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# Columella

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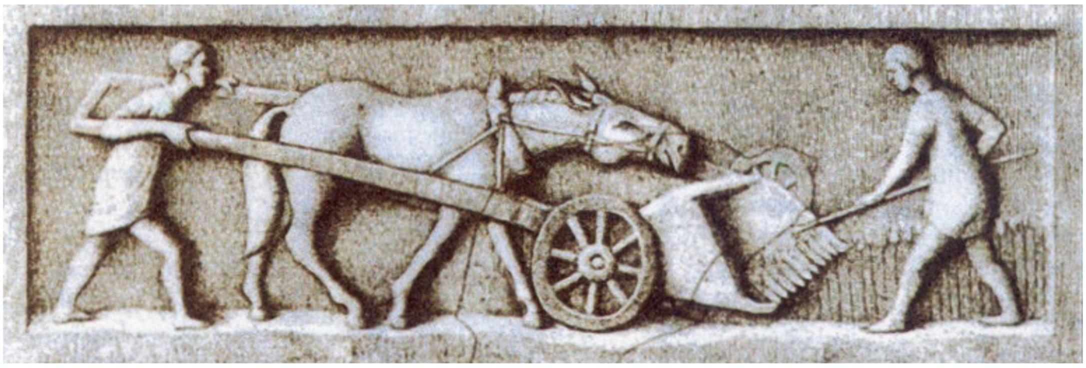

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# Habitat mapping and possibilities for evaluation on environmental management of Vésztő-Mágor Nature Reserve

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**Abstract:** Habitat mapping was carried out on Vésztő-Mágorpuszta Nature Reserve based on the Hungarian National Habitat Classification System. Habitat codes occurring within habitat patches and short description of each patch are given in parallel with a detailed species list (completed with dominance relations). Based on these, a habitat map of the area and habitat-based thematic maps of sodic areas influenced by water were prepared. The central part of the observed area is diverse and valuable from a botanical point of view, part of the area with complex patches is sodic, in between with sporadic lowland swards and some smaller lowland steppes. Possible reason for abandonment of management on these areas could be the influence of water. Rate of areas with higher dominance of weeds is small.

**Keywords**: habitat map, naturalness value, saline associations

Received 20 November 2019, Revised 25 November 2019, Accepted 5 December 2019

## Introduction

The mapping of Vésztő-Mágorpuszta nature conservation area was done in the frames of the Hungarian Biodiversity Monitoring Programme. The primary goal of the survey was the regional monitoring of the condition of the living world, the habitat-mapping of the area. We have also created a habitat-map-based thematic map about the area that was originally visited in order to be habitat-mapped. This work was done based on the data-samples collected in the area, in order to better record, emphasise and value the main characteristics.

## Materials and Methods

We completed the survey of Mágorpuszta. The field surveys included scouring the area many times in the whole vegetation period. While taking samples we followed the ideas to be found in the 2nd and 3rd chapter of Kovácsné Láng and Török (1997) IV. During the field work we used a basic M=1:25000 EOV map, where we marked the habitat-spots using ordinal numbers. Thanks to the mosaic structure of the area a given habitat-spot usually means the collective occurrence, the complex of more than one habitat. After we determined the GHHCS category/categories to each individual spot, we provided a detailed list of species – emphasising the protected and invasive species –, and we gave habitat-characterisations based on the condition and main characteristics of the habitat-spot.

Following the making of habitat-maps and the elaboration of the data in charts we created the habitat-maps using the ArcView GIS 3.1 software. The digitalisation and correction of the habitat-maps were assisted

*Table 1*. A general diagram about the methods of creating thematic maps

| Topics | Habitat-spots based on GHHCS categories |
|---|---|
| | **GHHCS** |
| **Areas affected by water** | **A** Euhydrophyte habitats |
| | **B** Marshes |
| **Expansion of saline areas** | **F** Halophytic habitats |
| **Saline habitat types** | |
| | **F1** *Artemisia* salt steppes |
| | **F2** Salt meadows |
| | **F3** Tall herb salt meadows |
| | **F4** Puccinellia swards |
| | **F5** Annual salt pioneer swards |
| **Characteristic habitats** | |
| | **D4** Lowland eu- and mesotrophic meadows |
| | **F** Halophytic habitats |
| | **H5** Closed loess and sand steppes |
| | **J4** Riverine willow-poplar woodlands |
| | **J5** Riverine ash-alder woodlands |
| | **J6** Riverine oak-elm-ash woodlands |
| | **K1** Lowland oak-hornbeam and closed sand steppe oak woodlands |
| | **S** Forestry plantations |
| | **T** Agricultural habitats |

by the EOV sections used as basic maps and aerial photos. During the field survey we digitally matched the characteristics of the spots to the spots, which later provided us with the possibility to value the area in different respects comprehensively. The colouring used by depicting the habitat-spots helps in easier distinction of the border-lines, but has no further informational value. The identification of the habitats is available by the ordinal numbers, since the great number of spots (178) makes a colour-based distinction impossible.

In order to make a more comprehensive valuation of the area we have also created some thematic maps of different positions using the maps of the habitat-spots. Considering the natural characteristics of Mágorpuszta we depicted the following characteristics on the maps: areas affected by water, expansion of saline areas, saline habitat types, and characteristic habitats.

By creating the thematic maps we used the habitat-patch-maps as basic maps, and we picked the habitat-spots according to different topics, based on the GHHCS categories of the spots (*Table 1*).

While valuing the surveyed area we concentrated on the distribution of characteris-


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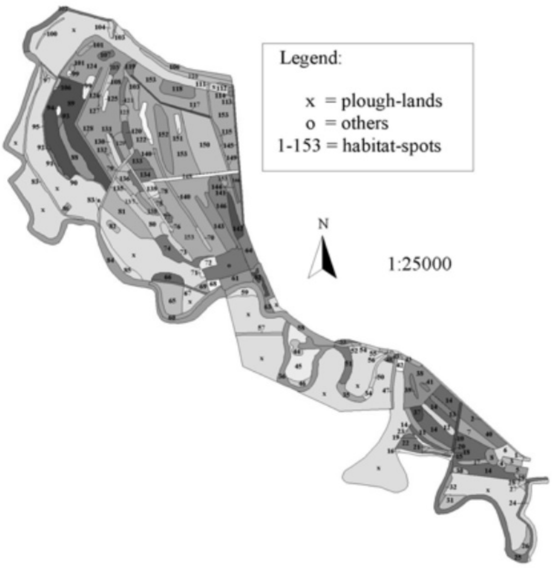


*Figure 1*. Habitat-map of Vésztő-Mágorpuszta

tic habitats, the expansion of the saline areas and the occurrence of their types according to the finished maps. Apart from the maps we have also finished diagrams for the valuation. For the general valuation and characterisation of the habitats of Mágorpuszta the maps and the diagrams provide the methods.

## Results and Discussion

During the mapping of Mágorpuszta we distinguished 178 spots (*Figure 1*). The map consisting of 178 spots includes 153

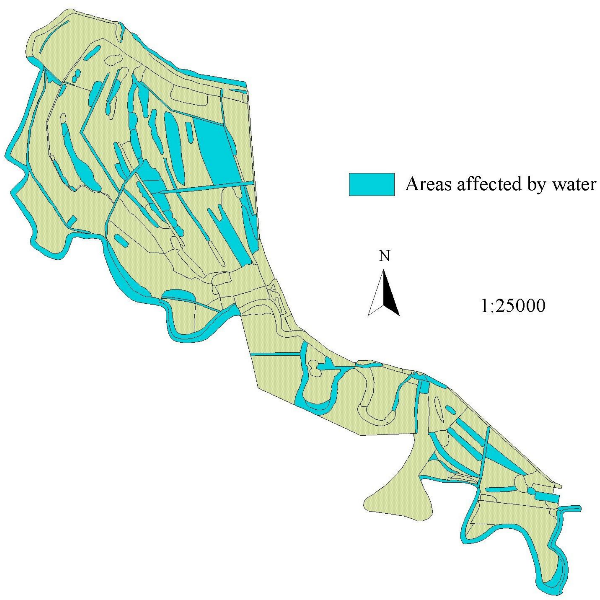


*Figure 2*: Areas affected by water in Vésztő-Mágorpuszta

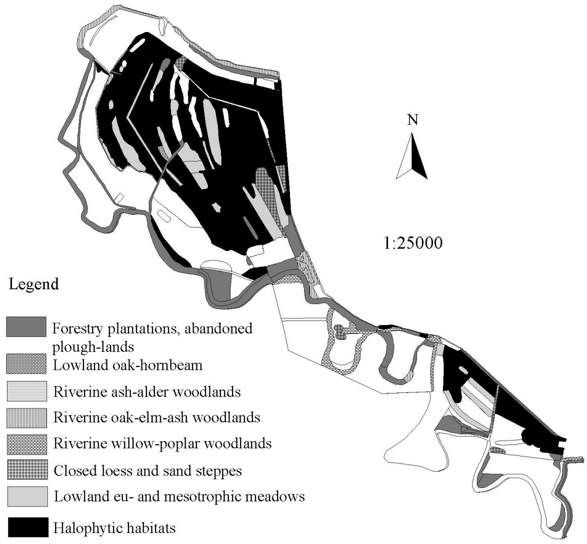


*Figure 4*: Characteristic habitats of Vésztő-Mágorpuszta

numbered habitat-spots. Based on the characteristics added to each spot it can be seen, that more than one GHHCS categories belong to a spot in most cases. Bordering the habitat-spots according to the GHHCS categories was not possible due to the great complexity of the area. From the separation and characterisation of the spots we can deduce information about the appearing, physiognomic and state-of-naturalness condition of the vegetation. The size and expansion of the habitat-spots can be said to be mosaic-like, made up of lots of small spots. The greater areas at the bottom boundaries of the key-formed area (W, SW parts) are mostly agricultural areas. The complexes made up of salty pastures and meadow de-

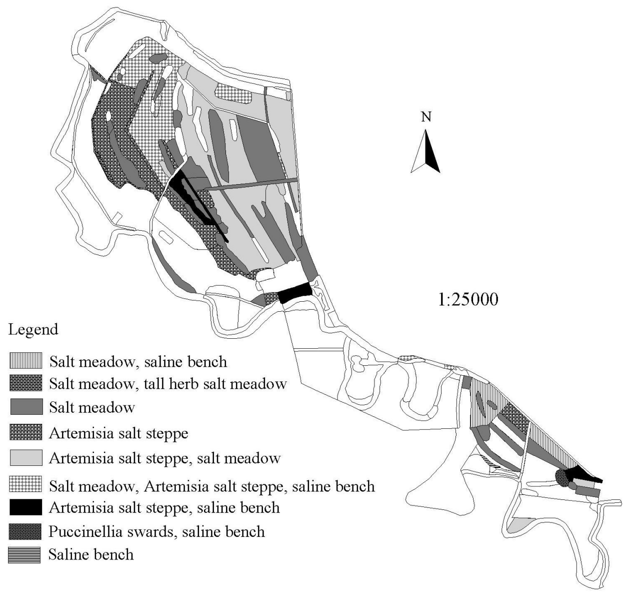


*Figure 3*: Halophytic habitat types of Vésztő-Mágorpuszta


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terminated by *Alopecurus* are significant in greater spots too.

According to *Figure 2*, it can be said that in three-quarter of the area those habitats are characteristic, that admit water effects of some form. Such areas are the woodlands near the canals, the lowland eu- and mesotrophic meadows, the euhydrophyte habitats, marshes and the wallows in the deeper parts of the halophytic habitats. It can also be noted, that abandoned plough-lands appear in greater numbers in areas affected by water, thus it can be concluded that the water was the reason of the ceasing of agriculture in those areas.

The types of halophytic habitats can be considered characteristic habitats of Mágorpuszta (*Figure 3*). These habitats can be found in 75% of this area. Among the halophytic habitats the complexes of *Artemisia* salt steppes and salt meadows are most common. In more than one habitat-spot the salt meadow type appears constantly. The triple complex of *Artemisia* salt steppes, salt meadows and saline bench is characteristic for 25% of the saline spots. The saline bench appear in more parts of the area, sometimes in the complexes of salt meadows or *Artemisia* salt steppes. The tall herb salt meadows and the saline bench of the halophytic habitat types rarely appear in independent spots, they are usually separated in complexes with other types.

The characteristic habitats of Mágorpuszta are shown on *Figure 4*. According to that the followings are to be pointed out: three-quarter of the area (the middle part) is saline. Between the saline areas some scattered lowland eu- and mesotrophic meadows can also be found, and a few small closed loess and salt steppes have also been formed. Along the Holt-Sebes Körös, that marks the boundary of the area run a number of forestry plantations, riverine oak-elm-ash, and willow-poplar woodlands. The riverine willow-poplar woodlands often appear together with forestry plantations (e.g. hybrid poplar, black-locust plantations), rows of trees and shrubberies. Alder-grove and lowland oak-hornbeam is significant only in spots. We can find many abandoned orchards, plough-lands in the surveyed area that are settled in cases by semi-natural sward, but the settlement of thick brush-woods, and/or black locust can also be characteristic. In some mosaic-like spots weedy lowland grass can also appear.

## Conclusions

On the basis of the habitat-mappings in Vésztő-Mágorpuszta nature conservation area the following can be stated: the area can be well characterised thanks to the finished habitat-map and the habitat-map-based thematic maps, and these results can be used in later researches in connection with this area. Dependences of effects upon a causes can be revealed based on the characteristics of the habitat-maps of the area, the lists of species, and the GHHCS classifications. With the finishing of the habitat-map the first recording of conditions in the frames of the HBMS has been done, and thus the present state has been recorded. It is definitely desirable to follow the conditions and the changes of the area with attention. It is especially important, since this is the only way to see if the changes point towards naturalness or degradation, and the decisions that can diminish or stop the unfavourable conditions can only be made if the changes are observed. In conclusion, the present results mean starting points and guidelines towards the long-term goal, the preservation of biodiversity.

## Acknowledgements

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# Investigations on the wastewater of a flow-through fish farming system

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**Abstract:** European and Hungarian fish consumption has been increasing for years. Intensive fish production is one potential methods to meet the ever-increasing demand of Hungarian consumers. However, for the sustainable growth of production, it is necessary to tackle one of the important problems of this type of fish production: reducing the nutrient content of the effluent water. Wetland can be a perfect application to solve the problem. In this research, we examine the efficiency of wastewater treatment in a fish farm where the effluent feeds the Szarvas-Békésszentandrás oxbow system. The current theoretical nutrient retention capacity of the wetland—based on literary data—is 53–61% for nitrogen (N), 76–84% for phosphorus (P) and 80–91% for chemical oxygen demand (COD). In recent years, the production capacity of the plant has increased to 500 T/year and a new pre-settling and drum filter were added to the filtration, and thus the deterrent effect of the filtration system in 2014–2017 was 74% for "N", 63% for phosphorus and 83% for COD. The efficiency of the wetland was demonstrated by measurements carried out by an accredited independent laboratory proving that no limit value has been exceeded for the last 15 times. We can conclude that the wetland is able to carry out its tasks in the long term, independently of the season, and to ensure that effluent water does not pose a significant impact to the natural environment.

**Keywords**: intensive fish culture, wetland, wastewater

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## Introduction

Some changes have been observed in the World's fish production for decades. The growing demand for fish consumption is increasingly less met by stagnant catches of natural water fishing, so this will only be fulfilled by growing aquaculture. Today, almost half of the fish consumed come from fish farms. Under Hungarian domestic conditions, this claim is even more true. Pond fish production and precision fish farms in Hungary are responsible for almost 80% of the fish on the plate. Noteworthy, fish consumption in the country is still low, although growing steadily. In order to meet the growing demand for a fish from a healthy, controlled environment, it is necessary to expand the production (Mahal 2018). The development can either be made by increasing the area of the current extensive farms (meaning considerable cost and labour input) or the production could be intensified. The latter can be a solution to growing production, but—as opposed to extensive farming—it leaves a significant ecological risk. The three main areas with the highest risks are a significant part of the feed used being from an unsustainable source, high energy consumption and, finally, the wastewater of the intensive system placing a strain on the environment. In this research, we are dealing with this latter problem.

Although the outlet water of an intensive fish farm typically does not contain toxic substances, a significant load of ammonium, nitrate, phosphorus, high organic matter and suspended solids, resulting from fish metabolism products and unconsumed nutrients, can pose a biological risk (van Rijn 1996). In a basic environment, ammonium ion can become poisonous for many organisms, while nitrate can directly be uptaken by plants and thus accelerates eutrophication if available in high quantities. Plants can only uptake phosphorus in a reactive form, therefore a significant proportion of this element is deposited in sludge (Ördög, 2000). The high content of organic and suspended materials contributes to the formation of deep soft mud and the development of anaerobic conditions (Primavera 2006). The latter is not only directly dangerous by killing living creatures in the pond bottom but also activates the phosphorus deposited in the sludge, which becomes available to plants and bacteria, thus accelerating the eutrophication process (Ördög 2000). The described processes are particularly beneficial for cyanobacteria, which, in a large mass, cause algae bloom. It makes not only off-flavour in fish and water, but also turn pH and oxygen to extreme values, which finally leads to the disappearance of sensitive species, opening the spreading of invasive species (Oberemm et al. 1999, Havens, 2008). Inadequately treated outlet water also has a detrimental effect on local wildlife and makes the proper management of the wetland fed by the fish farm wastewater impossible. Thus, wastewater treatment is a crucial point of modern, sustainable fish farming. Numerous solutions exist to solve the problem, but multi-species wetlands can provide an economical option. These semi-natural communities help to transform the organic and inorganic substances of the outlet water into a form of organic materials (Zhang et al. 2011), easily transformable to woody biomass (e.g., willow coppice), to herbaceous biomass (e.g., reed, sedge or tangle), to floating algae or, through the food chain, even to marketable fish meat (Vymazal, 2010).

The framework for long-term, sustainable use of natural resources is set by official regulations, which of course also bind fish farmers. The water licence for fish management facilities shall include the parameters and their threshold limits of the outlet water, which must be regularly sampled and examined by an accredited laboratory (27/2005. (XII. 6.) KvVM regulation). The results of these official analyses objectively illustrate the impact of the fish farm on its environment.

## Materials and Methods

The sample area is located in Szarvas. The targeted fish farm is a flow-through, African catfish producing plant that is one of the largest intensive fish farms in Hungary. Outlet water is driven to Szarvas-Kákafok Holt-Körös through a multi-pond wetland system that includes three stabilising ponds, a fish pond and a pond with water plants which filter out the most important nutrients. Wetland was developed in the framework of the SUSTAINAQUA project. The researchers carried out preliminary studies using several plants and fish species, and subsequently proposed the development of a five-pond water purification wetland. According to preliminary calculations, this system is able to remove the following substances on a daily basis (*Table 1*).

*Table 1.* Absorption of the wetland owned by Szarvas-Kft kg/day (based on Gál et. al 2009) (VSS=Volatile Suspended Solid)

| Water temperature range | N removal | P removal | VSS |
|---|---|---|---|
| 10–15 °C | 35.5 | 4.3 | 233.7 |
| 15–20 °C | 68.5 | 4.4 | 224.1 |
| 20–25 °C | 88.9 | 9 | 451.9 |

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Previous tests revealed that the wetland fulfilled its role; a significant amount of organic and inorganic materials from the outlet water of the fish farm was removed (Gál et al., 2009, Gál et al., 2003, Kerepeczki et al., 2003), and meanwhile, it produced economic value through biomass production. In the experimental system, 89.4–94.4% of the Total-N, 69.6–91.2% of Total-P, and 68.7–89% of COD was removed by the biologi-

*Table 2* Some parameters of the outlet water (threshold limit: maximum value determined by the

| Date | pH | COD (mg/l) | BOD (mg/l) | $NH_4$-N (mg/l) | Total inorganic-N (mg/l) | Total N (mg/l) | Total-P (mg/l) | TSS (mg/l) |
|---|---|---|---|---|---|---|---|---|
| 24/02/2014 | 7.5 | *75.8* | 8.1 | *15.8* | 15.8 | *16.9* | 2.6 | 8.0 |
| 30/03/2014 | 8.1 | 45.0 | 5.6 | *8.1* | 8.7 | 8.9 | 1.5 | 2.0 |
| 13/05/2014 | 7.9 | 36.0 | 4.6 | 4.4 | 4.6 | 10.8 | 1.5 | 16.3 |
| 05/08/2014 | 7.9 | 46.0 | 9.3 | 4.9 | 5.0 | 9.8 | 1.8 | 16.0 |
| 04/11/2014 | 7.9 | 38.0 | 5.6 | 4.5 | 4.7 | 5.2 | 1.5 | 4.0 |
| 24/02/2015 | 8.1 | 72.0 | 16.2 | 4.5 | 4.5 | 20.0 | 1.9 | 20.0 |
| 12/05/2015 | 7.9 | 69.0 | 22.0 | 4.9 | 4.9 | 18.7 | 1.9 | 44.4 |
| 11/08/2015 | 8.1 | 63.0 | 15.1 | 4.5 | 4.6 | 23.3 | 2.0 | 26.5 |
| 17/11/2015 | 8.0 | 48.0 | 4.0 | 4.6 | 4.6 | 23.9 | 2.0 | 10.7 |
| 23/02/2016 | 8.0 | 58.0 | 11.5 | 4.3 | 4.3 | 11.5 | 1.9 | 2.6 |
| 10/05/2016 | 8.2 | 66.0 | 11.5 | 4.3 | 4.6 | 9.1 | 1.6 | 16.0 |
| 30/08/2016 | 8.0 | 52.0 | 11.5 | 4.0 | 4.1 | 8.5 | 2.0 | 8.3 |
| 22/11/2016 | 7.9 | 55.0 | 16.5 | 4.4 | 4.5 | 14.5 | 1.9 | 24.7 |
| 03/04/2017 | 7.8 | 66.0 | 14.2 | 4.8 | 4.9 | 8.9 | 1.2 | 13.0 |
| 09/05/2017 | 7.9 | 62.0 | 8.6 | 4.9 | 4.9 | 9.9 | 1.9 | 7.4 |
| 22/08/2017 | 7.8 | 48.0 | 4.5 | 4.6 | 4.6 | 8.9 | 1.8 | 17.0 |
| 21/11/2017 | 7.9 | 46.0 | 17.9 | 4.9 | 4.9 | 8.3 | 1.5 | 6.2 |
| Average | 7.9 | 55.6 | 11.0 | 5.4 | 5.5 | 12.8 | 1.8 | 14.3 |
| SD | 0.2 | 12.0 | 5.4 | 2.8 | 2.8 | 5.7 | 0.3 | 10.6 |
| Minimum | 7.5 | 36.0 | 4.0 | 4.0 | 4.1 | 5.2 | 1.2 | 2.0 |
| Maximum | 8.2 | 75.8 | 22.0 | 15.8 | 15.8 | 23.9 | 2.6 | 44.4 |
| Threshold limit | 6.5-9 | 75.0 | 25.0 | 5.0 | 25.0 | 30.0 | 2.0 | 50.0 |

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cal filtration system. In the case of the final operating-size wetland, retention of N 53%–61%, P 76–84%, COD 80–91% was expected. Further results of the experiment included that the return of the investment costs of the wetland could be recovered in 2017.

In this research, the effectiveness of the wetland system built 11 years ago was examined by analysing the data from regular independent, accredited measurements in the framework of the self-monitoring plan. The measurement was made at the release point (where the wastewater enters the receiving water body). During four years (2014–2017), four measurements per year were made: in February, May, August and November. The analysed parameters were:

- pH
- chemical oxygen demand - COD (mg/l)
- biological oxygen demand - BOD (mg/l)
- ammonium nitrogen - NH4+-N (mg/l)
- Total inorganic N (mg/l)
- Total N (mg/l)
- P (mg/l)
- suspended solids (mg/l)

## Results

Measured parameters are described in *Table 2*. The results of the 17 measurements are not uniform. In the case of the first two measurements (February and March 2014), the filter unit was unable to lower the emissions below the required threshold. The exceedance of the limit value was barely 1% for COD values for the February measurement, but was 32% for P and 216% for NH4+-N. The reason for this was that, due to the increased production, a 100 μm drum filter unit was installed in the system in the second half of 2013. Although the effect of this intervention began to take affect at the beginning of 2014, the system fine-tuning was only completed in spring 2014. For the next measurement, only NH4+-N was exceeded (62%). In the next period, the wetland and drum filtration always completed the desired emission values.

## Discussion

The measured values clearly showed that the previous scientific work (Gál et al. 2009, Gál et al. 2003, Kerepeczki et al, 2003) assessed the ability to process wastewater under the given circumstances well. Moreover, after a minor technological change, the desired emission values can be ensured even with a more than 60% increase in fish production. On the basis of preliminary measurements, with a feed coefficient of 1.1 (i.e., 1.1 kg feed is necessary for the withdrawal of 1 kg of fish meat) and 500 tonnes of fish production per year, the annual COD content of the wastewater is 398 t, while it contains 37.3 t NH4+-N, 59.3 t total nitrogen, 5.8 t of total phosphorous and 228 t of TSS. The wetland filters a significant proportion of these substances (COD 83%, NH4-N 82%, total-N 74%, total-P 62%, TSS 92.4 t). Its filtering efficiency is the same as the calculations previously made by the authors. All these results, based on the measurements, are provided with no significant deviation on the effectiveness of filtration in different stages of the year.

Based on the above results, it can be concluded that a well-designed filter unit is able to provide sufficient filtration efficiency, with appropriate control and minor modifications. This means that in the case of sustainable feed and energy sources being available, domestic fish production can be intensified without significant damage to the environment. A further improvement could be the possibility that at least part of the wetlands would be designed to produce economic value in order to increase the profitability of fish farms.

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# The colonization of raccoon (*Procyon lotor* L. 1758) in Georgia – The beginning of the invasion?

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**Abstract:** Raccoons have been present in Georgia since the second half of the 20th century. Raccoons were introduced in most parts of the Soviet Union including Azerbaijan from where raccoons eventually found themselves on Georgian territory. Today rural residents are complaining about raccoon damage which is induced to their private property, crops, domestic animals and game birds.

Regardless of such active damages and frequent sightings of raccoons across Georgia, there are no scientific publications that document the presence of this species in the country. We collected pictures of raccoons that were taken primarily by camera traps set by photographers, researchers and wildlife enthusiasts in Georgia. In additions, the material was retrieved from various sources including social media like Facebook. We conclude that raccoons are not only present in Eastern Georgia but they are spreading towards the central Georgia. We conclude that there are breeding populations of raccoons close to the capital city of Tbilisi as well. According to the local residents, this species is causing tremendous damage both to their property and natural habitats. We thus recommend that in order to protect valuable habitats of Georgia, and resolve human-raccoon conflict monitoring and decreasing of raccoon populations must be set as a priority task of the wildlife conservation is Georgia. We also recommend to conduct further studies on raccoon population sizes which will give clearer picture of the damage degree done to the native species and to private property of local residents.

**Keywords**: Raccoon, Alien Invasive Species, distribution, Georgia

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## Introduction

Invasive Alien Species (AIS) around the globe are recognized as one of the greatest threats to native biodiversity (Louppe, 2019). Non-native species may cause disruption in local ecosystems not only by outcompeting native species, but also by modifying the habitat around them, either by their feeding behaviors or habitat use (Anderson et al. 2006.; Hayama et al. 2006). Alien species is a species introduced by humans outside its natural distribution areas. Only an alien species can be an invasive species (Convention on Biological Diversity, 1992). There are at least 81 different alien and invasive species that can be found in North-Europe alone (https://www.nobanis.org/fact-sheets/) among which is the raccoon (*Procyon lotor* L. 1758).

This meso-carnivore species is highly abundant and native to North and Central America. However, because of their high adaptability they are now found in most parts of Europe and in almost all kinds of environments including wooded areas, open and marshlands, near lakes, along streams and urbanized areas (Sanderson, 1987). Currently in most parts of Europe the raccoon populations are expanding and are causing concern among the local residents (Salgado, 2018). Raccoons are also found in distant parts of Asia like Japan where they have been present since the 1960s (Okabe, 2007). The species has been introduced to Europe and Asia for commercial purposes (like fur trade) and through pet trade (Louppe, 2019). However, it is frequent that after pet raccoons reach adulthood and become difficult to care after they are released into the wild. It also happens that the individuals escape by themselves from the houses or zoos, and are now forced to fend for themselves (Heltai et al. 2001).

The fact that raccoons are widely spread throughout the globe and are able to easily survive in a wide range of habitats, can be attributed to its generalist diet. Raccoons are capable of exploiting almost all available resources as a food source, including garbage and leftovers. Consequently, they are frequently found close to urban and suburban areas causing a strong conflict with local residents (Kays 2009). Raccoons are worrying for local farmers as well who claim that these species are causing damage to their crops and domestic animals (Beasley, 2008).

Its versatile diet also weakens the impact of potential competitors (Salgado, 2018). These medium sized carnivores which are very well adapted to urbanized areas increase connectivity between occupied natural habitats. Raccoons are also highly effective predators and are posing an especially great threat to insular ecosystems where they prey on native fauna species. In addition, they are known to be vectors of diseases like nematode-mediated pathogens and rabies (Arjo, 2005). These diseases are potentially transmitted to humans, domestic animals and/or other wildlife species causing serious, if not lethal consequences.

Introductions of raccoons in Europe began in the early 20th century. Raccoon introduction programs were taking place in Germany as early as in 1920s (Lutz, 1984). The raccoons were first released in Northern-Hesse, Germany in 1927 (Lutz, 1996), after which two pairs were released in 1934 (Müller-Using, 1959). Later, in 1935 few raccoons were also released in areas close to Berlin (Lutz, 1984). During the war time in 1939 – 1945, few tens of raccoons managed to escape fur farms near Berlin and established territories in the nearby areas. Over the course of 20 years of adapting to the European climatic and landscape conditions, the raccoon expanded its distribution area in all directions (Bartoszewicz, 2011). After the expansion of the German population, the species was first detected in France in 1934, in the Netherlands in 1960, in Austria in 1974, in Switzerland in 1976, and in Luxemburg in 1979. The presence of raccoon was also proven in Denmark, Belgium, Czech Republic, Poland (Kauhala, 1996), and only recently in Spain (Garcia et al. 2012) and Italy (Mori et al. 2015). In Hungary the first presences were proved at the late 1990s (Heltai et al. 2001) and the average hunting bag is between 1-3 specimens annually (www.ova.info.hu).

In Russia and Belorussia, raccoon was introduced in 1954 and 1958 with the purpose to increase hunting and economic profits. However, unlike in the western and central Europe, raccoon populations did not thrive in Eastern Europe as successfully (Czesnokov, 1989). It is interesting to note that there are certain claims that the raccoon was successful in surviving and expanding in Northern Caucasus and along Black sea coat (Bartoszewicz, 2011), however, there have not been any raccoon sightings documented in the western Georgia by hunters, researchers or agencies.

Despite many complaints of the local residents regarding raccoon damage, no scientific papers have been published regarding the presence, occurrence and the spreading of raccoons in Georgia. Due to increasing complaints by local communities, we had a reason to believe that the raccoon was not only present in Georgia but they are ex-


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panding towards the Central Georgia. Camera traps allowed us to observe the areas where raccoons would potentially be present. The main purpose of our study was to prepare the distribution map of raccoons in Georgia.

## Materials and Methods

Since there are no official scientific publications regarding the presence of raccoons in Georgia, we collected data from various other sources, like social media, forums and contacting either National research agencies or National parks. The photo evidences were produced by camera traps established in specific areas by researchers and wildlife enthusiasts as well as by hunters and amateur photographers who frequently pass through the area.

Social Media like Facebook offered the fastest and most effective way to reach out and gather the data from different professionals. Social media offered a very good insight in local residents' attitude regarding the presence of raccoons in their region. The intensity of damage done by raccoons was also described in detail by the local residents on social media.

In the end, data was gathered from Lagodekhi Protected areas, LEPL National Nursery, Tsiv-Gombori Mountain range, Mamkoda, and Gldani villages near to the Tbilisi National Park, Alazani valley, Shuamta Mountains, Telavi city, Gurjaani town, and finally from Iori plateau. Most of the visual evidences came from Kakheti County, however, few photos have been taken in Lower Kartli County.

## Results

### *Lagodekhi Protected areas (Kakheti County)*

Lagodekhi protected area is a combination of two protected areas is the Kakheti County of Georgia: Lagodekhi Strict Nature Reserve and Lagodekhi Managed Nature Reserve. The total area of the two is 24,451 hectares. The reserves are located in the north-eastern Georgia bordering Azerbaijan and Dagestan.

The presence of raccoon was documented on official Lagodekhi Protected area Facebook page. We contacted the Lagodekhi National park administration and were provided with pictures that came from camera traps. The administration also provided some additional information regarding raccoon damage and public attitude towards these species which turn to be highly negative. However, that information cannot be backed up with any official statistics.

*Data from Lagodekhi National Park*

The following pictures (*Figure 1.*) were retrieved from Lagodekhi protected area Facebook page, and from Lagodekhi National Park administration.

### *LEPL National Nursery (Lower Kartli county)*

9 Camera traps (RECONYX ULTRAFIRE) were placed in the national breeding farm LEPL National Nursery in Lower Kartli county in Georgia (*Figure 2.*). The territory of LEPL National Nursery is stretched out on 105 hectares and is located on Gombori-Telavi highway. The closest populated area to the National Nursery is a small village of Sartichala with a little over 7000 residents.

LEPL National Nursery breeds flora species that are listed in the Georgian red list. These species are hop-hornbeam (*Ostrya spp*), Mt. Atlas mastic tree (*Pistacia atlantica*), Zelkova species, English Yew (*Taxus baccata*), *Buxus sempervirens*, chestnut (*Castanea spp*), sour Cherry (*Prunus cerasus*) as well as oak species. However, the farm is also involved in breeding small game species such as red-necked Pheasant (*Phasianus colchicus*) and rock partridge (*Alectoris graeca*). The farm has also an artificial lake which holds different fish species, among which are rainbow trout (*Oncorhynchus*

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*Figure 1:* Picture a (Top-left) show two young raccoons which indicates that there is a breeding population of *P. lotor* in Lagodekhi Park. The picture was taken by the ranger in Lagodekhi National Park. Picture b (Top-right) was captured by one of the camera traps in Lagodekhi in August 2012. Picture c (Bottom) was taken by a local hunter close to the protected area.


*Figure 2*: The tracks were seen on 9 April 2019 on the territory of LEPL National Nursery. The photos from the camera traps were taken in August 2019


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*Figure 3*. The camera trap captured this individual on 3 August 2018. The camera trap was stationed in Tsiv-gombori Mountain range in Kakheti County. According to the owner of the camera trap, this particular camera was stationed only few kilometers away from the Ikhalto monastery.

*mykiss*) and catfish species. These species and habitats present ideal circumstances for raccoon to feed and breed.

***Tsiv-gombori Mountain (Kakheti County)***

Tsiv-gombori range is connected to Caucasus Mountain System in Kakheti County. It is a watershed of the two rivers – Alazani and Iori. The area is characterized by relatively humid climate, with subalpine meadows, grazing pastures as well as deciduous forests (*Figure 3*.).


*Figure 4*: The raccoon was seen twice near the Tbilisi National Park; ones near Village Mamkoda and ones near Gldani village.

***Tbilisi National Park (Lower Kartli County)***

Tbilisi National Park is located north of the Capital city of Tbilisi and holds the area of 243 square kilometers (*Figure 4*.). It is a valuable habitat as it hosts many endemic and "Red List" species. Among them: the red squirrel (*Sciurus vulgaris*), field mouse (*Mus macedonicus*), the black rat (*Rattus rattus*), East European hedgehog (*Erinaceus concolor*), Caucasian mole (*Talpa caucasica*), Imperial eagle (*Aquila heliaca*), spotted eagle (*Clanga clanga*).

When it comes to flora species, Tbilisi National Park is a habitat to boxwood (*Buxus colchica*), yew (*Taxus baccata*), a bare elm (*Ulmus glabra*), a small elm (*Ulmus glabra*), walnut (*Juglans regia*), Pontus oak (*Quercus pontic*a) all of which are listed on


*Figure 5:* Racoons in the Alazani Valley were frequently encountered close to the water body, suggesting high preference to wetland habitats.

the “Red List” (https://apa.gov.ge/en/biomravalferovneba/tbilisis-erovnuli-parkis-biomravalferovneba).

***Data from Alazani Valley***

The Alazani valley stretches for about 160 kilometers (*Figure 5*.). It is a relatively humid area with plains covered by forests. The forests comprise of species of oak, ash, maple and poplar. The valley is surrounded by large populated areas like Gurjaani, Lagodekhi and Telavi.

***Data from Telavi***

Telavi is the main city and administrative center of Georgia's eastern County of Kakheti. Its population consists of little more than 19,000 inhabitants. The city is located on the foothills of the Tsiv-Gombori Mountain Range quite close to the forest. Rac-


*Figure 6*. Raccoons have been observed in the forests and close to the city of Telavi.


*Figure 7*. Raccoon observed in Shuamta Mountain. This female individual was seen with three kits. This suggests that there are breeding populations of raccoons in the mountainous areas.


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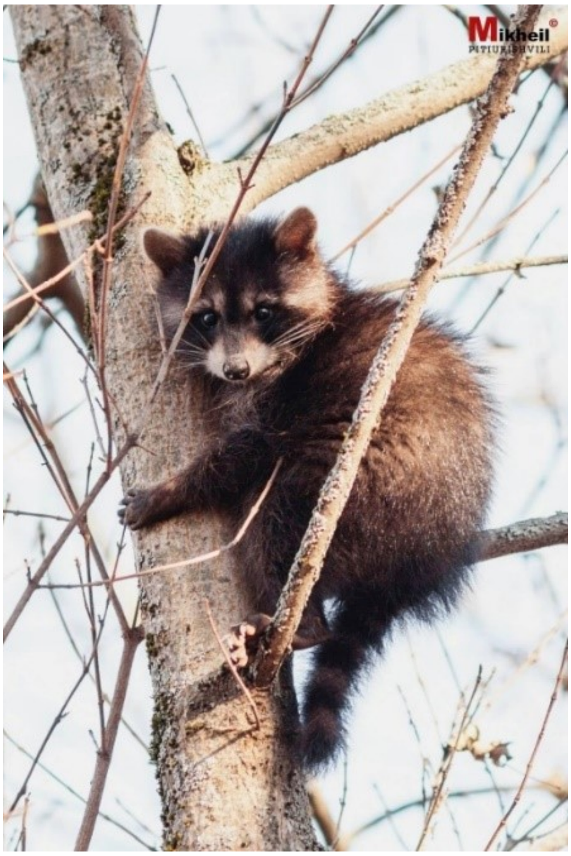

*Figure 8:* The photo was provided by a wildlife photographer from Gurjaani region.

*Figure 9:* The roadkill was founded close to river Iori. The location was marked with the exact coordinates recorded as 41.83990 45.13414. This individual was sighted about 50 kilometers away from the Capital City Tbilisi.

coons are frequently observed very close to the city of Telavi (*Figure 6*.).

***Data from Gurjaani***

Gurjaani is a town in Kakheti County, a region in eastern Georgia. It is located in the Alazani River Plain, at an elevation of 415 m above sea level. It is an urbanized area with the population of little more than 8000 residents. According to the locals raccoons are a frequent sight in the town (*Figure 8*.).

***Overall sightings of Raccoons in Georgia***

The map below shows all of the locations where the presence of raccoons were captured by camera traps or by photographers (*Figures 10-11*.).

**Discussion**

In the second half of the 20th century with the purpose of enriching biodiversity, Georgia saw the introduction of many different mammal species. Raccoon was exceptionally successful in adapting to Zaqatala region in Azerbaijan. About 120 individuals were introduced to Azerbaijan forests in 1991, also with the purpose of enriching biodiversity of the region. (www.cabi.org/isc/datasheet/67856#D93AA386-C32B-4244-A1D8-D3DDAF773579). There were no direct releases of the raccoon individuals in Georgia, so it is likely that *P. lotor* spread in Georgia from a neighboring region. The non-native species were released in few locations within the former Soviet Union countries. It is most likely that Zaqatala region in Azerbaijan is from where the raccoon found itself in Georgia, and dispersed along Alazani valley and Iori Plateau (http://www.eiec.gov.ge/).

Given the fact that there was only one source population outside the eastern border of Georgia, it is most likely for the species to have spread from the eastern border towards the central part of the country. Moreover, the earliest picture taken by the camera trap is from the year 2012 from Lagodekhi Protected area indicating that the species were first present in Lagodekhi Protec-

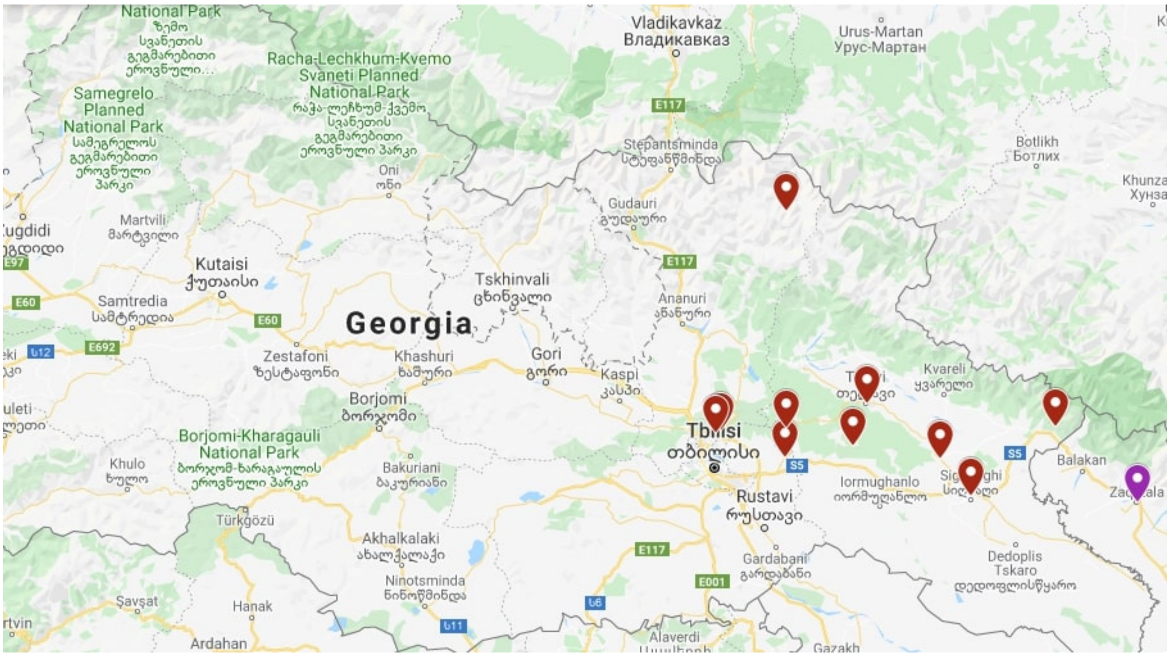


*Figure 10*. Raccoon sightings in Georgia are marked in red. The purple marker points out Zaqatala city of Azerbaijan – the most likely area from where raccoons dispersed in Georgia.

ted area before other sightings would take place anywhere else in the country. Although the official data is scarce, according to the frequency of sightings and intensity of locals' complaints regarding raccoon damage, it can be stated that one of the largest

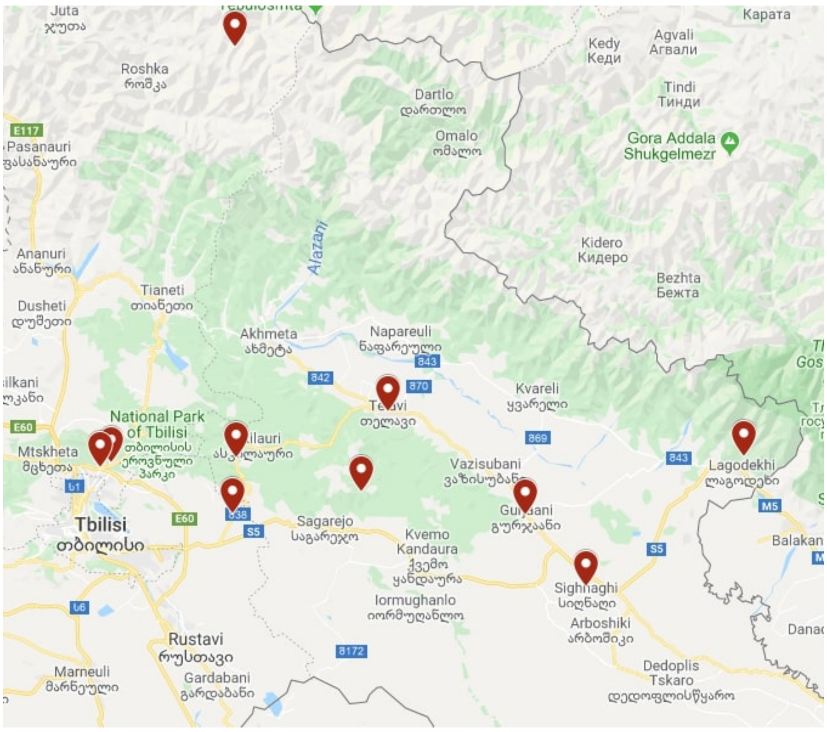


*Figure 11*. Locations from east to west. Lagodekhi National Park, Alazani Valley, Gurjaani, Telavi, Tsic-Gombori Mountain range, Shuamta Mountain range, Iori plateau, LEPL National Nursery, Village Mamkoda, Village Gldani.

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and strongest populations are found in Lagodekhi Protected area and nearby settlements.

The climate in the eastern Georgia –where the raccoon was first seen – is quite different from the climatic regions in the central Georgia where the raccoon is currently spreading. A study done by Louppe et al. (2019) predicted that by the year 2050 favorable areas are more likely to expand in the northern regions while also maintaining current favorable spaces. Such expansion is attributed to the effects of climate change, namely the temperature rise. Raccoons residing in Lagodekhi region is a known fact to locals as well as to independent researchers and institutions, however more and more individuals are being observed in the central and northern parts of the country. This spread could be due to effects of climate change as well as due to the high adaptability of the species. Today, stable and in some areas increasing population of raccoon can be observed in Lagodekhi, Kakheti forests and even in regions close to Tbilisi National Park. According to the camera trap that captured a female raccoon with a nursery suggests that the species managed to adapt to and establish a breading population in the high mountainous areas in Georgia such as Shuamta Mountain range.

The purpose of this study was to show that raccoons have established a strong breeding population in the eastern parts of Georgia and are spreading towards the central regions. Being an alien invasive species, raccoon has a potential to pose risk to many of the endemic species through its feeding and preying behavior (Anderson et al. 2006; Hayama et al. 2006). Georgia has a rich biodiversity and is recognized as one of the biodiversity hotspots as it is a habitat to many of the endemic species (https://www.conservation.org/). Allowing alien invasive species to adapt and have breeding populations is quite risky to the native species as they are generally easily outcompeted (Louppe et al. 2019).

According to the local residents, the raccoon is widespread in eastern Georgian areas like Alazani river valley, Iori Plateau, and on the Shiraki Plains. Like raccoon dog, raccoon managed to establish a wide range population and can cause massive damage to game bird populations such as grey partridge (*Perdix perdix*), rock partridge (*Alectoris graeca*), quail (*Coturnix coturnix*) and pheasant (*Phasianus colchicus*). However, no recorded data is available regarding the damage caused by raccoons in these areas. According to Louppe et al. (2019) raccoons are predicted to expand northward from their currently favored areas by 2050. Consequently it is likely to see more damage done by raccoons in following years unless a management or control action put in place.

***Management approaches***

Raccoon is an alien invasive species in Europe which is inflicting tremendous damage to native species. From the nature conservation point of view, this species is undesirable outside their natural range and management actions should focus on eliminating raccoons from the local ecosystems. The important aspect to consider is that the eradication programs of raccoon should start as early as possible, until the population density is still low and not well adapted to the new region. The goal should be to reach complete eradication as raccoon is not a native species in Europe and poses danger to native fauna species. However, raccoons are able to adapt to new environments rather fast, thus eliminating the species fast may prove quite challenging.

Eradication of raccoon in Europe is not a common practice. Raccoon was an important game species in countries like Germany where the yearly hunting bag would reach over 20 000 individuals. Although, the only successful raccoon trapping that was reported has been done around fenced areas near nesting sites of Great Bustard inside the protected areas close to Berlin, Germany (Bartoszewicz 2011). At this state, *P. lotor* has become a well-established species in Europe and complete eradication of the species from its non-native range with legal methods becomes rather questionable. Moreover, areas that are currently raccoon free but which are suitable for the species (such as low land forests and partly forested wetlands) should be expected to be colonized first of all due to raccoons' generalist behavior and secondly due to climate change.

Trapping raccoons could be an effective control method. Hunting with dogs and trapping are methods actively used in North America as well. It has been reported that raccoon control outside the breeding season is most effective, because that is the time when raccoons are most visible. Such control strategy showed a positive effect on seabird and their habitat conservation both on regional and local levels (Harfenist et al. 2000).

The spreading and impact of the alien and invasive species is one of the biggest problems in the field of wildlife management and conservation (Louppe et al. 2019). A massive presence of the medium-sized carnivores can significantly change the species community due to its preying behavior (Anderson et al. 2006; Hayama et al. 2006). The well known risk of IAS species are usually higher when the IAS species is a generalist predator. For the protection of valuable habitats of Georgia, monitoring and decreasing of raccoon populations must be set as a priority task of the wildlife conservation in Georgia. We also recommend to conduct further studies on raccoon population sizes either through counts or bag recordings. This in turn will show a clearer picture of the damage degree done to the native species and to private property of local residents.

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# Health status analysis of Norway spruce and shrubby pine along an elevation gradient

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**Abstract:** The results of numerous climatic models predict a significant increase in temperature, which coupled with other factors could affect mountain species distribution and community composition. In addition, it can accelerate an upward shift of alpine treelines. However the number of field measurements focusing on the health status of dominant trees in temperate mountains are limited. Our measurements were carried out in the Stuhleck Mountains along an elevation gradient from 850 to 1750 metres. Health status analysis of *Picea abies* and *Pinus mugo* have been completed by using FAKOPP 3D acoustic tomography, which is able to detect the size and location of decayed regions in the trunk non-destructively. For modelling the relationship between the decay of tree and other factors simple linear regression models were used. The results showed that the individuals of *Picea abies* and *Pinus mugo* had the worst health status in the lowest and uppermost range of the taxa in the studied area. It could be a sign of the upward shift of their range. Positive significant correlation was found between the decay and the ratio of whole trunk/healthy wood both in case of *Picea abies* and *Pinus mugo*. It seems, that acoustic tomography measurements are adequate to indicate non-destructively the altitudinal optimum and upward shift of different taxa.

**Keywords**: altitude, transect, acoustic tomography, decay, *Picea abies, Pinus mugo*

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## Introduction

The rate of increasing temperature in mountain systems is projected to be two to three times higher in this century than that recorded during the 20th century (Nogués-Bravo et al. 2007). In addition, there is growing evidence that the rate of warming is amplified with elevation, such that high-mountain environments experience more rapid changes in temperature than environments at lower elevations. Elevation-dependent warming can accelerate the rate of change in mountain ecosystems (Pepin et al. 2015).

In light of these projections, warming is considered likely to affect ecosystem services and biodiversity (Máliš et al. 2016). The latter can be expressed through species extinctions and changes in the composition of associations (Nogués-Bravo et al. 2007).

The growing season has lengthened an average of 2.7 days every decade since 1951 (Defila & Clot 2005; OcCC 2008), and longer growing seasons enable plants to grow at higher elevations (Lenoir et al. 2008). Climatic warming is expected to induce an upward shift in species and forest distribution in parallel with alpine tree line (Vittoz et al. 2013, Bussotti et al. 2015, Máliš et al. 2016). The latter is because regeneration and growth of trees there are limited by low temperature (Liang et al. 2016).

An instrumental analysis focusing on the health status of different-aged *Quercus petraea* stands in the Carpathian Basin showed, that sessile oak stands located in a subatlantic area were the healthiest (Trenyik et al. 2019). The most severely deteriorated

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stands occur in the continental region where the value in the 60 years old age group reached 4.24%.

The aim of the study was to determine the state of health of *Picea abies* in the mountain, and *Pinus mugo* in the subalpine belt in a typical Eastern Alps mountain. Another goal was the compare the health status of the measured layers in both species in the light of the possible elevation shift.

## Materials and Methods

The examinations were carried out in the Stuhleck Mountain, in the Eastern Alps along a vertical transect from 850 m to 1750 m above sea level in 2019. Among the dominant species of the given vegetation belt 3-3 tree individuals were measured in every 5 (between 1705-1750 m), 10 (between 850-1000 m) or 50 (1000-1700 m) meters. The sampling design based on the evaluation of preliminary results, using a 50 m masl (meters above sea level) sampling frequency, and conducted in 2018. In the montane belt (850-1700 m) the Norway spruce (*Picea abies*), while in the narrow subalpine belt (1700-1750 m) the shrubby pine (*Pinus mugo*) were investigated with an acoustic tomography. The measurements were completed in different layers from the soil respecting the various physiognomy of the species (0.4, 0.8, 1.2 m for *P. abies* and 0.2, 0.4 m for *P. mugo* respectively).

Measurements were made using the FAKOPP 3D acoustic tomography, which is able to detect the size and location of decayed or hollow regions in the trunk non-destructively (Trenyik et al. 2017), and calculate the ratio of whole trunk and healthy wood. This non-destructive mobile instrument is suitable for determining the extent of rotting. Parallel to the fibers the propagation speed of sound can reach 4000 to 5000 m/s; it is 15 times faster than in the air. FAKOPP has been developed based on this considerable difference as well as on the fact that propagation speed of sound waves is in strong correlation with the mechanical characteristics of wood substance (Divós and Divós 2005). This advanced method of examination measures the propagation speed of sound within the tree. The basic measurement principle is that sound velocity drops if there is a hole between two sensors. The existence of deterioration and cavities are mapped by identifying the change of propagation speed (Divós et al. 2005, 2007). FAKOPP is generally used in case of park trees in order to examine the health status of one specimen (Trenyik et al. 2019).

### *Statisitical analysis*

Data input and processing was carried out in Microsoft Excel 365 online version and for professional statistical computing it was used R programming language and environment version 3.6.1. (R Core Team 2019). For editing of the R scripts during the statistical analyses, it was used Tinn-R code editor (Faria et al. 2013) together with RStudio integrated development environment (R Studio Team 2015). For advanced statistical graphs, it was used the additional packages „ggplot2" (Wickham 2016).

For modelling the relationship between the decay of tree (*expressed by percentage*) and some other factors – wall thickness (ratio of whole trunk and healthy wood), high of measurement and metres above sea level – it was used simple linear regression models (Faraway 2005), where decay of tree was used as continuous dependent variable and the other factors as continuous explanatory variables. During the regression analysis the best-fitting curve was obtained by the method of ordinary last squares (OLS). Coefficient of determination (R2) was used for measurement of how close the data are to fitted regression line. However, in case of graphical representation of results we were using local regression models, the curve fitting was carried out with help of locally estimated scatterplot smoothing (LOESS)

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with 95% interval confidence (CI) of the regression line. Smoothing method was chosen based on the size of the largest group and smoothing parameter (α) was 0.8, which means the loess curve incorporate 80% of the total data points (Jacoby 2000).

One-way analysis of variance (ANOVA) type I (sequential) sum of squared was used (Zar 1984) in case of the modelling the relationship between decay of trees and the metres above sea level (MASL), where MASL was used as categorical explanatory variable. To detect the difference among factor level means after ANOVA, Fisher's least significant difference (LSD) test with Bonferroni correction (Mendiburu 2019) and Dunnett-Tukey-Kramer pair-wise multiple comparison test (Lau 2013) was used also at significance level 0.05. Calculating the factor level means (with 95% confidence intervals – CI) were carried out with help of „treatment contrasts" which was also used to determine the difference among factor level means (Pekár and Brabec 2016). In this case the lowest MASL factor level value was used as control group.

After analysis all statistical models were checked. For testing the normality of data, it was used Cramer-von Mises test and Anderson-Darling test at significance level 0.05 from the "nortest" package (Gross and Ligges 2015). For testing the heteroscedasticity (also at significance level 0.05) it was used Breusch-Pagan test from package "lmtest" (Zeileis and Hothorn 2002) and Fligner-Killeen Test of Homogeneity of Variance. D'Agostino's K-squared test was used for testing the skewness and Anscombe-Glynn test was used for testing the kurtosis from the "moments" package (Komsta and Novomestky 2015). To detect outliers in data it was used Grubb's test from "outliers" package (Komsta 2011) and Cook's distance. Durbin-Watson test from "lmtest" package (Zeileis and Horthorn 2002) was used for measuring of autocorrelation in the residuals from regression analysis. The assumption checking of all selected statistical models was also repeated with help of different diagnostic plots.

**Results**

There is no significant linear relationship between the decay and elevation of Norway spruce individuals (F1,250 = 0.005, r2 < 0.001, p = 0.94), however, a clear trend appears (*Figure 1.*). Nevertheless, due to the LOESS curve it can be concluded that the decay showed a continuous decrease from 850 to 1350 m, then the rate of deterioration increased significantly from 1350 to 1750 m. At higher elevations a statistically significant increase of the decay occurred of *Picea abies* stand from 1650 to 1700 m. The Anova also showed statistically significant difference between the decay of tree and metres above sea level ($F_{27,224} = 6.18$, $p < 0.001$). The largest difference of was found between elevation of the 850 m and 1700 m (Fisher's LSD-test: $p < 0.001$, Tukey's HSD test: $p < 0.001$). The highest average deterioration considering all examined layers were detected at the uppermost occurrence (1700 m) of *Picea abies* stand (averagely extent of deterioration is almost 39% (95% CI [31.8, 46.0])). On the other hand, the lowest average deterioration was recorded at 1200 m (0.7% (95% CI [0, 7.73]), 1350 m (0.44% (95% CI [0, 7.50]) and 1400 m (0% (95% CI [0, 7.05]) altitudes dominated by Norway spruce (Fig1).

In the case of *Pinus mugo* a significant correlation was found between the decay and elevation based on linear regression model ($F_{1,46} = 24.56$, $r^2 = 0.35$, $p < 0.001$) and Anova ($F_{7,40} = 6.51$, $p < 0.001$) analyses (Fig2). The decay slightly decreased from 1700 to 1715 m masl, then continuously increased up to the timberline. The differences were most pronounced between 1705 and 1710 m (Fisher's LSD-test: $p < 0.001$, Tukey's HSD test: $p < 0.001$) and 1705 m and 1745/1750 m (Fisher's LSD-test: $p < 0.001$, Tukey's HSD test: $p <$

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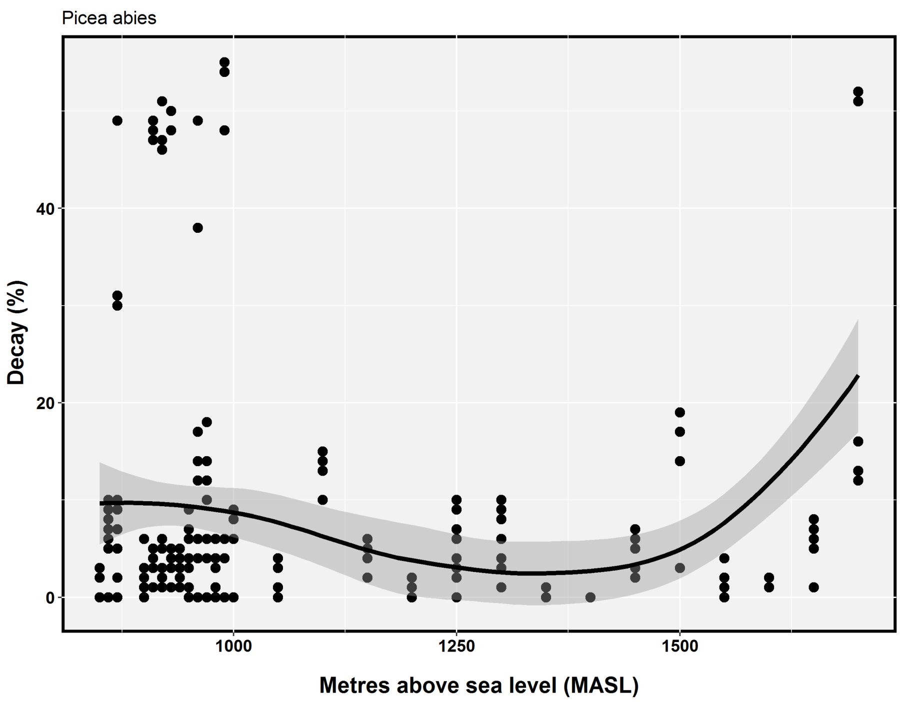


*Figure 1*. Spatial changes of the decay of *Picea abies* along an elevation gradient.

0.001). The highest deterioration (averagely 79% (95% CI [67.8, 90.9])) was found in case of 1745/1750 m of altitude, and the lowest deterioration (averagely 79% (95% CI [67.8, 90.9])) in case of 1710 m of altitude. The highest rate of deterioration and the highest average deterioration considering the two sampled layers were detected at the upper limit of the tree line (1745/1750 m), which is overlap with the uppermost

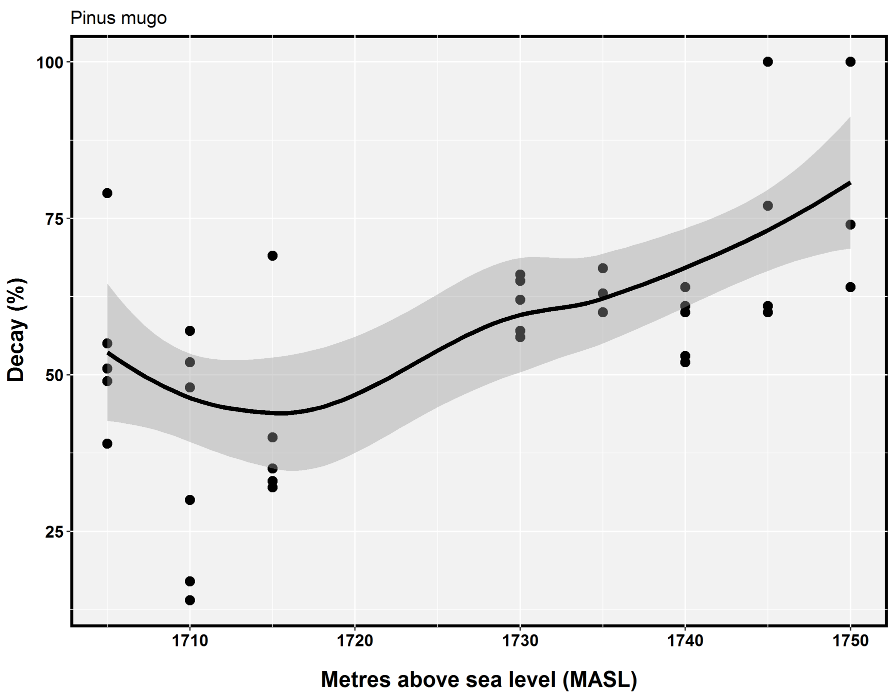


*Figure 2*. Spatial changes of the decay of *Pinus mugo* along an elevation gradient.


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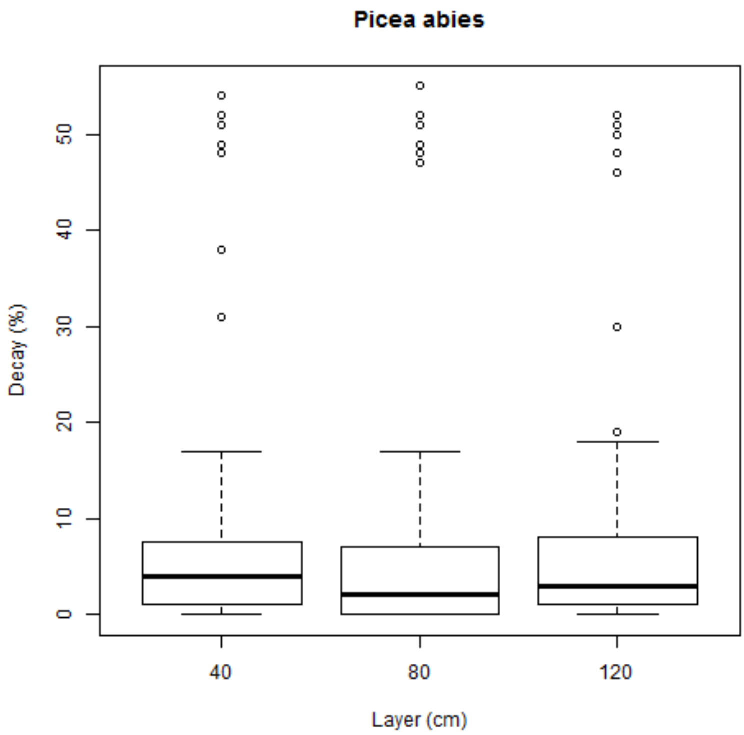


*Figure 3*. Comparison of the wood decay among different layers in Norway spruce stands.

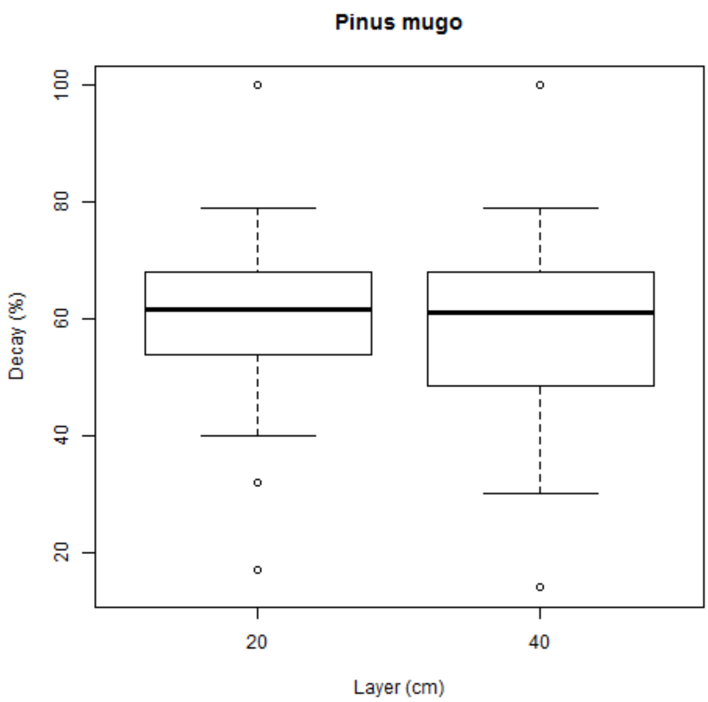


*Figure 4*. Comparison of the wood decay among different layers in shrubby pine stands.

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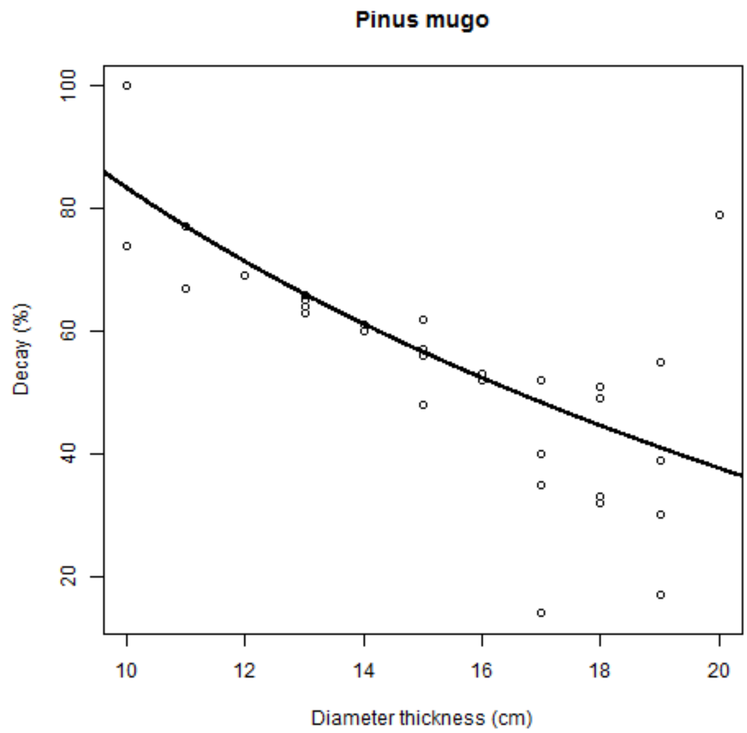


*Figure 5*. Correlation between the decay (expressed in percentage) and the wall thickness (ratio of whole trunk/ healthy wood) in case of *Pinus mugo*.

range of *Pinus mugo* (*Figure 2*.).

Statistical analyses did not show any significant difference among the different layers of *Picea abies* (*Figure 3*.; $F_{2,249} = 1.16$, $p = 0.85$) and *Pinus mugo* (*Figure 4*.; $F_{1,46} = 0.20$, $p = 0.66$). However, in both taxa the highest level of deterioration was found in the layer closest to the ground (*Picea abies*: 8.7% (95% CI [5.81, 11.60]), *Pinus mugo*: 62% (95% CI [53.8, 69.5]). Due to the results of linear regression analysis it can be conclude, that there are a middle stronger relationship between the decay and the wall thickness ratio of whole trunk/healthy wood only in case of *Pinus mugo* (*Figure 5*.; $F_{1,46} = 45.30$, $r^2 = 0.50$, $p < 0.001$).

## Discussion

The results showed that the individuals of *Picea abies* and *Pinus mugo* had the worst health status in the lowest and uppermost range of the taxa in the studied area. The higher deterioration rate observed in the lower limits of Norway spruce and shrubby pine stands could be a sign of the upward shift of their range. The latter is in harmony with Máliš et al. (2016) findings, that ongoing climate change shift tree species distribution. In addition, the higher rate of decay at the uppermost range of *Picea abies* and *Pinus mugo* may indicate, that upward shift of trees coupled with increasing stress and declining fitness. The greater absolute and average decay of *Pinus mugo* compared to *Picea abies* could be explained by the most severe environmental conditions.

The reverse bell curve shape pattern (Fig1) of the decay indicates, that the altitudinal optimum of Norway spruce is presently between 1200-1450 m masl in Stuhleck Mountain. From 1100 to 1450 m, the decay of *Picea abies* had similar values than different-aged *Quercus petraea* stands in the Carpathian Basin (Trenyik et al. 2017, 2019).


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The measured data correspond with the field observations of Lenoir et al. (2008) and Liang et al. (2016), as well as the model of Vittoz et al. (2013) and Bussotti et al. (2015) which predicts the future expansion of species and vegetation belts to the higher alpine zone due to climatic warming.

It seems, that acoustic tomography measurements are adequate to indicate non-destructively the altitudinal optimum and upward shift of different taxa.

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# Assessment of weed invasion at bait sites in the Mátra Landscape Protection Area

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**Abstract:** The effects of wild game feeding have been widely investigated, but little consideration has been given to it in Hungary. Feeding places for capturing and shooting wild boar (so-called bait sites) are spreading in some regions and they have a growing impact on vegetation. The aim of our study was to assess the extent of weed invasion in two different aspects. For this purpose, we selected two types of bait sites, located in forest and clearing areas, in the Mátra Landscape Protection Area. Four transects were arranged from the centre of the bait sites, each consisting of 22 1×1m quadrats, where vegetation surveys were carried out in May and August 2016, 2018. The results revealed a stress gradient along the transects: the proportion of weeds decreased further from the centre, while indigenous plant species increased. Bait sites in clearing areas were most invaded by weeds, possibly due to its greater accessibility. Here we detected a significant difference between plant communities as T4 weeds dominated in August. Conversely, bait sites in the forest were less weedy with similar vegetation states between the two surveys which had a sparse understory cover.

**Keywords**: wild game feeding, weed infection, habitat degradation, biological invasion

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## Introduction

Supplementary feeding and baiting of game wildlife is a widespread conservation and management practice in the world (Selva et al. 2014). It is particularly common throughout Europe and North America (Putman and Staines 2004; Inslerman et al. 2006; Apollonio et al. 2010; Arnold et al. 2018).

Most studies focus on animal populations and only a few of them deal with the effects on vegetation. Some research indicates that supplementary feeding impacts the local environment at feeding sites, modifies plant-herbivore interactions and the high browsing impact often causes locally reduced shoot growth (Ginnett et al. 2001; Smith et al. 2004; Heltai and Sonkoly 2009; Mathisen et al. 2015).

Study of the effects of supplementary feeding on the herbaceous layer are specifically neglected. A limited number of publications describe feeding places as focal points of exotic species invasion and they can induce severe habitat degradation (Kosowan and Yungwirth 1999; Spurrier and Drees 2000; Rinella et al. 2012).

In Hungary the importance of supplementary feeding is low due to the mild winters. However, feeding places for capturing and shooting wild boar (so-called bait sites) are spreading and they have a growing impact on surrounding vegetation. A bait site is a small clearing established approx. 30 to 50 metres from hunting blinds. Usually corncobs or corn seed is scattered at the sites, although agricultural and food industry by-products (e.g. fresh and dried beet slices, marc, molasses, bran or wheat middlings) are used in many cases. Currently regular feeding implemented year-round involves more than 30,000 feeding places; the total weight of nutritive mixes used exceeds 60,000 tons per year (Heltai and Sonkoly, 2009). Additionally, feed is generally scattered on the ground (Selva et al., 2014).

Taking into consideration that agricultural products – in particular cereals – contain weed seeds (Fay, 1990; Shimizu, 1998; van Barneveld, 1999; Shimono 2008; Wilson et al, 2016; Gervilla et al, 2019) it can lead to the invasion of noxious weed species in natural habitats. Furthermore, detrimental impacts are enhanced by anthropogenic activity due to feeding, increased game density, bare and degraded soil and increased availability of nutrients. This clearly indicates the potential dangers of frequent bait use and related placement of animal feed contaminated by weed seeds. Though, weed invasion typically extends to the intermediate environment of the bait sites (Rusvai 2018), valuable habitat patches can also be destroyed and bait sites may be the focal points of biological invasions. Strong evidence of this was found by a national survey according to which annual ragweed (*Ambrosia artemisiifolia*) was present in almost all of the nearly one hundred feeding places included in that study (Hirka and Csóka 2009).

The aim of our study was the spatial and temporal investigation of the effects of the bait sites on the herbaceous layer in the Mátra Landscape Protection Area. We examined two types of bait sites; three bait sites were in clearing areas and three bait sites in forests. Vegetation surveys were carried out in two parts, in May and August of 2016 and 2018. We hypothesized (i) a stress gradient along the transects where the proportion of weeds decreased from the centre of the bait sites, while the natural species increased. (ii) There would be differences between the weed invasion of bait types and (iii) we assumed a temporal difference in plant communities where there would be more weed species in August than in May.

## Materials and Methods

### *Study area*

The study was carried out in a typical Central European low mountain region, in the Mátra Landscape Protection Area. Mátra is part of the North Hungarian Mountain Range. The study sites belong to a submontane region. Depending on the altitude mean annual temperature vary between 6.0 and 8.0°C. Annual precipitation at the highest peaks and lower slopes is approx. 800 to 850 mm and 600 to 700 mm. Fast-flowing mountain streams can mainly be found at higher altitudes, while water shortage can be experienced in the southern slopes (Földváry, 1988; Bereczki et al., 2014).

*Table 1*. Species number and the proportion of the degradation indicator species on the bait sites (bait sites average in the examined aspects)

| | | 2016 | | 2018 | |
|---|---|---|---|---|---|
| | | No. of species | The proportion of degradation indicator species | No. of species | The proportion of degradation indicator species |
| C average | May | 57,7 | 28,1% | 64,0 | 34,1% |
| | August | 60,3 | 34,7% | 59,7 | 37,7% |
| F average | May | 43,3 | 19,7% | 34,7 | 21,5% |
| | August | 45,3 | 25,3% | 35,0 | 22,9% |

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*Table 2*. The most abundant degradation indicator species and their cumulative coverage on the bait sites

| 2018 | | Cumulative coverage of the degradation indicator species (%) | The 3 most abundant degradation indicator species and their cumulative coverage (%) | | |
|---|---|---|---|---|---|
| | | | 1. | 2. | 3. |
| C1 | May | 765 | Polavi (273) | Capbur (221) | Cynoff (87) |
| | August | 2603 | Xanspi (909) | Polavi (700) | Datstr (604) |
| C2 | May | 1645 | Capbur (599) | Broste (336) | Polavi (285) |
| | August | 2171 | Polavi (967) | Triino (603) | Xanspi (222) |
| C3 | May | 3896 | Broste (1350) | Polavi (1025) | Capbur (423) |
| | August | 2870 | Polavi (1334) | Broste (794) | Balnig (252) |
| F1 | May | 12 | Helann (5) | Ambart (5) | Galapa (1) |
| | August | 10 | Ambart (5) | Polavi (4) | Galapa (1) |
| F2 | May | 100 | Conarv (43) | Rumcri (26) | Polavi (15) |
| | August | 88 | Conarv (28) | Polavi (17) | Rumcri (16) |
| F3 | May | 94 | Rumcri (43) | Chealb (14) | Polavi (9) |
| | August | 92 | Chealb (20) | Rumcri (19) | Polavi (18) |

The examined area was located at lower elevation of the mountain, near Markaz that belongs to the oak forest belt. The forests are mainly semi-natural, dominated with mainly commercial forestry tree species and characterized by intensive wild game management. The majority of the area is part of the hunting grounds of Egererdő Zrt, while other hunting societies and communities undertake hunting and wildlife management tasks in the remaining forest. Main wild species are wild boar (*Sus scrofa*), mouflon (*Ovis aries*), European roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) (Katona et al., 2011).

***Field experiment***

We selected two types of bait sites, located in forest areas (F1, F2, F3) and in clearing areas (C1, C2, C3). Four transects were arranged from the centre of the bait sites, each consisting of 22 1 $m^2$ tangential quadrats, in which vegetation surveys were carried out with visual estimation of percentage cover.

The transects were directed in four directions with a relative angle of 90 degrees. The first direction was determined by a random number generator set between 0 and 360 degrees. In case a species was represented in a quadrat its value was at least 1%. Depending on the vegetation density abundance values may have exceeded 100%. Centres of the bait sites were determined by the actual placement of the feed station, clearly visible in each case.

The survey was carried out in May and August 2016 and 2018 with 3-3 repetitions per bait sites. Altogether, 88 (4×22) quadrats were set down and examined for each bait site. 528 and 1056 examination units were checked in one examination period and during the entire survey.

**Results**

A total of 175 plant species were surveyed in the study sites (6 bait sites, 2 months, 2 years) with more than a quarter (28,6%) of degradation indicator species according to the Borhidi ecological indicator value categories (Borhidi 1995). The proportion of degradation indicator species was always higher in the clearings than in the forest (ii), and in general it was higher in August than in May (iii) (*Table 1*.). The average proportion of degradation indicator species in the clearing was more than one third of the species. The maximum was 44,4% (C3, 2018 August). This proportion was lower in the forests. The average was about quarter of the species, and the maximum was only 34,7% (F2, 2016 August). The species count was also different. It was always higher in the clearings with a maximum of 77 species in C1 (2018 May). While in the forest we found 28 species (F1, 2018 August) and the maximum was only 49 species (F2, 2016 May). The number of plant species was highly variable during the examined months. It can be explained by the typical weather conditions and life form characteristics of the plants.

The interannual difference was not remarkable, but 2018 was slightly more wet, and it improved the conditions of weed germination in clearing areas with high sunlight exposure. This might be the reason for the higher proportion of degradation indicator species. In the forest, the high level of groundwater along with the high canopy closure discouraged growth of plant species, resulting in a decrease in species number and in weed proportion as well.

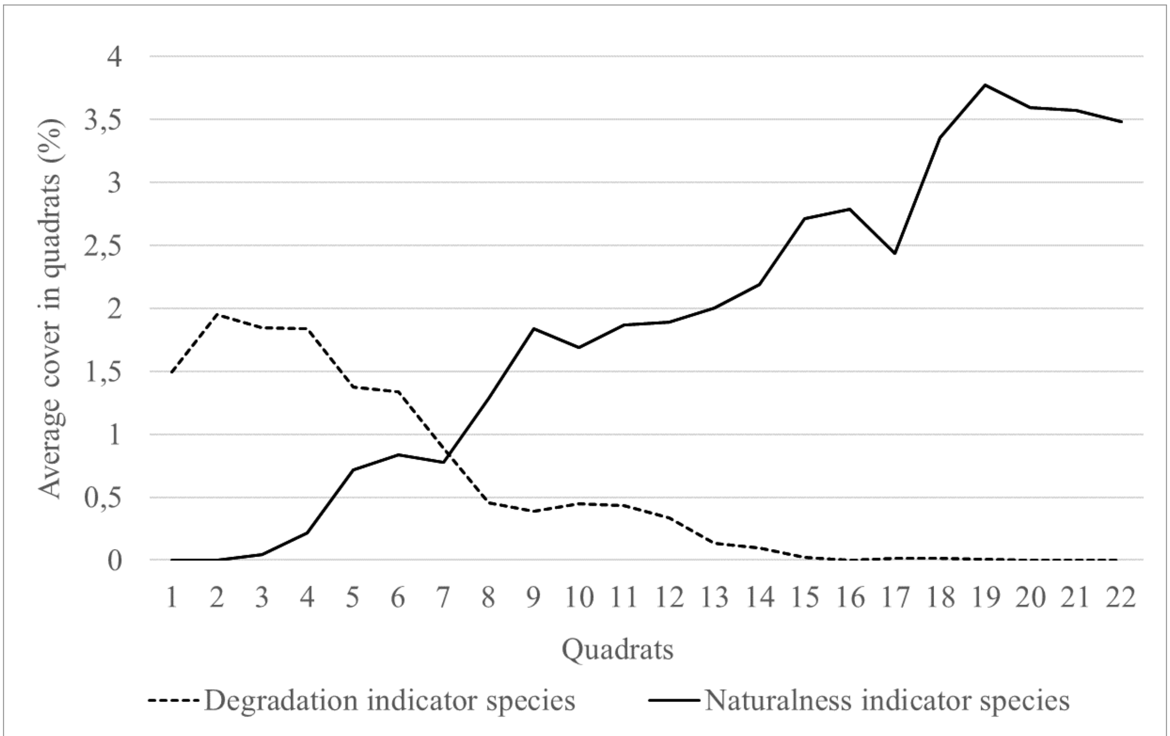


*Figure 1*. The average proportion of degradation and naturalness indicator species in quadrats (C1, 2018 August)


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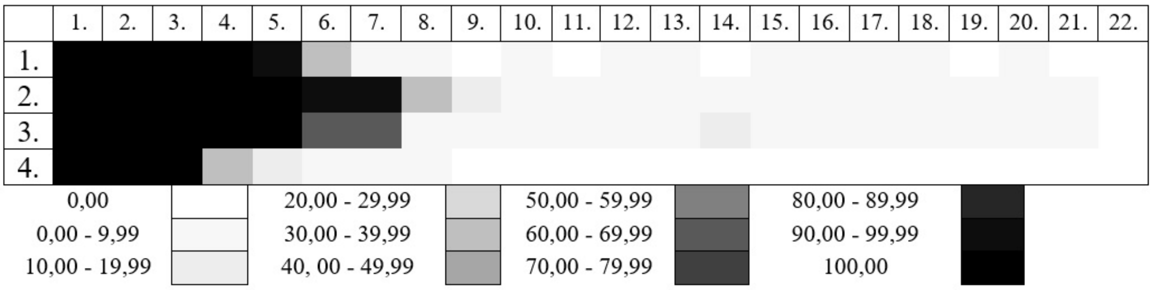


*Figure 2*. The cover of the degradation indicator species in quadrats (C2, 2018 August; rows: the 4 transects; columns: the 22 quadrats)

Focusing the species rank based on their cumulative coverage (*Table 2*.), it is clear that weed species were dominant in August not only by species count but in abundance as well (iii). The most abundant weed species in May were T1 and T2 weeds, e.g. *Capsella bursa-pastoris* and *Bromus sterilis*. In August, T4 weeds dominated (e.g. *Polygonum aviculare*, *Xanthium spinosum* and *Datura stramonium*) in the clearings. Additionally, it is evident that bait sites in the clearings were the most weed infected. In these places the cumulative cover of the degradation species was very high and, in general, it continued to increase in August. Forest bait sites were less weedy, their state was similar in the two surveys with a low cover of degradation indicator species and a sparse understory cover.

We could confirm the stress gradient hypotheses (i) over the two years, in all aspects and at all bait sites. If we consider the average number of the degradation and naturalness indicator species in the quadrats, it is clear that the number of the degradation indicator species is the highest in the centre of the bait sites and it decreases with distance. Naturalness indicators became dominant from the 8th to 10th meter (*Figure 1*.).

The stress gradient can also be detected based on species abundance (i). This was evident at all of the feeding sites and most significant at bait sites in the clearings. If we look at the cover of degradation indicator species in the quadrats (from the total cover per sites), it is clear that the abundance of the degradation indicator species is very high, often 100%, in the centre and it decreased with distance (*Figure 2*.).

## Discussion

Based on the survey of the bait sites in the Mátra Landscape Protection Area, it can be concluded that the bait sites can cause significant degradation in natural habitats. Weed invasion typically extends to the immediate environment of the bait sites. We detected a stress gradient along the transects, originating from the centre of the bait sites. In general, the degradation indicator species are present in higher abundance only until the 8th-10th meter. Then it almost disappears and the natural plant species become dominant. Rinella et al. (2012) and Mathisen et al. (2015) had similar results. They examined the effects of supplemental winter feeding and they found that the degradation did not appear to extend great distances. Lloyd et al. (2006) also found that the invasive and dangerous weedy species are present only near to touristic structures similar to bait sites.

We found a significant difference between the invasiveness of examined sites. Forest bait sites were less weedy and had a sparse understorey in the two examined aspects, possibly due to the dense canopy closure (Honnay et al. 2002; Ibáñez et al. 2009; Burst et al. 2017). However, bait sites in the clearings proved to be highly degraded. The stress gradient mentioned and the temporal variables between the examined aspects were more prevalent on these sites due to greater accessibility (Wesson and Waering, 1969; Pons, 2000).

Consequently, if feeding sites are located in small, valuable habitat patches (such as the examined forest clearings), degradation of their vegetation, species loss or the complete loss of habitat can happen and bait sites may be the focal points of biological invasions. Therefore, we recommend the regulation of the quantity and quality of forages used at bait sites and the revision of related laws. However, it is also suggested that bait sites mainly be positioned in forests, and possibly not in clearings or near protected areas.

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**Source of the graphics**

*Front cover:*
Gallo-Roman harvesting machine, called Vallus. Source: U. Troitzsch - W. Weber (1987): Die Technik : Von den Anfangen bis zur Gegenwart

*Rear cover:*
Portrait of Columella, in Jean de Tournes, Insignium aliquot virorum icones. Lugduni: Apud Ioan. Tornaesium 1559. Centre d'Études Supérieures de la Renaissance - Tours

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## Lucius Junius Moderatus Columella

(AD 4 – 70) is the most important writer on agriculture of the Roman empire. His De Re Rustica in twelve volumes has been completely preserved and forms an important source on agriculture. This book was translated to many languages and used as a basic work in agricultural education until the end of the 19th Century.