

Research article

FOREST REGENERATION AND TREE DAMAGE – HOW TO ASSESS THE IMPACT OF WILD UNGULATES?

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ABSTRACT

*Abundance of large game in Serbia is currently below the habitat's potential, mostly due to negative anthropogenic factors. For this reason, fenced hunting grounds, commonly established in forests, serve as important habitats for the management of wild ungulates. Fenced hunting grounds are usually run by profit-oriented state forest enterprises, where game management is based on economic carrying capacity, requiring higher population densities. Such practices directly affect forest management, due to more frequent tree damage caused by wild ungulates. In order to provide a sustainable solution which would be acceptable to both foresters and wildlife managers, it is necessary to accurately estimate the impact of game species on forest regeneration. In this study, we propose an innovative research design for the Republic of Serbia, which is based on the use of both traditional and novel methods. Research was conducted in the fenced hunting grounds "Plavna" and "Ristovača", both managed by the State enterprise "Vojvodinašume" during the period from autumn 2023 to summer 2024. In each hunting ground, two sample plots of the same size (9 x 9 m) were established next to each other, one fenced and one non-fenced, and monitored with trap cameras. In "Plavna", the sample plots were in a poplar regeneration area, where the main game species are Red Deer (*Cervus elaphus* L.) and Wild Boar (*Sus scrofa* L.), while in "Ristovača", the sample plots were located in an oak stand, where Fallow Deer (*Dama dama* L.) and Wild Boar are managed. Results indicate a significant difference between the number of seedlings and the extent of damage between fenced and non-fenced sample plots in both locations, as well as the presence of all three wild ungulate species recorded on trap cameras. However, game activities varied from browsing to passing by the sample plots. The obtained findings indicate the advantages of the applied methodology and provide useful information for estimating forest damage on large areas.*

Key words:

tree damage, Red Deer, Fallow Deer, sample plots, trap cameras, fenced hunting grounds

Citation:

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INTRODUCTION

Serbian forests serve as natural habitats for several wild ungulate species, which in these woodlands find both food and shelter. These species include Red Deer (*Cervus elaphus* L.), Roe Deer (*Capreolus capreolus* L.), Fallow Deer (*Dama dama* L.), Wild Boar (*Sus scrofa* L.), Chamois (*Rupicapra rupicapra* L.), and Mouflon (*Ovis aries musimon* Pallas). Among them, Fallow Deer and Mouflon are introduced species that have adapted to their new habitats, while the remaining four species are autochthonous in Serbia. Regardless of their origin, all species play a significant role in game management practices and contribute to hunting tourism. However, the presence of wild ungulates in forest ecosystems is often associated with various forms of forest damage, leading to conflicts with forestry (Arnold et al., 2018). Numerous studies across Europe have investigated Red Deer-related damage. Vospernik (2006) identified bark stripping by Red Deer as a major cause of forest degradation in Austria, while Cukor et al. (2019) examined the relationship between stem rot damage caused by Red Deer and spruce (*Picea abies* L.) stand infection in the Czech Republic. Their findings highlight that spruce is among the tree species most frequently debarked by ungulates in Central Europe. Broadleaf trees are also vulnerable to damage caused by Red Deer. For example, Tomljanović et al. (2022) monitored Red Deer bark stripping on narrow-leaved ash (*Fraxinus angustifolia* Vahl) in Croatia and found damage on almost every young tree in the stand. Researchers have also focused on other wild ungulates and their impact on forest ecosystems. Roe Deer, the most abundant and widely distributed wild ungulate in both the Republic of Serbia and Central Europe, browse young trees, potentially impeding future forest composition and species diversity (Boulanger et al., 2009; Kupferschmid et al., 2015; Schwegmann et al., 2023). Skoták et al. (2021) documented the negative effects of Wild Boar on tree plantations in the Czech Republic. Both species have been monitored in Serbia by Popović (2007), who identified food scarcity as the main driver of forest damage. Felton et al. (2022) reported that wild ungulates, including Fallow Deer, significantly influence plant abundance, vegetation dynamics, and the survival of various herbaceous, shrub, and tree species. While Mouflon and Chamois generally exert less impact on forests, due to their habitat preferences, studies suggest that they are not without effect. Kárpáti and Náhlík (2023) explored Mouflon space use and foraging strategies as potential causes of forest damage, including ground vegetation degradation through trampling. Fluri et al. (2023) found no correlation between Chamois population density and forest damage in the Swiss National Park. However, it is important to note that forest management practices and habitat characteristics in the Swiss National Park differ substantially from those in areas of Serbia inhabited by Chamois. Thus, it is likely that Chamois populations in Serbian hunting grounds are not associated with severe forest damage. Not all of the species mentioned above have the same impact on forests, nor do they occupy the same habitats; however, the presence of wild ungulates is usually associated with forest damage, which can manifest in various forms. Common damaging behaviors include bark stripping, browsing, antler fraying, and trampling, all of which can negatively affect tree vitality and ground vegetation (Vospernik, 2006). These impacts hinder forest regeneration processes and reduce forest productivity (Motta, 1996). According to Vacek et al. (2020), wildlife-induced damage is among the most significant biotic threats to forest ecosystems, particularly because wildlife is an integral part of these systems. Globally, the extent of forest damage has increased over recent decades (McDowell et al., 2020), coinciding with the growing abundance of wild ungulates across Europe (Felton et al., 2022; Schwegmann et al., 2023). This trend is likely to further intensify conflicts between forestry professionals and wildlife managers, undermining efforts to sustainably manage stable game populations within forest habitats. Forest coverage in the Republic of Serbia is steadily increasing. Results from the latest National Forest Inventory (Forest Administration, 2024), compared to the penultimate one (Banković et al., 2008), show an increase in forest coverage from 29% in 2008 to 39% at present. The expansion of forest coverage leads to greater overlap with hunting grounds, bringing forestry and game management practices into closer interaction. Meanwhile, the Republic of Serbia has a total of 364 hunting grounds, which cover, according to Lavadinović (2016), 88,280.44 km², or 99.86% of the entire territory. The first National Forest Inventory indicates that settlements cover approximately 4% of the Republic of Serbia (Banković et al., 2008), suggesting that the actual area under hunting grounds is slightly lower than the estimates made by Lavadinović (2016). Nevertheless, it is accepted that hunting grounds cover around 95% of the country (Lavadinović et al., 2017), which, alongside Austria, represents the highest ratio in Europe. Despite favorable national characteristics and high biodiversity potential, game abundance in the Republic of Serbia is still below its habitat capacity (Lavadinović, 2016), and lower compared to other European countries. For this reason, the Serbian hunting sector commonly uses fenced hunting grounds as a tool to protect the most valuable game species, such as wild ungulates. Fenced hunting grounds are usually managed by state forest enterprises such as “Srbijašume” and “Vojvodinašume,” and they have higher game population densities than non-fenced ones. Since fenced hunting grounds are commonly established in forests, they are more vulnerable to wildlife-induced forest damage compared to other hunting grounds.

Although the size of large game populations in the Republic of Serbia remains below the habitat's potential, their presence in forest ecosystems is still associated with a certain degree of damage, particularly in hunting grounds with higher population densities, such as fenced areas. In the future, European trends are expected to positively influence the growth of wild ungulate populations across Serbian hunting grounds. Such a scenario could lead to a greater extent of forest damage and to increased tensions between the forestry and the hunting sector in the Republic of Serbia. Therefore, this study aims to test innovative methodologies for monitoring forest damage in fenced hunting grounds and to propose potential solutions to current conflicts and future challenges. To that end, the study was conducted in two well-established fenced hunting grounds, selected due to their higher game densities, managed by the state enterprise "Vojvodinašume" in the northern Serbian province of Vojvodina.

MATERIAL AND METHODS

Study area

The research was conducted in two fenced hunting grounds, "Plavna" and "Ristovača", both managed by the Forest Estate "Novi Sad" of the State Enterprise "Vojvodinašume". The "Plavna" hunting ground is located near the village of the same name and belongs to the forest sub-estate also named "Plavna". It is situated 75 km west of Novi Sad, and approximately 160 km northwest of Belgrade, positioned on the border between the Republic of Serbia and Croatia, along the Danube River (Figure 1).

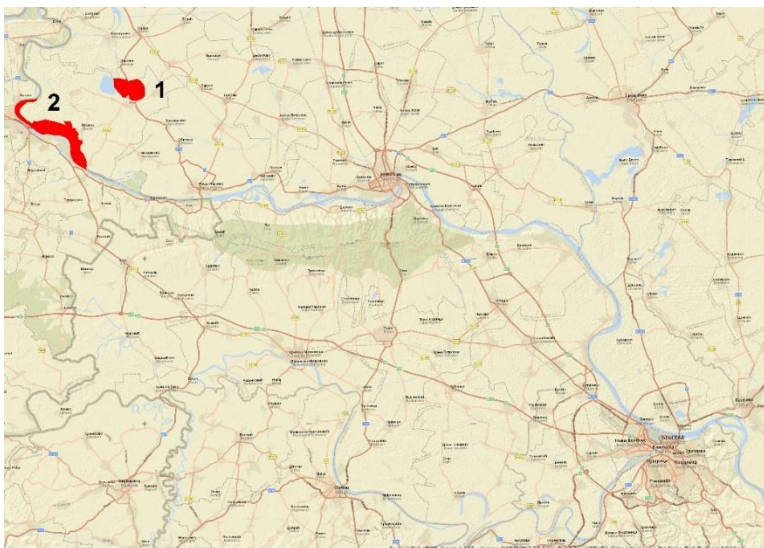


Figure 1. Location of the hunting grounds "Ristovača" (1) and "Plavna" (2) in relation to Novi Sad and Belgrade

The total area of the hunting ground is 3,629.29 ha, of which 630 ha is fenced. It lies at a low elevation, ranging between 80 and 87 meters above sea level. Three wild ungulate species are present in the fenced area, with Red Deer and Wild Boar being the primary management targets, while Roe Deer occurs naturally (Vojvodinašume, 2024a). The "Ristovača" hunting ground is located near the town of Bač, 12 km east of the previously mentioned hunting ground and about 70 km from Novi Sad. The total area of the hunting ground is 1,718.34 ha, of which 250 ha is fenced. The main game species within the fenced area is Fallow Deer (Vojvodinašume, 2024b), while Wild Boar and Roe Deer are also present (Table 1).

Table 1. Number of wild ungulate species managed in hunting grounds "Plavna" and "Ristovača" (Vojvodinašume, 2024a, 2024b)

| Game species | Plavna | Ristovača |
|--------------|------------|------------|
| Red Deer | 130 | - |
| Wild Boar | 200 | 128 |
| Fallow Deer | - | 156 |
| Roe Deer | 70 | 66 |
| Total | 400 | 350 |

Field methods

Forest damage was monitored on Euroamerican poplar and pedunculate oak. Data on the condition of Euroamerican poplar (*Populus × euramericana* (Dode) Guinier, cl. I-214) seedlings were collected from experimental plots within the fenced area of the “Plavna” hunting ground, while data on pedunculate oak (*Quercus robur* L.) seedlings were collected from experimental plots within the fenced area of the “Ristovača” hunting ground. Data collection focused on seedling vitality (condition) and height, in order to compare growth dynamics in relation to game damage under different conditions (fenced and open areas). Height measurements were taken using a measuring tape with an accuracy of 1.0 cm.

In each hunting ground, experimental plots were established on representative sites where forest regeneration was taking place. However, in the “Plavna” hunting ground, the sample plot was situated within a Euroamerican poplar stand established through afforestation, whereas in the “Ristovača” hunting ground, the sample plot was located within a naturally regenerated pedunculate oak stand. Both sample plots were established in accordance with the methodology proposed by Gubka et al. (2024). At each location, two adjacent plots (9 × 9 m) were set up: one was enclosed with a fence to exclude wild ungulates, while the other remained open and accessible to wildlife. This experimental design enabled comparison of vegetation condition and the extent of damage between the fenced (enclosed) and open plots at each site, providing an estimate of herbivore-induced damage across different locations (Figure 2). A trap camera was placed at each experimental plot to monitor wildlife activity. For this purpose, two SPromise S328 cameras with 12 MP resolution, a 58° field of view (FOV), and a detection range of 25 m were positioned on trees near the experimental plots to cover both adjacent plots. Although both cameras were installed on trees closest to the sample plots, their distances varied due to field conditions. In the “Ristovača” hunting ground, the trap camera was placed approximately 20 m from the sample plot, while in the “Plavna” hunting ground, it was about 30 m away. Data from the trap cameras were collected manually every two months and entered into an Excel spreadsheet. Remote data sampling was not possible due to the proximity of the state border and poor mobile network coverage.

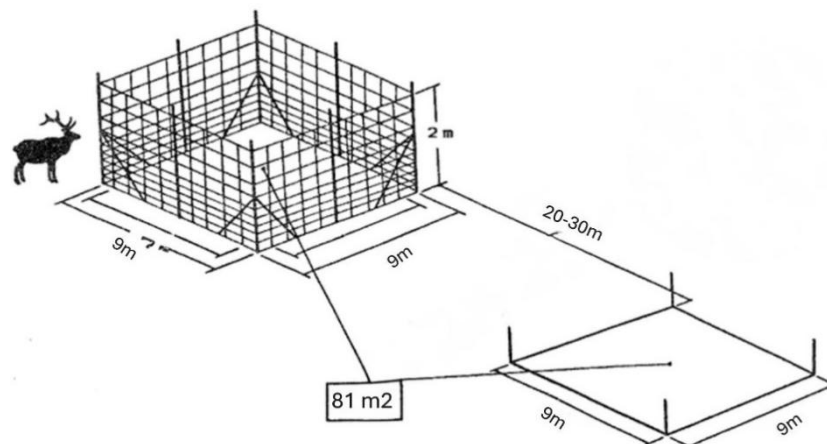


Figure 2. Layout of experimental plots placed in each hunting ground (Gubka et al., 2024)

Data processing was conducted using descriptive statistical analysis. Additionally, a comparative analysis of seedling development under different conditions (fenced and non-fenced areas) was performed using two-sample t-tests. The normality of all dependent variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests.

RESULTS AND DISCUSSION

Trap cameras in both hunting grounds recorded the presence of several game species, with higher species diversity observed in “Plavna”. This study did not detect any wild animals outside the game species listed in the official hunting ground management plans. Out of 1,747 photos taken in the “Plavna” hunting ground, 181 contained images of game species, meaning that only 10.36% of the total photos were used for further analysis. In “Ristovača”, from a total of 956 photos, 90 were suitable for analysis, which represents 9.41% of all images. At both sites, there was the high number of blank images (approximately 90% of the total). This proportion was nearly three times higher than that reported by Jacobs and Ausband (2018). Such high proportion of blank images was attributed to site-specific conditions, as the cameras monitoring seedlings were frequently triggered by wind, causing sensor activation. Additionally, the trap cameras were placed on trees and hidden behind branches to prevent detection and theft by

trespassers, which resulted in frequent activation due to branch movement in the wind. Although both hunting grounds are fenced and managed by professional gamekeepers from the State Enterprise “Vojvodinašume,” hiding cameras was necessary because of their close proximity to settlements. Vandalism and theft of camera traps commonly cause economic losses to researchers and pose a major threat to effective wildlife monitoring (Meek et al. 2016). For this reason, a compromise had to be made between the rate of blank images and protecting the equipment. Among the pictures from “Plavna”, Wild Boar was the most frequently observed species (83%), followed by Red Deer (10%), Roe Deer (2%), and Brown Hare (2%). In 3% of the photos, it was not possible to identify the species. In “Ristovača”, Fallow Deer was the most represented species (78%), followed by Wild Boar (18%), Roe Deer (3%), and Brown Hare (1%). Neither of the two trap cameras recorded the presence of carnivores, particularly the Golden Jackal (*Canis aureus* L.), a species that poses a significant threat to herbivore populations in the Vojvodina region. Although fenced hunting grounds are intended to protect wild ungulates, they do not always prevent jackals from entering. The absence of jackals may be the result of responsible hunting management, which effectively controls predator abundance in both hunting areas. The average number of individuals per photo was approximately one (“Plavna” – 1.05; “Ristovača” – 1.3). No photo captured more than one species at the same time; instead, each image contained only a single game species, with one or more individuals present.

In the “Plavna” hunting ground, the trap camera did not capture any photos in March and April due to technical issues. Most photos there were taken in January and February. In contrast, in the “Ristovača” hunting ground, the highest number of photos was recorded in March and April (Table 2). Despite being out of operation for two months, the camera in “Plavna” still produced twice as many photos as the one in “Ristovača”.

Table 2. Distribution of photos from trap cameras in hunting grounds “Plavna” and “Ristovača” by months

| Month | “Plavna” | | “Ristovača” | |
|--------------|------------|------------|-------------|------------|
| | N | % | N | % |
| January | 56 | 30.94 | 13 | 14.45 |
| February | 52 | 28.73 | 14 | 15.56 |
| March | - | - | 25 | 27.77 |
| April | - | - | 16 | 17.78 |
| May | 25 | 13.81 | 14 | 15.56 |
| June | 27 | 14.92 | 2 | 2.22 |
| July | 5 | 2.76 | 4 | 4.44 |
| August | 16 | 8.84 | 2 | 2.22 |
| Total | 181 | 100 | 90 | 100 |

All analyzed photos were categorized separately for each hunting ground into two categories: those showing game species individuals present inside the open sample plots, and those showing individuals outside the plots. The second group included animals at varying distances from the plots, engaged in different activities such as grazing, standing, or passing by. In “Plavna”, the trap camera recorded 181 photos showing game activity. Of these, only 9 photos (5%) captured individuals inside the open sample plot, while the remaining 172 photos (95%) documented animals outside the plot. In “Plavna”, the highest level of damage to the open sample plot was observed in January, although only about 1 in 10 photos taken during that month recorded such activity. In the following months, the presence of game species within the open sample plot decreased, while the proportion of “outside” photos increased. From June onward, no game activity inside the open sample plot was recorded (Table 3). However, all these findings should be interpreted with caution, as the trap camera was placed at the maximum operational distance from the sample plot due to site-specific conditions. As previously mentioned, the camera had to be concealed to prevent vandalism or theft (Meek et al., 2016), and there were no trees closer to the sample plot where it could be safely placed. Although our findings are considered reliable, it is possible that some detections of game activity at the sample plots were missed, which is a limitation also discussed by Jacobs and Ausband (2018). Data from “Ristovača” showed a noticeably different pattern. The number of game activity photos from “Ristovača” was half that of “Plavna” – a total of 90 photos. However, approximately one third of them (34 photos, or 38%) captured individuals inside the open sample plot. The highest number of browsing activities occurred in March, when almost three-quarters of the photos showed animals inside the open sample plot, compared to approximately one-quarter showing them outside. Additionally, during January, February, and April, game activity inside the open sample plot remained high, ranging from around 28% to nearly 44%. Due to technical issues with the trap camera in “Plavna,” it was not possible to compare the frequency of wild ungulate presence at experimental plots between the two hunting grounds, nor to fully analyze the frequency of wildlife activities per month in that hunting ground. Thus, it remains unknown whether the same pattern occurred in “Plavna” as in “Ristovača.” A common feature of both hunting grounds is the low number

of trap camera images documenting the presence of wild ungulates in the open sample plots. This is likely due to several factors. One possible explanation is the greater availability of food sources. The State Enterprise “Vojvodinašume” provides year-round supplemental feeding of wild ungulates in fenced hunting grounds, which meets their nutritional needs. In addition, both hunting grounds are located in forested areas that offer natural food sources. Another possibility is the mild winter without snow during the study. According to Náhlik et al. (2005), such conditions reduce the extent of browsing damage by deer, as animals have easier access to food. Finally, both sample plots were established in young forest stands with low seedling height. Renaud et al. (2003) found in their experiment that Red Deer prefer to browse at shoulder height, suggesting that other localities may have been more attractive to the animals.

Table 3. Game activities recorded on sample plots per months in hunting grounds “Plavna” and “Ristovača”

| Month | “Plavna” | | | | | | “Ristovača” | | | | | |
|----------------|-----------------|----------|------------------|----------|--------------|----------|-----------------|----------|------------------|----------|--------------|----------|
| | Inside the plot | | Outside the plot | | Total | | Inside the plot | | Outside the plot | | Total | |
| | N | % | N | % | N | % | N | % | N | % | N | % |
| January | 6 | 10.71 | 50 | 89.29 | 56 | 100 | 4 | 30.77 | 9 | 69.23 | 13 | 100 |
| February | 2 | 3.85 | 50 | 96.15 | 52 | 100 | 4 | 28.57 | 10 | 71.43 | 14 | 100 |
| March | - | - | - | - | - | - | 18 | 72.00 | 7 | 28.00 | 25 | 100 |
| April | - | - | - | - | - | - | 7 | 43.75 | 9 | 93.00 | 16 | 100 |
| May | 1 | 4.00 | 24 | 96.00 | 25 | 100 | 1 | 7.14 | 13 | 99.00 | 14 | 100 |
| June | 0 | 0.00 | 27 | 0.00 | 27 | 100 | 0 | 0.00 | 2 | 0.00 | 2 | 100 |
| July | 0 | 0.00 | 5 | 0.00 | 5 | 100 | 0 | 0.00 | 4 | 0.00 | 4 | 100 |
| August | 0 | 0.00 | 16 | 0.00 | 16 | 100 | 0 | 0.00 | 2 | 0.00 | 2 | 100 |
| Total | 9 | - | 172 | - | 181 | - | 34 | - | 56 | - | 90 | - |
| Average | 1.50 | - | 28.67 | - | 30.17 | - | 4.25 | - | 7.00 | - | 11.25 | - |

In the “Plavna” hunting ground, Red Deer was identified as the most common game species inside the open plot, appearing in 8 out of 9 photos. Wild Boar was recorded in only one photo within this area. Similar results were observed in the “Ristovača” hunting ground, where Fallow Deer was the most frequent species in 22 photos (65%), followed by Wild Boar in 10 photos (29%), and Roe Deer in 2 photos (6%). These results indicate that deer species were responsible for most of the damage within the open sample plots in both hunting grounds, which is consistent with other studies identifying deer species as a major cause of forest damage (Vospertnik, 2006; Cukor et al., 2019; Felton et al., 2022; Tomljanović et al., 2022).

According to trap camera data, game species in both hunting grounds were most active during the night. Two-thirds of all photos were taken at night – 66% in “Plavna” and 68% in “Ristovača”. Animals were less active during the day, accounting for 22% of photos in “Plavna” and 26% in “Ristovača”, while the least activity was recorded during periods of limited sunlight (sunrise and sunset), with 12% and 6% respectively. Such findings are in accordance with other authors (Georgii, 1981; Mattiello et al., 1997; Russo et al., 1997; Johann et al., 2020).

In the “Plavna” hunting ground, game damage was observed on 71.4% of Euro-American poplar seedlings in the open plot, whereas no damage was recorded in the fenced plot. Additionally, the number of seedlings in the open plot was 28.6% lower compared to the fenced area. A similar situation was found in the “Ristovača” hunting ground, where 84.8% of seedlings in the open plot showed damage, while the fenced plot remained undamaged. The number of seedlings in the open plot was 27.7% lower than that inside the fenced plot. Game damage in the Vojvodina region is regularly observed in non-fenced areas (Pap et al., 2015, 2018). For instance, during the winter–early spring period of 2015, in the Bački Monoštor forest administration area (specifically the Monoštorske šume, Karapandža locality), Red Deer gnawed and stripped bark from 6,023 trees in middle-aged poplar stands (9–15 years old), as well as in stands of narrow-leaved and American ash (10–70 years old) and other hardwood species (7–70 years old). Similar damage was also recorded in clonal poplar, willow, and white poplar plantations (1–2 years old), affecting 3,007 plants (Pap et al., 2015).

The average height of Euro-American poplar seedlings within the fenced plot in the “Plavna” hunting ground is 436.0 cm. This is 25.6% higher than the average height of seedlings growing in the open plot (347.0 cm). Similarly, in the “Ristovača” hunting ground, the average height of pedunculate oak seedlings inside the fenced plot is 103.7 cm, which is 34.7% higher than the average height of seedlings in the open plot of the experimental field (77.0 cm) (Table 4).

Table 4. Height of the analyzed seedlings in the research objects (cm)

| Management unit | "Plavna" | | "Ristovača" | |
|-----------------|---------------------|-----------------|-----------------|-----------------|
| Tree species | Euroamerican poplar | | Pedunculate oak | |
| Treatment | Fenced area | Non-fenced area | Fenced area | Non-fenced area |
| min | 390.0 | 189.0 | 32.0 | 29.0 |
| max | 510.0 | 410.0 | 175.0 | 141.0 |
| \bar{x} | 436.0 | 347.0 | 103.7 | 77.0 |
| $S_{\bar{x}}$ | 20.88 | 29.86 | 10.90 | 5.68 |
| cv (%) | 10.71 | 22.77 | 48.20 | 40.44 |

Using two-sample t-tests, it was determined that the average heights of seedlings inside the fenced plots at both experimental fields were statistically significantly greater than those of seedlings grown in the open plots (Figure 3). In the "Plavna" hunting ground, a statistically significant difference was found for Euro-American poplar seedlings at the $p < 0.05$ level ($p = 0.049276$; $t = 2.2367$). Similarly, in the "Ristovača" hunting ground, a statistically significant difference was observed for pedunculate oak seedlings at the $p < 0.05$ level ($p = 0.022747$; $t = 2.3518$). The positive impact of fencing on forest regeneration is particularly evident in the initial phase of seedling development, where the seedling height, diameter and relative growth rate serve as performance indicators (Pettersson et al., 2020; Barrere et al., 2021; Löf et al., 2021).

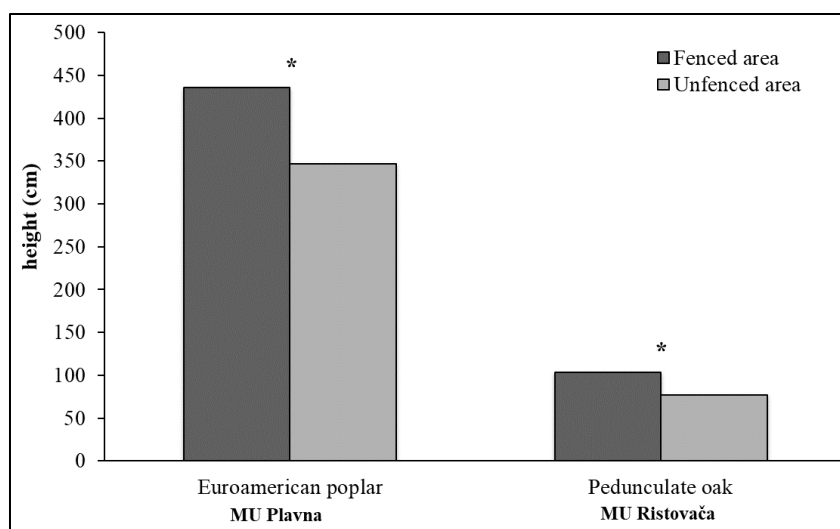


Figure 3. Average seedling heights in fenced and non-fenced areas (* statistically significant at the $p < 0.05$ level)









CONCLUSION

The findings of this study clearly demonstrate that fencing is an effective management measure for enhancing forest regeneration success, particularly in areas with high densities of large herbivores such as Red Deer and Fallow Deer. Protected plots exhibited greater seedling survival, vitality, and growth performance compared to non-fenced areas, underscoring the significance of physical exclusion as a silvicultural tool.

The use of trail cameras proved valuable for monitoring wildlife activity and assessing its influence on forest regeneration. However, several methodological constraints were identified, including suboptimal camera placement and technical limitations that affected data collection efficiency. Future studies should consider employing multiple cameras per site and optimizing camera positioning to ensure comprehensive coverage and improved data reliability. Overall, this research contributes to the growing body of evidence highlighting the importance of integrating adaptive management practices and remote monitoring techniques in sustainable forest and wildlife management.

Authors' Contribution: Conceptualization: V.L. and Z.P.; Methodology: K.B.; Software: D.B.; Validation: M.P.H., M.V. and C.K.; Formal Analysis: D.M.; Investigation: V.L.; Resources: V.L. Supervision: D.B.; Project Administration: V.L.; Funding Acquisition: D.M. All authors have read and agreed to the published version of the manuscript.

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