing in an African savanna. Ecology 88(1): 200-209.

Gjerstad D. H., Nelson L. R., Dukes J. H., Retzlaff W. A., 1984. Growth Response and Physiology of Tree Seedlings as Affected by Weed Control. Volume 14 of the series Forestry Sciences pp 247-257

Goheen J.r., Keesing F., 2004. Effect of large mammals on Acacia seedling survival un an African savanna. Ecology, 85(6), 2004, pp. 1555–1561

Gordon, I. J., Hester, A. J. & Festa-Bianchet, M., 2004. The management of wild large herbivores to meet economic, conservation and environmental objectives. Journal of Applied Ecology, 41, 1021–1031

Kuijper D. P. J., 2011. Lack of natural control mechanisms increases wildlife–forestry conflict in managed temperate European forest systems, Eur J Forest Res. 130:895–909, DOI 10.1007/s10342-011-0523-3

Kuijper, D.P.J., Jedrzejewska, B., Brzeziecki, B., Churski, M., Jedrzejewski W., Zybura, H., 2010a. Fluctuating ungulate density shapes tree recruitment in natural stands of the Białowieża Primeval Forest. Journal of Vegetation Science 21: 1082-1098.

Kuijper, D.P.J., Cromsigt, J.P.G.M., Jedrzejewska1, B., Miscicki, S., Churski, M., Jedrzejewski1, W., Kweczlich I., 2010b. Bottom-up versus top-down control of tree regeneration in the Bialowieza Primeval Forest. Journal of Ecology 2010, 98, 888–899 doi: 10.1111/j.1365-2745.2010.01656.x

Metslaid M., Randveer T., Sims A., Jogiste K., Palli T., 2013. The condition of Scots pine stands in Lahemaa National Park, Estonia 25 years after browsing by moose (Alces alces) Boreal Environmental Research 18 (suppl. A) 25-35

Morellet N., Gaillard JM., Hewison M. A. J., Ballon P., Boscardin Y., 2007. Indicators of ecological change: new tools for managing populations of large herbivores. Journal of Applied Ecology 44, 634–643 doi: 10.1111/j.1365-2664.2007.01307.x

Palmer, S. C. F., Hester, A. J., Elston, D. A., Gordon, I. J. and Hartley, S. E., 2003. The perils of having tasty neighbors: Grazing impact of large herbivores at vegetation boundaries. Ecology, 84: 2877–2890. doi:10.1890/02-0245

Putman R.J., Moore M.P., 1998. Impact of deer in lowland Britain on agriculture, forestry and conservation habitats. Mammal Rev. Volume 28, No. 4, 141–164. Printed in Great Britain.

R Core Team., 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Raspe O. et al., 2000. Sorbus aucuparia L., Journal of Ecology 2000, 88, 910-930

Shannon, C.E., Weaver, W., 1963. The mathematical theory of communication. Urbana: University Illinois Press.

Skogsstyrelsen, 2016. I wonder how many deer there about it in Sweden. Available : http://www.skogssverige.se/jag-undrar-hur-manga-radjur-det-ungefar-det-finns-i-sverige

SMHI, 2015. Length of vegetation period. Available : http://www.smhi.se/en/climate/climate-indicators/climate-indicators-length-of-vegetation-period-1.91482

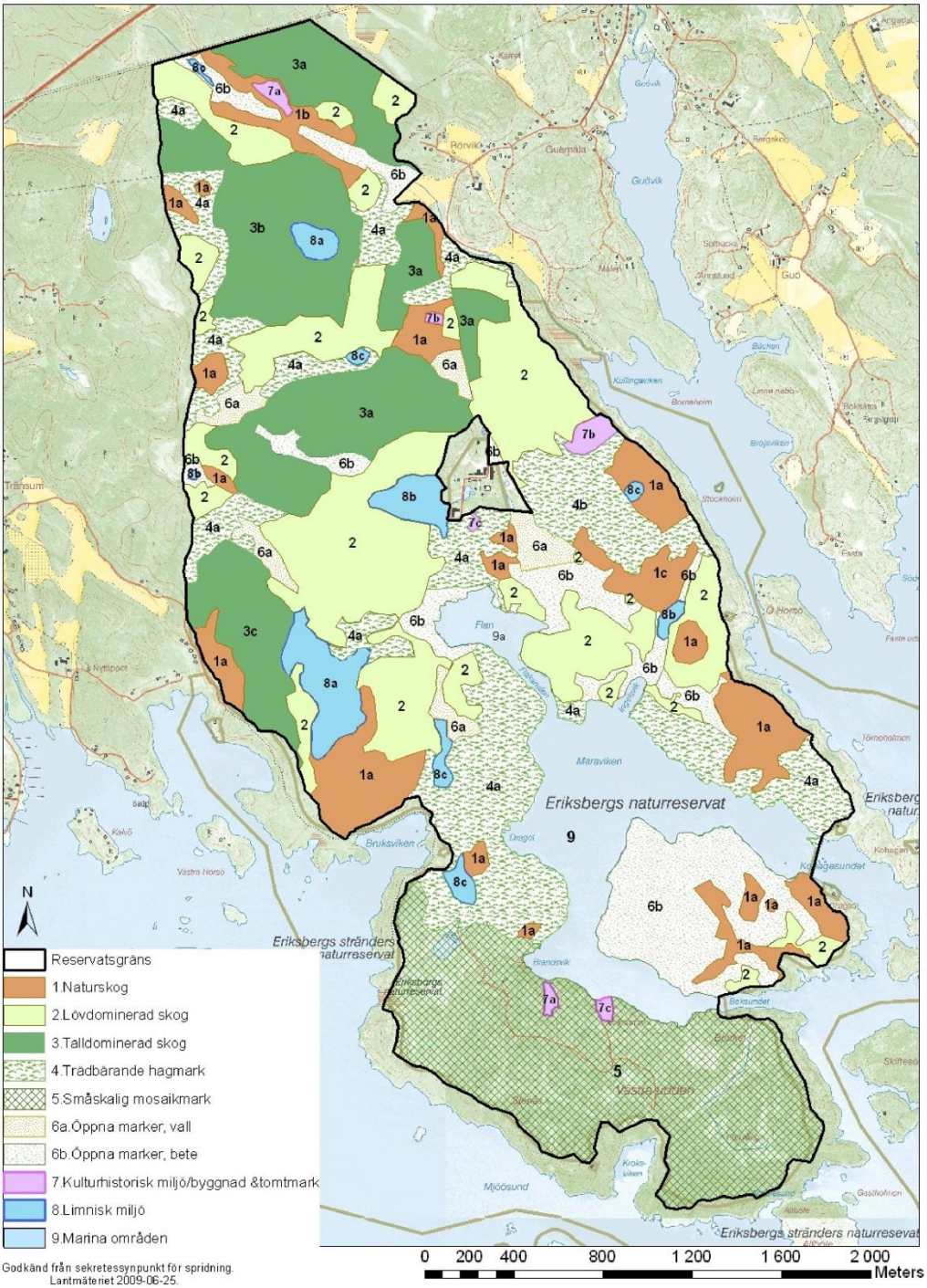
Smit C., Béguin D., Buttle, A., Müller-Schärer H., 2005., Safe sites for tree regeneration in wooded pastures: A case of associational resistance?, Journal of Vegetation Science 16: 209-214, 2005

Smit, C., Ruifrok J. L., 2011. From protege to nurse plant: establishment of thorny shrubs in grazed temperate woodlands. Journal of Vegetation Science 22(3): 377-386.

Snow D., Snow B., 1989. Birds and berries: A study of an ecological interaction. ISBN 0856610496 doi:10.1016/0169-5347(89)90161-4

Appendix

Appendix 1. Forest and land types according to management plan (MP) of Eriksberg wildlife park



Appendix 2. Photos of habitat types

Flat area

Big rock

Wet area

Small island in Eriksberg Wildlife Park (EWP)

Fallen tree

Rocky area

Juniper stand

Cliff

Thorny bushes

Agriculture land