# THE IMPORTANCE OF UNDERGROWTH VEGETATION AND BROWSING PATTERN ON OAK SEEDLINGS

**Mariama Mattila**
Supervisors: Anna Monrad Jensen, Magnus Löf

**Swedish University of Agricultural Sciences**
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Drawing: M.Mattila


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## Abstract

This 30 ECTS master thesis aim was to investigate how the species composition and structures in the understorey vegetation community affects oak seedling browsing risk, frequency and severity.

The study was conducted in 10 mixed broadleaved forests in Southern Sweden. A sub-plot sampling inventory method over transect was used in order to evaluate browsing pattern on natural regenerated oak seedlings. Data for studies was collected in July 2009. In the total of 200 focal oak subplots evaluation, around 8 500-undergrowth vegetation species individuals were carried out.

The results showed that in all 10 sites together, more than half of all oaks were browsed and third part of all damaged undergrowth species were oaks. Undergrowth vegetation species composition and density didn't affect browsing pattern and severity in all ten forests. In all 200 focal oak subplots the most damaged undergrowth species were: *Quercus* sp, *Sorbus aucuparia*, *Populus tremula*, and *Fraxinus* sp. Browsing choice and severity was dependant on the oak seedling height by itself and available undergrowth species height in the surroundings.

Oak stands should have a high amount of broadleave species in the undergrowth until regeneration phase is over in order to provide enough oak seedlings per hectare for future stand management without fencing.

**Key words**: oak, seedling, browsing, undergrowth vegetation, species composition

## Tiivistelmä

Tämän 30 ECTS maisterin väitöskirjan tavoitteena oli tutkia, miten lajikoostumus ja –rakenne kenttäkerroksessa vaikuttavat tammentaimien syöntituho riskiin, sen yleisyyteen ja vakavuuteen.

Tutkimus tehtiin kymmenessä sekalehtimetsässä Etelä-Ruotsissa. Linjoittaista koealainventointia käytettiin määrittämään syömisen toistuvuutta luontaisesti syntyneillä tammentaimilla. Tutkimuksen maastotyöt tehtiin heinäkuussa 2009. Yhteensä käytiin läpi 200 koealaa ja noin 8500 kenttäkerroksen kasvia.

Tulokset osoittivat kaikissa kymmenessä metsässä, että yli puolet kaikista tammentaimista oli syötyjä ja kolmannes kaikista vahingoittuneista lajeista oli tammia. Kenttäkerroksen kasvillisuuden koostumuksella ja tiheydellä ei ollut vaikutusta syömisen yleisyyteen tai vakavuuteen kaikissa kymmenessä metsässä. Kaikista 200 koealasta vahingoittuneimmat lajit olivat: *Quercus* sp, *Sorbus aucuparia*, *Populus tremula* ja *Fraxinus* sp. Syödyksi tulemisen valintaan ja vakavuuteen vaikuttivat tammentaimien pituus ja saatavilla olevan kenttäkerroksen kasvillisuuden pituus lähiympäristössä.

Tammimetsissä pitäisi olla suuri määrä lehtipuulajeja kenttäkerroksessa, kunnes uudistumisvaihe on ohitse. Näin saadaan säilytettyä tarpeeksi, monta tammentainta hehtaarilla tulevaisuutta varten ilman aitaamista.

**Avainsanat**: tammi, taimi, syönti, kenttäkerroksen kasvillisuus, lajikoostumus

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# 1. Introduction

Forest is the most important natural resource in Sweden (more than 60% of land area); consequently forestry is essential for the national economy (12% of Swedish export income) (Anon, 2010). In southern Sweden, where conifer-dominated production stands comprise almost 90% of the forest area, many small, semi-natural, broadleaved stands have been identified, often containing large oaks that grow up in semi-open woodland, used for agriculture (Götmark, 2005). The total area of mature forest with a large deciduous component is over 1.3 million hectares, so large trees are fairly unusual in the Swedish landscape and most of them are oaks (Hildingsson; 2009).

The increased interest in broadleaved trees species such as oak (*Quercus sp*) is caused by three main reasons. Firstly, the wood industry demands more hardwood than before. Secondly, to protect biodiversity there is a need to expand areas with important habitats such as rich broadleaved forests with oaks and finally, many forest owners are looking for alternatives to spruce, which is susceptible to wind throw and root rot (Anon, 2009).

Oaks are best known for their timber production, resulting good quality furniture, flooring and other products (Anon, 2000). However oaks are vulnerable to diseases and pests, some can cause severe damage e.g. sudden oak death, *Microsphaera alphitoides* (leaf disease), etc (Evans, 1984; Solomon, 1987). Moreover, oak seedlings are often palatable for large herbivores (Kullberg, 2001).

For the forest owners, browsing damages may increase regeneration costs and fencing is a necessity, but hunting is also important. Close to 300 000 people are registered as hunters at the Swedish National Environmental Protection Agency (Anon; 2009). The present high densities of moose and roe deer in Sweden cause heavy economic losses in forestry, because trees are damaged not only by the direct consumption of biomass but also by trampling, striping of bark, fraying and breaking of the stems (Kalen; 2004). Young oaks seem to be preferred and heavily browsed by deer, influencing stand development (Hambāck; 2003; Kullberg, 2001; Löf, 2000).

It is necessary to adapt moose density to the local biological conditions if the aim is to optimise the benefits from forestry and hunting (Hörnberg; 2001). Mainly, there are two alternative ways to decrease the relative browsing damage, either by lowering the animal density or by increasing the availability of preferred food (Kalen, 2005; Marquis; 1981).

In high biodiversity forests, silvicultural investments are playing important role to achieve both: valuable oak timber and rich biodiversity forest areas. Still large herbivores are an appreciated part of the Swedish nature, but the population greatly influences the landscape, for example with respect to the mix of both tree and other plant species, thus affecting the biodiversity (Anon; 2009).

In theory, increasing the availability of edible food will decrease the relative browsing damage, however, for this to be efficient it must be made on a large scale, otherwise one may only attract more animals to sites rich in resources (Kalen; 2005). Perhaps, more browsing resistant oak stand should be multilayered, mixed and naturally regenerated. But on the other hand such conditions may result in problem of oak poor regeneration or its absence (Götmark; 2005).

On a landscape level it is important to understand which undergrowth vegetation species has strongest impact on the browsing pattern within the forest. Plant species normally associated with early-successional sites tend to be more influenced by browsing than late successional species (Bergquist; 1998). Alternative food habitat availability such as meadows, forest edges, peat lands etc., consequently is important in stand browsing damage level. Risk for predation, human settlement, food accessibility and site productivity also determine where animals are located and where they forage (Kalen; 2005). It was also important to investigate how the mechanical structures such as lying dead wood and rocky outcrops affect the browsing pattern in broadleaved stands.

The study was conducted in 10 mixed broadleaved forest plots in southern Sweden, Götaland. All ten studied forests were former pasturelands, between 2002 and 2003 a partial cuttings, where 30% of the standing volume was removed to increase light availability for the understory, were accomplished (Götmark et al; pers com). Two out of ten sites are nature reserves (protected area of importance for wildlife, which is reserved and managed for conservation) and rest of them are woodland key habitats (WKH), which have no legal protection unless they are formally set aside as protected areas with compensation to the forest owner (Anon; 2009).

The aim of this thesis was to investigate how the species composition and structures in the understorey vegetation community affected oak seedling browsing risk, frequency and severity scale.

## 2. Materials and methods

### 2.1. Study site and plot characteristics

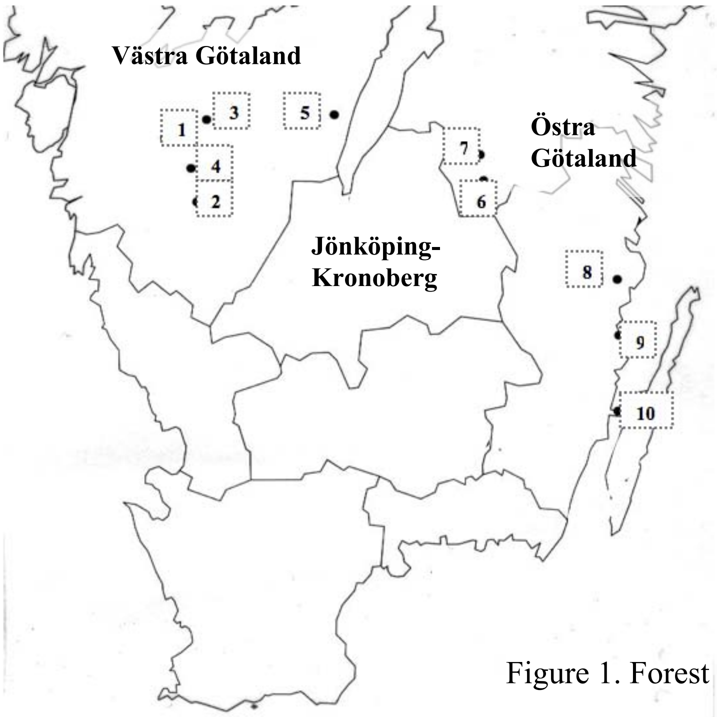
Figure 2. Transect in Lindö.
Photo: M. Mattila.

The ten study forest sites were located in southern Sweden, boreonemoral transition zone of mainly cold temperate, deciduous forests (Anon; 2009) (see Figure 1).

Seedlings of *Quercus robur* and *Q. petraea* were both present and were pooled during measurements and data analysis.

Many other tree species occurred at the sites - the most common ones in the undergrowth vegetation level were: *Fraxinus excelsior, Rubus ideaus, Corylus avellana, Betula sp., Populus tremula, and Sorbus aucuparia.*

All the subplots had similar density and species composition and in these terms were representative for the sites.




1. Östadkulle
2. Rya åsar
3. Karla
4. Sandviksås
5. Strakaskogen
6. NorraVi
7. Aspenäs
8. Fårbo
9. Emsfors
10. Lindö

Figure 1. Forest site distribution, Southern Sweden.

Table 1 Possible surrounding factors, which influences the browsing behaviour

Abbreviations: *WKH* = Woodland Key Habitat*; NR* = Nature reserve*; "+" and "-"*, means factor presence or absence, in the current site

| Site | Plot size, m | Uneven relief (not flat land) | Water resource availability near by | Forest mono-culture near by | Infra-structure near by | Agri-culture land near by | Human influence |
|---|---|---|---|---|---|---|---|
| 1.Östadkulle WKH | 120x83 | + | + | - | + | + | + (Houses) |
| 2.Rya åsar NR | 120x83 | + | + | - | + | - | + (Houses) |
| 3.Karla WKH | 120x83 | + | + | - | + | + | + (Houses) |
| 4.Sandviksås WKH | 100x100 | + | + | + (Spruce) | + | - | - |
| 5.Strakaskogen WKH | 100x100 | + | - | + (Spruce) | + | + | + (Houses) |
| 6.NorraVi WKH | 100x100 | + | - | - | + | - | + (Houses) |
| 7.Aspenäs WKH | 100x100 | + | + | + (Spruce) | + | + | - |
| 8.Fårbo WKH | 100x100 | + | + | + (Spruce) | - | - | + (Hunting tower) |
| 9.Emsfors WKH | 120x83 | + | + | + (Pine) | + | + | + (Houses) |
| 10.Lindö NR | 100x100 | + | + | - | + | + | + (Houses) |

Based on visual observations all selected sites had uneven topography, consequently the risk of damage to oak saplings could increase near habitats where ungulates seek shelter (Table 1).

Almoust all sites had access to water resource and were situated next to infrastructure, quite many had agricultural land near by. Five sites were situated next to monocultures and most of sites had human activities influence, like hunting towers, feeding places availability and housing.

## 2.2. Experimental design

Data for studies was collected in July 2009. Sub-plot sampling inventory method was used. Transect, which was placed on the midline, parallel to a longest side of the plot (e.g. 100/120 m) (Table 1 and Figure 2) was used to sample subplots. Oak density per hectare was estimated by walking along (both ways) in 1 m distance from the midline, counting each oak seedling.

20 subplots (radius = 2 m) were established along transects in each site. First focal oak was chosen randomly, others with same distance from each other at every subplot. If there were no oak regeneration in supposed place, then closest oak in perpendicular direction from the midline was chosen as a focal oak. In the total 200 subplots were evaluated around 8 500 undergrowth vegetation individuals.

2.2.1 Focal oak subplot:

***Quercus***

All focal oaks were recorded as browsed or non-browsed. Browsing severity scale was estimated in 3 categories (Table 2).

Table 2 Oak seedlings estimated browsing categories

| Category 0 | Category 1 | Category 2 |
|---|---|---|
| No browsing | Slight browsing:<br>(Browsed, still green, can produce “shoots”, growth is not affected much) | Severe browsing:<br>(Browsed, still growing, but will not be a good quality tree, most probably will have bush shape) |

Figure 3. Browsed oak shoot. Rodents. Photo: M.Mattila

Figure 4. Browsed oak shoot. Cervids. Photo: M.Mattila

I recorded amount of browsed and unbrowsed shoots. Browsing damages were estimated as caused by cervids or rodents (Figure 3 and 4).

Seedling base diameter (mm) and two height types were recorded: seedling height (cm) was measured from the ground till top with seedling stretching and without seedling stretching. Browsing choice height (cm) was calculated as a difference between undergrowth vegetation mean height (cm) and focal oak height (cm) without stretching. This factor was calculated to estimate availability of alternative food resources or accessibility.

***Undergrowth***[1]

Undergrowth species were identified and recorded as browsed or unbrowsed. The maximal, mean and minimal height (cm) of the surrounding undergrowth vegetation was measured. Ground vegetation[2] mean and maximal heights (cm) were measured and compared with undergrowth vegetation height.

Ground vegetation coverage density (0-100%) was estimated within $1m^2$ area subplots around the focal oak. Undergrowth vegetation coverage density estimation was made in focal oak subplot in 3 categories (Table 3).

Table 3 Undergrowth vegetation coverage density, % from subplot area

| Category 0 | Category 1 | Category 2 |
|---|---|---|
| < 35% | < 65% | < 100% |

Mechanical barriers: rocky outcrops and lying logs were estimated separately in 3 categories (Table 4).

Table 4 Mechanical barriers coverage density, % from subplot area

| Category 0 | Category 1 | Category 2 |
|---|---|---|
| Almost no rocks/logs | Less than 50% of subplot area is covered by rocks/logs | More than 50% of subplot area is covered by rocks/logs |

2.3. Statistical analysis

All data was analyzed in Minitab statistical program using different methods and models according to the raised question.

To find out which central oak subplot measured parameter is the most influencing in browsing pattern - data was structured using Multivariate analysis, factor analysis, using

[1] **Undergrowth/understorey** in this study: all vegetation, shrub and young seedling community until 5 m height.
[2] **Ground vegetation** in this study: all herbaceous plants on the ground level.

maximum likelihood and an equamax rotation. Structure of affecting factor data was examined by explaining the correlations among central oak plot measured parameters.

Graphical, statistical analysis was used to evaluate oak damage significance in whole undergrowth species pattern. Scatterplot with regression line was used to illustrate the relationship between undergrowth species by plotting each species against the other species.

To assess and compare species distributions were used boxplots, displaying all 10 forests undergrowth vegetation in damaged and undamaged groups.

Histogram with Fit and Groups was used to examine how frequently oak seedlings were browsed in comparison with surrounded alternative food resources in order to evaluate browsing pattern species choice.

One-way ANOVA was used to check, raised hypothesis; that all 10 site data set are equal; it was made in order to be sure about similar result trustfullness and their correct interpretation ability. Descriptive statistics was used to check if all influencing factors fit into normal distribution curve.

A 2-sample t-test was used to examine height and density differences in all central oak browsing categories, between oak seedlings, ground vegetation and undergrowth, to determine possible influence on browsing pattern. All three categories contain uneven number of individuals, for that reason t-test is able to make inference about mean values, testing whether the difference between the means of independent categories.

The same test was used to evaluate browsing intensity difference between all browsed oaks and oak seedling density. To evaluate browsed oak seedling amount significance in browsing pattern I tested the difference between browsed oak stems per hectare and browsed undergrowth vegetation stems per hectare. To determine browsed oak amount significance in whole undergrowth vegetation pattern I tested the difference between browsed oak seedlings and whole undergrowth vegetation amount per hectare.

## 3. Results

### 3.1. Overview of the ten forest sites

The most dense undergrowth vegetation sites (including all species in each plot) were Östadkulle, Rya åsar and Karla. Oaks were also the most browsed in terms of numbers in the same sites.

Undergrowth mean density was about 35 000 stems/ha and mean oak density was more than 6 000 stems/ha. About 4 000 stems/ha are browsed. One third of all undergrowth species were browsed. The highest oak density was in Karla, Rya åsar and Östadkulle with more than 14 000, 10 000 and about 10 000 stems/ha respectively. Mean browsed oak seedling amount was 1 500 stems/ha higher than undamaged individuals (Table 5).

Table 5 Browsed and unbrowsed undergrowth vegetation and *Quercus* species stems/ha in all ten forests site pattern

| | All Understorey (stems/ha) | | | *Quercus* species (stems/ha) | | |
|---|---|---|---|---|---|---|
| Site | Total Density | Unbrowsed | Browsed | Total Density | Unbrowsed | Browsed |
| Östadkulle | 68934 | 54893 | 14041 | 9706 | 4853 | 4853 |
| Rya åsar | 52466 | 32299 | 20167 | 10103 | 1392 | 8711 |
| Karla | 44232 | 30708 | 13524 | 14041 | 4614 | 9427 |
| Sandviksås | 47574 | 32418 | 15155 | 5410 | 2784 | 2625 |
| Strakaskogen | 34288 | 21599 | 12689 | 1154 | 239 | 915 |
| NorraVi | 23548 | 14041 | 9507 | 5131 | 2029 | 3103 |
| Aspenäs | 30032 | 21718 | 8313 | 2824 | 2029 | 796 |
| Fårbo | 14519 | 8035 | 6484 | 3341 | 756 | 2586 |
| Emsfors | 15752 | 11376 | 4375 | 2745 | 1591 | 1154 |
| Lindö | 17303 | 8274 | 9029 | 7080 | 2944 | 4137 |
| Mean | 34865 | 23536 | 11329 | 6154 | 2323 | 3831 |

Oak seedling density did not affect the frequence of browsing. On the other hand, browsed oak density shows statistical significant difference within other species in the browsed undergrowth vegetation. Browsed oak density was statistically significant in whole undergrowth vegetation pattern (P Value < 0.05).

The most frequent browsed species were: *Quercus* sp. in Karla, Rya åsar, Östadkulle, Norra Vi, Lindö; *Populus tremula* in Aspenäs and Emsfors; *Sorbus aucuparia* in Strakaskogen and *Betula pendula* in Sandviksås. Total number of *Quercus* seedlings in all ten forest sites was 61 535 stems/ha. The highest amounts of browsed oaks/ha (from Quercus sp/ha) were in Rya åsar, Strakaskogen, Fårbo and Karla with 86%, 79%, 77% and 67% respectively (Figure 5).

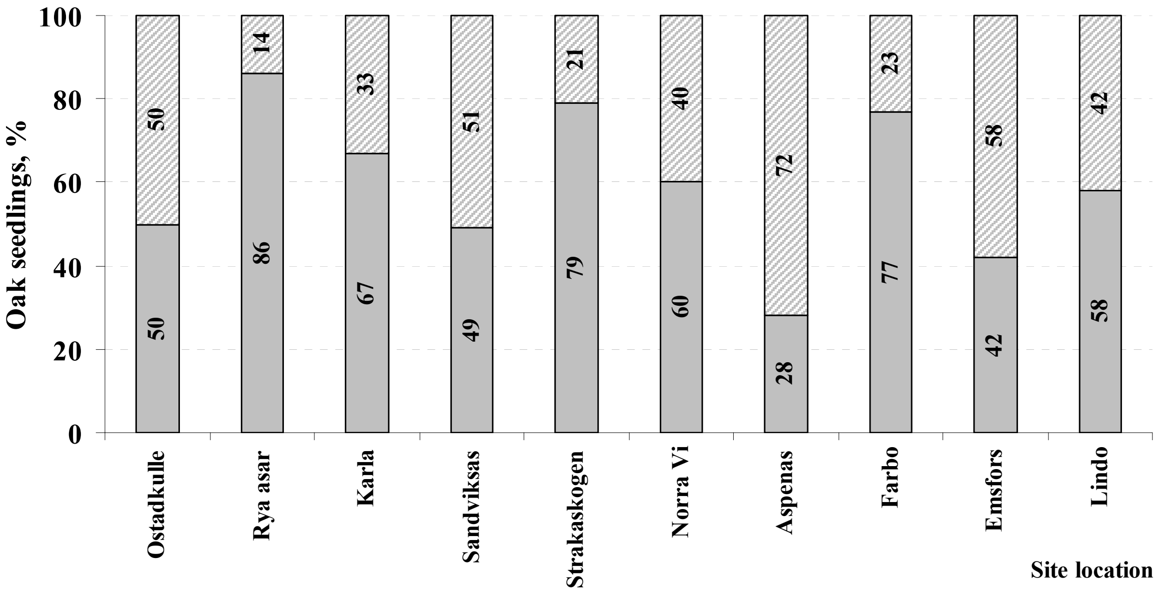



Figure 5 Percent of browsed and unbrowsed oak seedlings (grey column part – browsed oak seedlings; striped column part unbrowsed oak seedlings)

### 3.2. Undergrowth vegetation species composition in relation to focal oak damage scale

All understorey species, from 200 subplots across ten sites, were devided into 3 groups according to focal oak browsing conditions. Category, where focal oak was untouched was formed in order to estimate browsing pattern major species choice. Categories, where focal oak seedling was slightly/heavily browsed were formed in order to estimate browsing animal, additional undergrowth species choice.

Species composition in the understorey had no affect on the browsing severity in none of the three categories.

#### 3.2.1. Vegetation composition in unbrowsed focal oak surrounding

The most common understorey species in category 0 were: *Fraxinus* sp. (about 30%), *Rubus ideaus* (about 20%), *Quercus* sp. and *Populus tremula* (together are about 20%). The most browsed species were: *Populus tremula*, *Quercus* sp., *Fraxinus* sp. (Figure 6). However, *Fraxinus* sp. and *Rubus ideaus* were the least browsed undergrowth species.

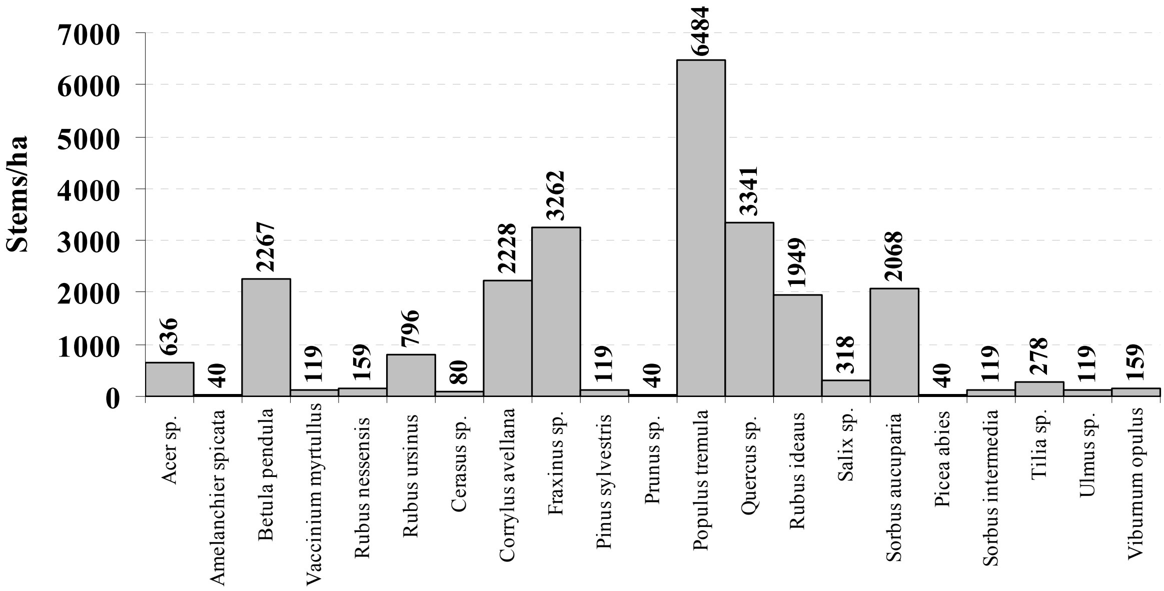



Figure 6 Group 0, Understorey community browsed species composition per hectare

3.2.2. Vegetation composition in, slightly browsed, focal oak surrounding

The most common understorey species in category 1 were: *Rubus ideaus* (about 25%), *Quercus sp.* are about 20%, *Fraxinus sp.* and *Vaccinium myrtillus* (together are more than 20%).

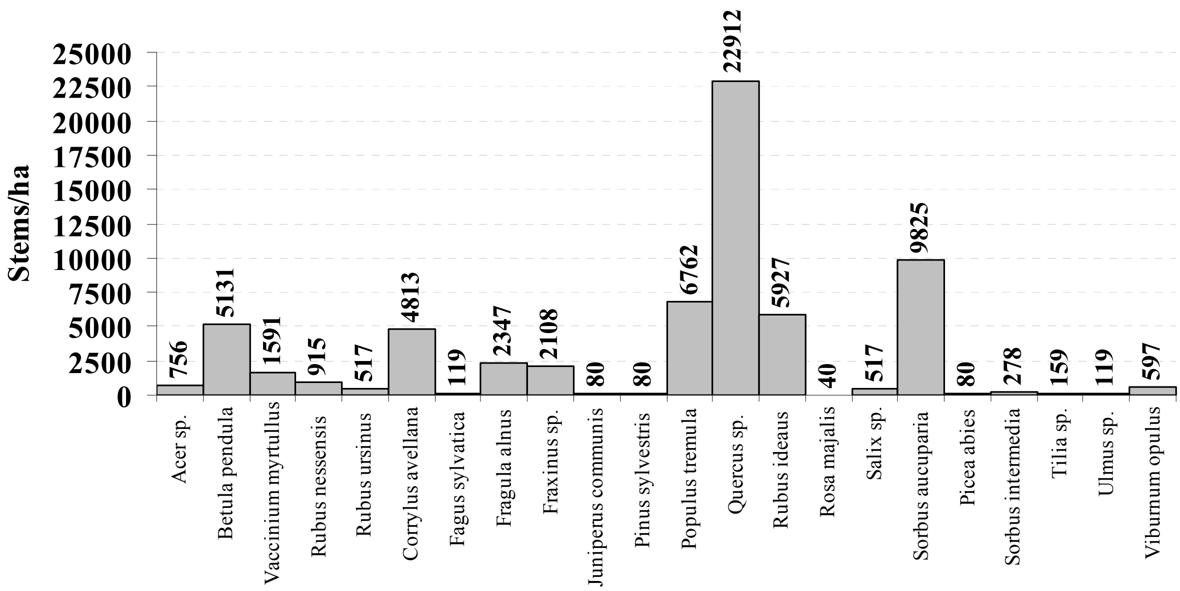



Figure 7 Group 1, Understorey community browsed species composition per hectare

The most damaged were *Quercus* sp., *Sorbus aucuparia, Populus tremula* and *Rubus ideaus* (Figure 7). However, *Rubus ideaus* and *Fraxinus sp.* were the least browsed undergrowth species/ha.

3.2.3. Vegetation composition in heavy browsed focal oak surrounding

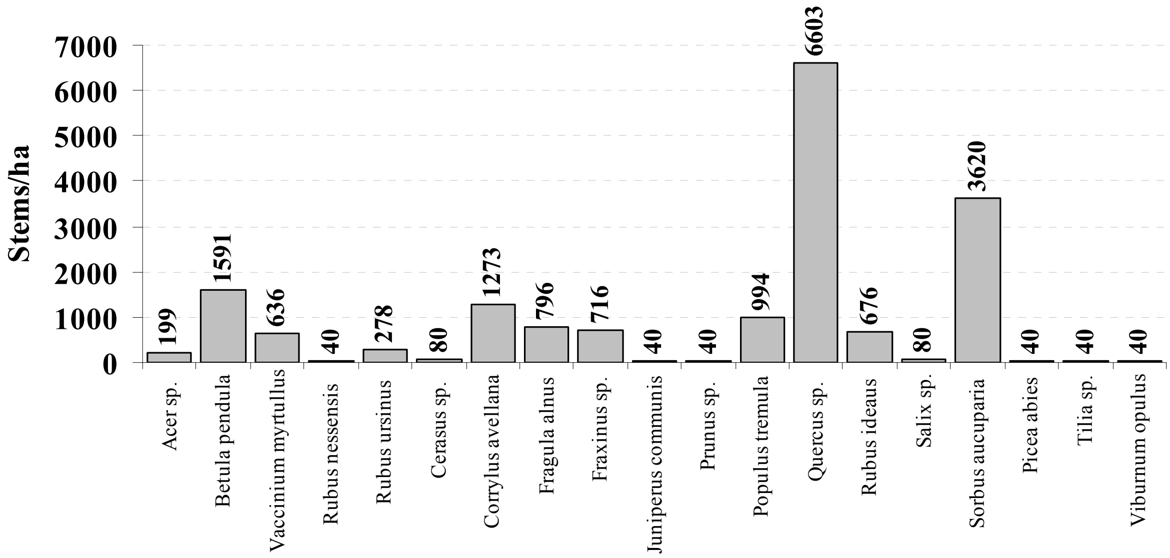



Figure 8 Group 2, Understorey community browsed species composition per hectare

The most common understorey species in category 2 were: *Rubus ideaus* (more than 20%), *Vaccinium myrtillus* and *Quercus* sp. (together are 36%), *Sorbus aucuparia* (about 10% from all species amount/ha). The most browsed were *Quercus* sp. and *Sorbus aucuparia* (Figure 8). *Rubus idea*us and *Vaccinium myrtullus* were the least browsed undergrowth species/ha.

**3.3. Factors affecting browsing pattern, statistical analysis results**

Height (browsing choice, oak seedling, undergrowth vegetation mean, minimal; ground vegetation maximal and mean); number of browsed and unbrowsed shoots, oak diameter and ground vegetation coverage were important factors (correlation among variables > 0.500) in description the browsing pattern (Table 6).

Undergrowth maximal heigh (>5 m) and undergrowth vegetation density were not important factors in browsing pattern in all 10 forests. Oak seedling browsing, caused by cervids has bigger affect than rodents. Mechanical structures such as lying logs and rocky outcrops were not important factors.

Table 6 Results from factor analysis in all study sites

| Variables | Correlations among variables |
|---|---|
| Browsing choice height, cm | 1.000 |
| Oak seedling height (not stretched), cm | 1.000 |
| Undergrowth mean height, cm | 1.000 |
| Shoots - not browsed | 0.773 |
| Collar diameter, mm | 0.739 |
| Shoots - browsed | 0.666 |
| Ground vegetation mean height, cm | 0.648 |
| Undergrowth minimal height, cm | 0.603 |
| Ground vegetation max height, cm | 0.586 |
| Ground vegetation cover, % | 0.540 |
| Cervids | 0.442 |
| Undergrowth maximal height, cm | 0.272 |
| Rocky outcrops | 0.242 |
| Undergrowth density in 1-3 scale | 0.226 |
| Lying logs | 0.194 |
| Rodents | 0.155 |

Oak seedling heights were statistically different in all 3 browsing categories (P Value $< 0.05$). Undamaged, slightly and severly browsed focal oak seedling has significant height difference with groung vegetation (P Value $< 0.05$ respectively) and understorey vegetation (P Value $< 0.05$ in two first categories), but insignificant difference between oak seedlings vs understorey vegetation.

3.3.1. Oak seedling favourness over other undergrowth vegetation species

*Quercus* sp were the most favoured over other species in all ten site pattern. Other preferly-browsed species were: *Sorbus aucuparia*, *Rubus ideaus*, *Betula pendula* (especially in Sandviksås site), *Corrylus avelana* and *Populus tremula,* see Figure 9.

*Rubus ideaus, Vaccinium myrtillus*, *Fraxinus* sp., *Frangula alnus* and *Betula pendula* were the most unprefered undergrowth species in unbrowsed species pattern.

The same species occurence in both scaterplots can be explained with the stand undergrowth species composition, density and the fact that species were divided in damage categories.

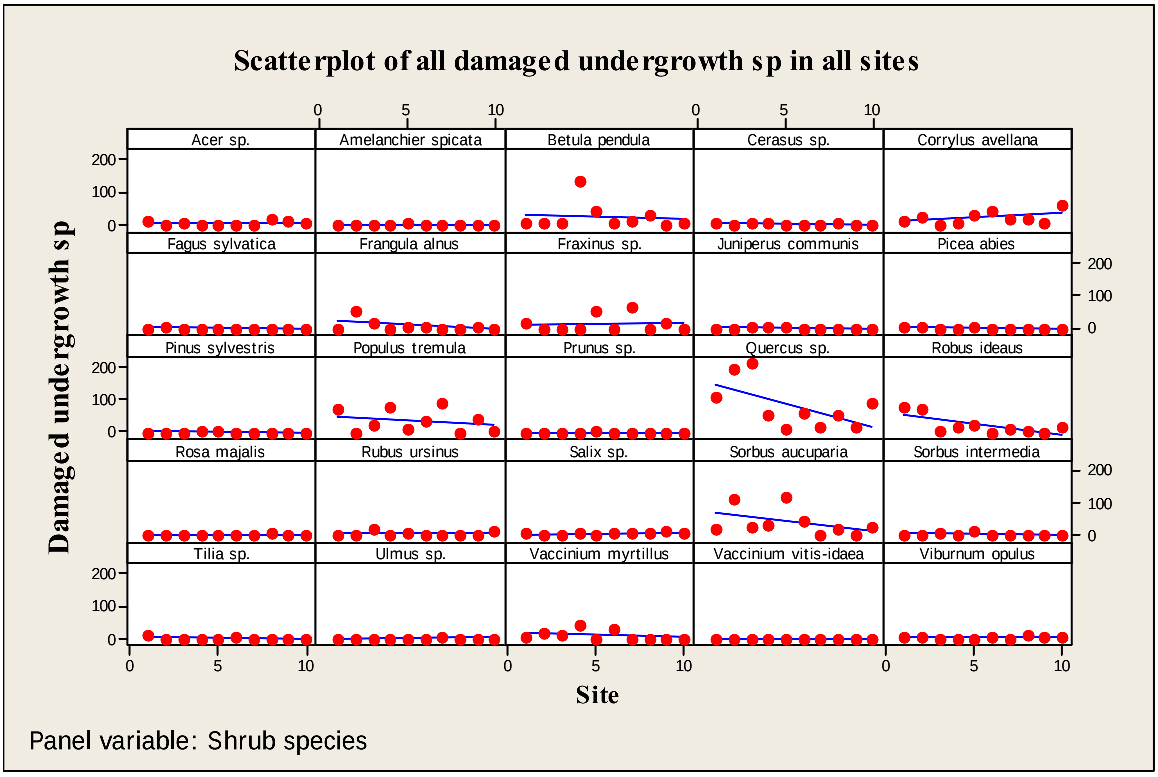



Figure 9 Scatterplot of all damaged undergrowth species per each forest site, *line* indicates linear regression, the more it slopes, the higher importance has particular species in all forests browsing pattern

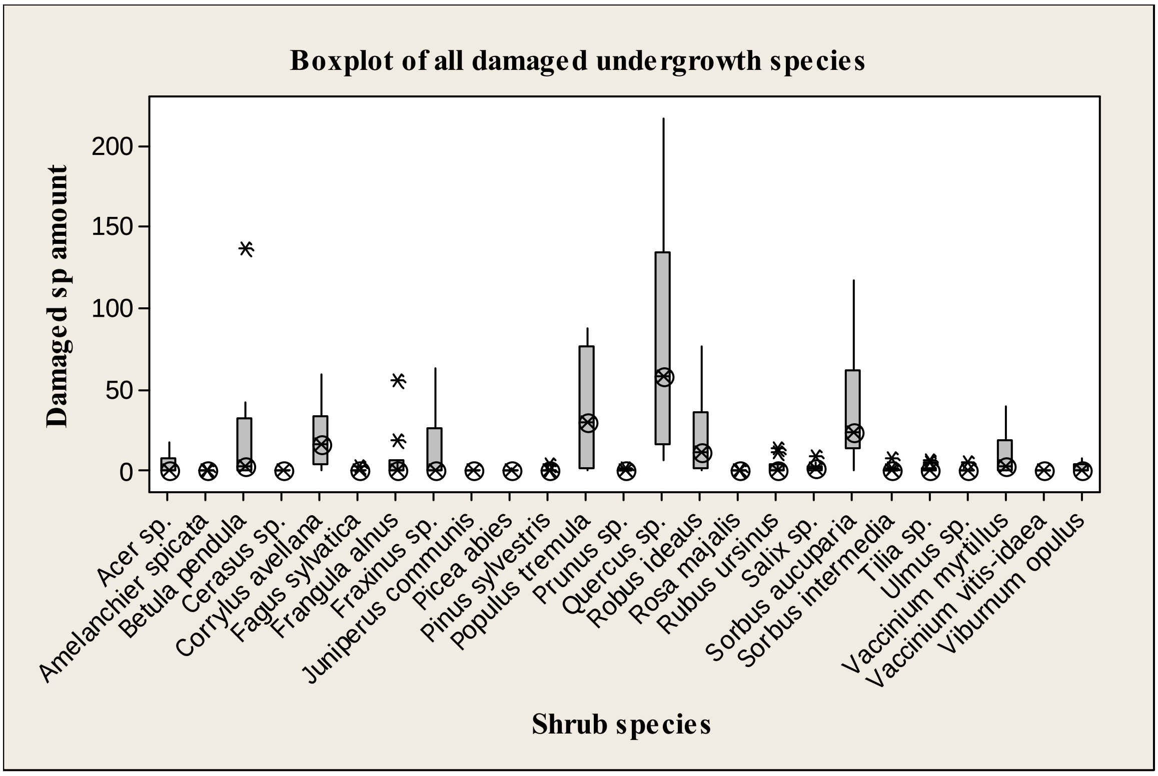



Figure 10 Boxplot of all damaged undergrowth species in all sites (+ mean, □ mean ± SD, I – min-max)

In all damaged undergrowth vegetation, the most common species across ten sites were: *Quercus* sp., *Sorbus aucuparia*, *Populus tremula* and *Betula pendula*, see Figure 10. It indicates that those species were the most distributed in browsing pattern, mainly because of current species availability and hight's variations.

In all unbrowsed understorey vegetation, the most commonly distributed species across all ten sites were: *Rubus ideaus*, *Fraxinus* sp. and *Vaccinium myrtillus*.

### 3.3.2. Oak browsing frequence in whole undergrowth vegetation pattern

Undergrowth vegetation species browsing frequence was twice higher, than oak browsing frequence, what was howewer high result (Appendix 1). Despite amount of different unbrowsed undergrowth species, *Quercus* has very high probability to be browsed as well.

# 4. Discussion

## 4.1. The influence of regional management on browsing pattern to oak seedlings

Swedish forests have been exploited for centuries. The best forestland was cleared for farming; large areas were claimed for shifting cultivation and forest grazing was widespread (Anon; 2009). All sites in this study were located next to Jönköping-Kronoberg region where old forest areas, rich in broad-leaved trees have been changed in production forestland or agricultural fields (Hildingsson; 2009).

In this study, forests surrounding evaluation shows that there could appear future regional browsing risk areas. The amount of browsing damage could be explained with the surronding factor availability and previous partial thinnings, which provide the establishment of many plant species, their growth and reproduction (Götmark et al. pers com.; Tilman, 2004). Attracting factors in habitat choice for large herbivores are for example abundant sprouts, open fields, forest edges, meadows, territories near to forest monoculture and water resource availability in the neighbourhood (Castleberry, 2000; Euler, 1981; Hamilton et al., 1980).

This study presents, that browsing on oak seedling caused by cervids was more severe than browsing from rodents. At the same sites, previous studies (Götmark et al., 2005) also showed that browsing by moose (*Alces alces*) and roe deer (*Capreolus capreolus*) was common. Attracting factors, which influence browsing probability, are for example edge effects, stand composition, previous browsing, season, site productivity and plant traits (Kalen; 2005).

Consequently, regional changes and cervids bahavior may explain browsing damage occurrence, because both moose and roe deer are highly mobile and use a large areas for finding forage (Heikkila et al, 1993; Heikkila, 2003; Kalen; 2005).

In this study mechanical structures had no effect on browsing pattern at the oak regeneration sites. However in other studies unpalatable plants, rocky outcrops and tree stumps seem to form safe sites for young seedlings in grazed system, improving their establishment and survival (Smit; 2005).

## 4.2. The effect of undergrowth vegetation species composition on browsing risk for oak seedlings

In the all subplot types (browsing severity), the most common understorey species were: *Fraxinus* sp., *Rubus ideaus*, *Quercus* sp., *Vaccinium myrtillus*, *Populus tremula* and

*Sorbus aucuparia*. However, the most damaged undergrowth species were: *Quercus* sp, *Sorbus aucuparia*, *Populus tremula*, *Fraxinus* sp. Consequently main ungulate browsing choice is connected with species composition and availability; even if focal oak was unbrowsed this was not preventing near by *Quercus* seedling from being browsed. That means that if majority of available alternative food resource contains such undergrowth species like *Vaccinium myrtullus* and *Rubus ideaus*, which are normally slightly browsed or unbrowsed, it is not affecting target species browsing damage intensity and severity. It is common, that many species in forest are relatively not heavily browsed, while increasingly few undergrowth species are very severily browsed.

Undergrowth species composition did not statistically differ between three damage categories, what is in support, that species composition and diversity, (which allows greater plant biomass (Loreau; 2009) in oak regeneration sites are not affecting browsing pattern. On the other heand, in present study *Quercus* sp. seedlings were the most significantly browsed. *Rubus ideaus, Sorbus aucuparia, Populus tremula* presence in oak sites, could be an effective alternative food source in a browsing pattern.

Studies from the same area (Götmark; 2005), shows that frequently browsed species were: *Populus tremula*, *Sorbus aucuparia*, *Betula sp*., *Salix* sp. and *Fraxinus sp*. In the study by Kullberg and Bergström (2001), the descending order, based on number of browsed seedlings, was *Quercus robur, Alnus glutinosa, Fagus silvatica, Tilia cordata, Prunus avium, Betula sp, Picea abies and Fraxinus sp*.

Consequently, in browsing risk areas it could be usefull to keep alternative species in the undergrowth (despite nutrients and light competition with oak seedlings) e.g. till first precommercial cuttings because by manipulating the alternative vegetation, available to the herbivore, it may be possible to reduce browsing damage (Holt; 1977). However, browsing mainly influences the competitive ability of plant species, therefore it will take longer for browsing to influence plant species composition (Bergquist; 1998).

**4.3. The influence of seedling height and growth on browsing pattern**

Such factors as seedling diameter and hight, ground vegetation coverage were affecting the browsing pattern. The biomass, available for browsing, increased with tree height but only to approximately 2.5 m height (Kalen; 2005) Within species, initially taller seedlings can be more often selected than shorter ones (Götmark; 2005).

In all browsing damage categories oak seedling height significantly differed from ground vegetation and understorey heights. However undergrowth vegetation height was insignificant in comparison with severly browsed oak seedling height. That means that browsing choice and severity was dependant on the oak seedling height and available undergrowth species height in the surrounding.

Number of damaged and undamaged shoots per oak seedling was also important factor in the browsing pattern, so if surrounding undergrowth species are covering oak seedling until it reaches browsing choice height, oak could be less browsed.

When the understorey exceed 5 m height it has no significant impact on the browsing pattern, which is supporting previous research results (e.g. Bergquist et al, 1998; Götmark et al, pers com.; Kalen, 2005), that browsing damage tended to decrease with the height of surrounding vegetation, additionally oak seedling heights significantly differ in all three browsing categories. Consequently it could be important to keep undergrowth species in the oak stands e.g. until first precommercial cutting.

### 4.4. The influence of undergrowth vegetation and *Quercus sp*. density on the browsing pattern

In this study, the sites with most dense undergrowth vegetation were in Västra Götaland and at these sites oaks were also the most browsed and it could have a link to previous human activities, like land use change, silviculture management etc. However, in cool temperate forests it is possible that dense undergrowth (herbs, shrubs and trees) protects oak seedlings against browsing by large mammals (Götmark et al; manuscript).

Amount of browsed oaks was significant in the whole undergrowth vegetation pattern. More than half of all oaks were browsed and 34% of all browsed undergrowth species were browsed oaks. Consequently, oak stands should have high density untill first precomercial cutting, or should be used partial cutting method, to provide high density of alternative species in the undergrowth untill regeneration phase is over in order to provide enough oak seedlings per hectare for future stand management (without fencing). Undergrowth vegetation density did not influence browsing pattern in all 10 forests, this result is supporting findings by previous researches, e.g. for spruce sites (Bergquist; 1998), where browsing damage was expected to be only weekly related to density, thus complicating efforts to control damage through a reduction in animal numbers.

## 5. Conclusions and Suggestions

Main ungulate browsing choice: *Quercus sp., Sorbus aucuparia, Populus tremula, Fraxinus sp.*, was connected with species availability within the subplots. Undergrowth species composition did not affect the severity of browsing. If the majority of available food resource contains unprefered undergrowth species like *Vaccinium myrtullus* and *Rubus ideaus*, it is not affecting target species browsing intensity and severity. Consequently, leaving preferred alternative food sources, in *Quercus* species regeneration sites, might reduce oak seedling browsing risk.

Oak seedling browsing choice and severity was dependant on the heights of seedling and surrounding undergrowth. In high browsing pressure areas, could be usefull to keep alternative food sources in the undergrowth e.g. till first precommercial cuttings, because if surrounding undergrowth species are covering oak seedling until it reaches browsing choice height, oak could be less browsed.

Amount of browsed oaks was significant in the whole undergrowth vegetation pattern; because more than half of all oaks were browsed and a third of all browsed undergrowth species were oaks. Consequently, oak stands should have a high density of preferred alternative species in the undergrowth untill regeneration phase is over in order to provide enough oak seedlings per hectare for future stand management without fencing.

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## Appendix 1

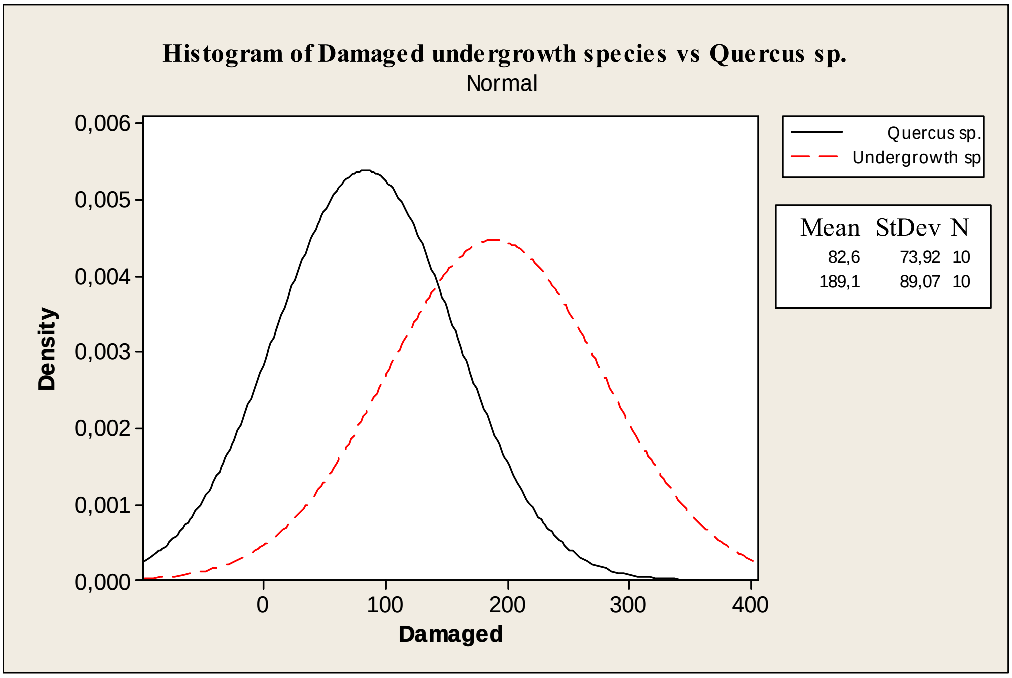


Figure (a) Histogram of all damaged undergrowth species in all sites vs Quercus sp.

Mean number of damaged oaks is 82.6 and for damaged undergrowth sp in total = 189.1. So, it will be: 3 286 oaks/ha vs 7 522/ha undergrowth species, what is almoust double amount (Figure a).

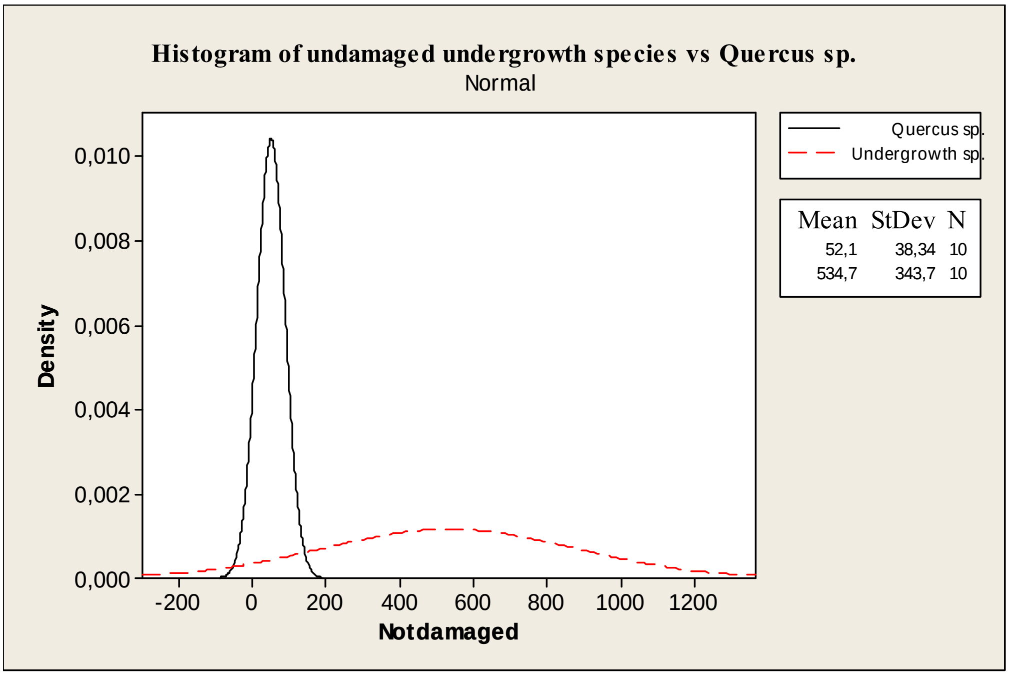


Figure (b) Histogram of all undamaged undergrowth species in all sites vs Quercus sp.

The standard deviation for undergrowth sample (343.7) is much greater than that for Quercus sp. (38.3). This translates into a shorter and wider-looking fitted distribution for undergrowth species (Figure b). Undamaged data is often skewed in this manner.

Because damaged sample data are so skewed, the normal distribution does not fit very well, also the data set is significally different in all 10 sites like it was prooved in hypothetically equality testing, therefore the data was transformed.

**Hypothetically equality graphical interpretation**

(Level = forest site number; N = balanced amount of subplots per site; Mean = oak damage factor; StDev = The Standard Deviation)

```
Level  N    Mean    StDev   ---------+---------+---------+---------+
  1    20   0,6500  0,7452       (----*----)
  2    20   1,1500  0,3663              (----*----)
  3    20   1,4500  0,5104                  (----*----)
  4    20   0,7000  0,7327        (----*----)
  5    20   1,0000  0,6489            (----*----)
  6    20   0,9000  0,6407           (----*----)
  7    20   0,3000  0,4702  (----*----)
  8    20   0,8000  0,7678          (----*----)
  9    20   0,6500  0,6708       (----*----)
 10    20   0,7500  0,4443         (----*----)
                            ---------+---------+---------+---------+
                                   0,50      1,00      1,50      2,00
```

All intervals doesn’t contain zero it means, that there is statistically significant diference between the corresponding means. Pooled StDev = 0.6145

All analysed factors fit into normal distribution curve with small exeptions howewer all these factors are in possible mistake limits.