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Long-term effects of browsing in a beech stand

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Abstract. Our hypothesis was that the browsing damage caused by large herbivores in the seedling stage has a negative long-term impact on the quantity and quality of forest stands, trees, and timber. The data were collected in beech (*Fagus sylvatica*) stands in the Bükk Mountains, Hungary. In even-aged stands, affected by different levels of game damage after regeneration, sample and control plots were designated. The sampling method was those of quadrats within which all trees have been surveyed. Data from the areas affected by browsing and the control areas were compared. The results show that the number of trees in the forest area affected by browsing was significantly lower, and the number of forked and curved trunks was higher.

Keywords: ungulate browsing, browsing damage, shape defects, red deer, roe deer, mouflon

1. Introduction

Grazing and browsing, which is part of the lifestyle of large herbivore species, has always played a role in the structure and dynamics of natural ecosystems. Thus, when large herbivore densities in forests reach a certain threshold level, they can have a significant impact on the vegetation of their habitat [1], [2].

Large herbivores have a significant influence on forest composition and structure through their selective feeding [3], [4], which slows the growth of seedlings, prolongs their exposure to browsing, and sometimes renders them unable to regenerate [5].

Deer herbivory play a crucial role in tree regeneration as a top-down process in natural ecosystems [6]. Red deer is the first to browse the actively growing and most nutritious parts of trees, the apical shoots, and upper leaves [7]. As a result, browsing severely reduces seedling growth [4], [8].

In addition to reducing growth, browsing can also affect tree survival rates, which significantly reduces seedling density [9]. Beech is often considered a species well adapted to conditions, even under low light conditions. However, like any other tree species, it responds positively to increased light [10], and [11] suggest that regeneration growth can be adequately supported by creating an open canopy.

Náhlik et al. (2012) analysed two forest plots at the Szilvásvárad Forestry (Hungary), where in one of them a high level of wildlife damage was described [12]. The results of this study showed that fewer trees per hectare survived in the area affected by wildlife damage (3,570 ± 330) compared to the control area (4,660 ± 542). The number of seedlings in the baseline condition was not known, so no firm conclusions can be drawn, but it is a fact that in the wildlife-damaged area, there was a greater mean distance between the seedlings, which may indicate the effect of wildlife predation. Significantly lower densities of seedlings were registered in the damaged area, which may also be a consequence of wildlife predation.

Prolonged browsing can lead to a loss of habitat and species diversity, as well as the alteration of key processes such as nitrogen and carbon cycling [13].

The aim of our research was to provide evidence at the forest stand level for the hypothesis that prolonged, repeated browsing has a demonstrable negative effect on forest structure.

2. Materials and methods

For our investigation, we selected beech forest stands with similar characteristics within areas managed by the Lillafüred Forestry Directorate of Északerdő Private Joint Stock Company (*Fig. 1*).

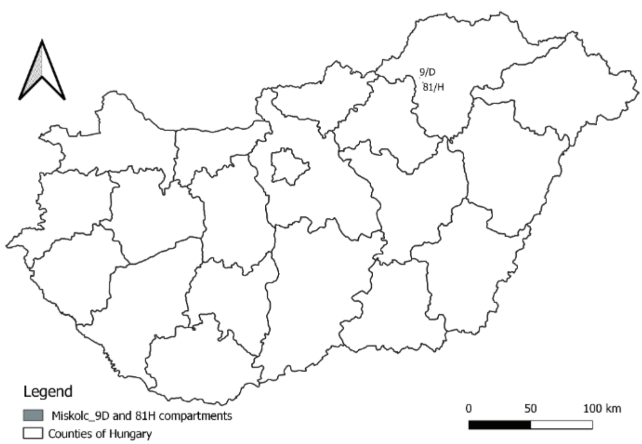

Figure 1. Location of the study area – Miskolc County, Hungary

The two forest areas were: Miskolc 81H compartment (48°05’12.39” N 20°34’12.15”; hereafter referred to as the sample area) and Miskolc 9D compartment (48°07’13.46” N 20°32’05.50”; hereafter referred to as the control area). The difference was that the sample plot was subject to wildlife damage from seedling age onwards, whereas the control plot was damage-free. The genetic soil type of both forest stands was brown soil, the topsoil thickness was deep-medium deep, and the physical soil type was loam. None of the forest stands have been affected by excess water; elevation is around 750 m above sea level, with an exposure to south-southeast (SSE) and a slope of 10-15°. The long-term target species is beech.

The sample forest compartment is located in a beech climate zone, covering an area of 4.13 hectares, of which 0.4 hectares is dead larch (*Larix decidua*) stand. The beech is of seed origin, and in addition to beech and larch, European ash (*Fraxinus excelsior*) and sycamore maple (*Acer pseudoplatanus*) are also found in the area (*Fig. 2*). First, in 1986, qualitative browsing damage occurred in 9% of the area, followed by drought in the next two years. In 1987, 2.8 ha and in 1988 0.5 ha were damaged by drought. From 1986 onwards, browsing damage was continuously recorded in the area. In 1987 and 1988, beech was replanted. In 1989, 6%, in 1992 2%, in 1993 20%, in 1994 11%, and in 1995 15% of the afforestation was damaged by wildlife. The damaging game species in all cases were red deer, roe deer, and mouflon. At that time, the control of game damage was attempted through increased damage control hunting.

Figure 2. Sample (81H) compartment

The control compartment is also in the beech climate zone, with beech of seed origin as well as the sample compartment, and has an area of 6.26 ha. Apart from beech, the species composition of the forest contains sycamore maple and European ash. The afforestation started in 1981, and there has been no significant browsing damage (*Fig. 3*).

Figure 3. Control (9D) compartment

In the studied forest stands, 7-7 sample quadrats of 10 x 10 m were randomly selected. In order to mark the sample areas, a 20 m measuring tape was used, which was marked at 10 m (side length) and 14.14 m (diagonal of the 10 x 10 m quadrat).

Within the quadrats, the height and diameter at breast height (DBH) of each tree was measured. Trunk defects (curvature and forking) below 2 m were also recorded. When determining the DBH, a simple tape measure of the circumference was used, from which the diameter of the trunk was calculated. A tree height measuring device (Suunto PM-5/1520 PC) was used to determine tree heights.

Chi-square normality tests and Kolmogorov–Smirnov goodness of fit tests were performed to check the distribution of the DBH and measured heights data among sample plots. Due to the normal distribution of data, t-tests, independent, and by-samples were used for the comparisons of mean DBH and mean heights among sample plots.

To compare the occurrence of forked and curved trunks between sample plots, 2 by 2 Chi-square tests were used.

Statistical analyses were carried out using STATISTICA version 14.0.1.25 [14] and Microsoft Excel.

3. Results and discussion

The data were recorded in the field and then evaluated in Microsoft Excel. The mean height and mean DBH per sample quadrat were calculated, and this calculation was repeated for the whole area. We also counted the number of forked and curved trees below 2 m (*tables 1–2*).

Table 1. Descriptive statistics of beech stands in sample areas

Sample plot	**Measured tree [No]**	**Mean DBH [cm]**	**Measured mean height [m]**	**Forked below 2 m [No; %]**	**Curved below 2 m [No; %]**
S1	19	14.62	16.89	7; 36.8	10; 52.6
S2	20	9.71	13.30	9; 45.0	12; 60.0
S3	14	12.66	12.85	10; 71.4	6; 42.8
S4	5	11.01	8.40	4; 80.0	3; 60.0
S5	8	13.81	9.00	4; 50.0	5; 62.5
S6	15	12.77	8.93	11; 73.3	7; 46.7
S7	15	12.51	8.80	11; 73.3	10; 66.7
Per plots	95	12.43	11.94	56; 58.9	53; 55.8
Per compartment	5,605	12.43	11.94	3,304; 58.9	3,127; 55.8

Table 2. Descriptive statistics of beech stands in control areas

Sample plot	**Measured tree [No]**	**Mean DBH [cm]**	**Measured mean height [m]**	**Forked below 2 m [No; %]**	**Curved below 2 m [No; %]**
C1	20	13.94	16.53	1; 5.0	0
C2	17	11.89	15.62	0	1; 5.9
C3	20	14.51	18.25	1; 5.0	0
C4	21	15.40	17.57	1; 4.7	0
C5	12	18.13	20.42	0	0
C6	12	20.31	20.96	1; 8.3	0
C7	13	15.85	17.92	0	0
Per plots	115	15.32	17.91	4; 3.5	1; 0.9
Per compartment	10,284	15.32	17.91	358; 3.5	89; 0.9

In the sample forest plot, 1,557 – of which 1,357 beech – trees per hectare were estimated, while in the control area 1,771 was the total number of trees per hectare, out of which 1,643 were beeches. There was also a difference in mean tree height and DBH between the two forest compartments (*Table 3*, *Fig. 4*).

Table 3. T-test results of DBH and measured height comparisons between sample and control area

Variable	Mean sample	Mean control	t-value	df	p
DBH [cm]	12,43568	15,32191	-3,5151	208	0,000540
Measured height [m]	11,93684	17,91000	-10,3053	208	0,000000

For the DBH, lower averages were observed in the sample (wildlife-damaged) area, with a significant difference ($p < 0.001$). A similar significant difference was observed for heights, the mean height in the damaged area being almost 6 meters lower than in the control area ($p < 0.001$).

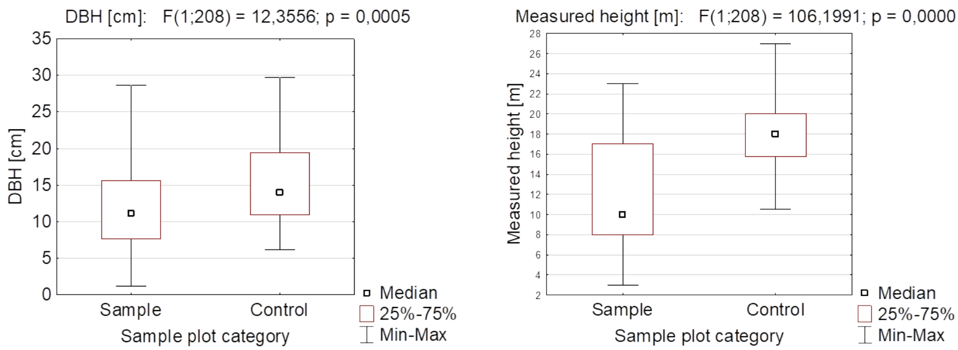

Figure 4. Boxplot by sample plot category for DBH and measured heights

Our results suggest that the browsing damage caused by large herbivores has a stronger impact on the increase in height than on the evolution of diameter at breast height.

The number of forked trees below 2 m differed significantly between the two forest plots ($\chi^2 = 78.43$, df = 1; $p < 0.001$). In the sample plot, 58.95% of the trees were forked compared to 3.48% in the control plot. In the sample area, 55.79% of the trees showed a curvature below 2 m. However, this shape defect occurred with a frequency of only 0.9% in the control area. This difference between the sample plot categories was also significant ($\chi 2 = 82.15$, df = 1; $p < 0.001$).

4. Conclusions

Our study suggests that prolonged, repeated annual browsing has a negative effect on tree growth. Due to the effect over several years, some trees develop into "bonsai" trees with denser foliage on the lateral branches [15]. A smaller effect is assumed for the diameter at breast height. The damaged forest stand had a higher proportion of forked trees, which is probably a consequence of continuous browsing. Trunk defects resulting from browsing may also affect tree growth and survival [16].

The long-term impact of large herbivores' browsing depends on several factors. The most important factor is the time of browsing, but it also depends on the tree species, the growing site, and the intensity [12]. Čermák et al. (2009) found that an increase in the proportion of beech and a decrease in the proportion of species preferred over beech (e.g. maple, ash, rowan) resulted in the more intensive browsing of the latter, leading to disappearance from the stand species composition [8].

In our study, there was a difference in the number of trees per hectare between the two areas, which could also be caused by seedling mortality due to browsing. Harmer (2001) also investigated the regeneration of beech using simulated wildlife browsing treatments [17]. Wildlife browsing was simulated by clipping new shoots that were longer than 1 cm. The study showed that pruning significantly reduced seedling survival.

Results must be evaluated in the light of the fact that only two forest compartments were surveyed and that the damaged area was subject to significant and recurrent damage. The findings can be refined by increasing the number of surveyed trees and including areas with different levels of damage (in terms of timescale and intensity). The selection and designation of additional forest compartments as sample plots has started, and the surveys will be carried out in the following years, using the above-described method.

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