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The Effect of the Dam-building Activity of the Eurasian Beaver (*Castor fiber*) on Changes in the Soil Moisture Conditions and Vegetation Associations of the Beaver Meadows in the Valley of Ablánc-stream

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Nowadays, more information is available about the activities of the Eurasian beaver (*Castor fiber*) as an ecosystem engineer species and the resulting ecosystem services. The environment-shaping activity of beavers not only affects the bed conditions of a given body of water but also affects the degree of diversity of the vegetation and fauna surrounding it. The research published in connection with this topic has only in recent years begun to deal more intensively with the condition characterisation and function analysis of the flooded areas under constant beaver influence, called beaver meadows. The focus of this paper is the investigation of beaver meadows directly connected to the dam system consisting of 19 beaver dams located along the Ablánc stream. The research examines the effect of the activity of the beaver colony, which has been continuously monitored for almost two years, on the soil moisture conditions of the beaver meadows in the Natura 2000 nature conservation area and to what extent this is reflected in the characteristics of the plant community. The focus of the analysis is the vertical distribution of soil moisture in the upper soil layer. During the vegetation mapping, 10 squares were designated to determine plant community parameters. High soil moisture values were detected in the examined quadrates, which varied between 39.0 φ% and a maximum of 50.0 φ%. A significant number of taxa could be identified - such as *Myosoton aquaticum* and *Petasites hybridus* - whose primary ecological requirements are a permanent wet environment and continuous water impact.

1. Introduction

The Eurasian beaver (*Castor fiber*) was once one of the largest rodents in Europe and Asia, if not the largest, but by the 19th century, it had become almost completely extinct due to overhunting (Collen and Gibson, 2000). However, due to spontaneous immigration and planned reintroduction programs, it is now an integral part of the domestic mammal fauna again (Juhász et al., 2019). Beavers are key species, which means nothing more than species that, compared to their population size, have a disproportionately large impact on the ecosystems that surround them. In this case, the effect exerted by the ecosystem services resulting from the activity of beavers mostly prevails with fluvial ecosystems (McKinstry et al., 2001). Beavers are often referred to as ecosystem-engineering species (Wright et al., 2002) because their dam-building activities modify and transform the river systems and the surrounding land areas along the coast (Puttock et al., 2017). According to this, they create a habitat for themselves that provides the right conditions for the species to settle, helps supply their habitat with food, provides protection against potential predators (Larsen et al., 2021) and creates an environment suitable for reproduction and care of offspring. The environment-shaping activity of beavers affects the composition of plant communities in the area. In this case, ecological facilitation occurs, through which a certain interaction between species takes place in such a way that one species can make a given habitat more suitable for the settlement of other organisms (Nummi et al., 2019). The dams or dam systems built by beavers back up the water in the given body of water, as a result of which the retained water floods the coastal areas and raises the groundwater level of the areas. As a result of all this, a wetland is formed in an area where a completely different type of habitat is typical (Willby et al., 2018). The effect of their dam-building and environmental transformation

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activities on the vegetation can be shown in two main ways. On the one hand, the effect of selective chewing activity can be shown on both woody and herbaceous vegetation. On the other hand, the rise in the groundwater level can be observed in the area flooded with water as a result of the damming, thereby changing the composition of the plant vegetation living in the area (Larsen et al., 2021).
Consequently, beaver activity greatly promotes the increase in the number and dominance of tree species that are not typical for beaver feeding habits and also creates a habitat complex rich in grasses and herbaceous species (Pollock et al., 1995). Water damming indirectly results in the destruction of coastal trees, which consequently leads to a local reduction in the diversity of tree species. At the same time, all of these increase the general species richness of the vegetation, and new mosaics of plant species characteristic of terrestrial (Wright et al., 2002) and aquatic vegetation habitats are created on the established beaver meadows (Bartel et al., 2010). Water level rise often significantly widens the area of the wetland and modifies the physical, chemical and biological conditions of the littoral zone (Nummi et al., 2019). The channels dug by the beavers are almost like a small drip irrigation system that runs along the entire coastal zone, thus promoting a constant, high soil moisture level (Fairfax and Small, 2018). One of the main effects of damming is the increase in the proportion of water and wetlands in the landscape (Johnston and Naiman, 1990), the process of which consists of three main steps: 1) because of the water damming and tree felling, the closed nature of the canopy decreases, thus increasing the light supply of the lower levels (Larsen et al., 2021), 2) the nutrient supply and moisture content of flooded soils under the influence of water increases (Naiman et al., 1994), 3) the size of the contiguous, open water area increases significantly (Larsen et al., 2021). Soil moisture is important for different plant covers in areas with limited water (Bi et al., 2008). It comes from rainfall, groundwater, and nearby water sources (Duan et al., 2008). Due to the vertical heterogeneity of individual microclimate and water management variables, the response and growth characteristics of the vegetation may differ, especially in stressful situations (Elliott et al., 2015). The formation process of the land and water vegetation complex thus formed is called reverse succession since beavers, as an active source of influence (Larsen et al., 2021), facilitate the return to an earlier stage of the succession process (Rosell et al., 2005). Some plants are unable to maintain their productivity, as both low and high soil moisture levels cause chronic stress (Brzostek et al., 2014). Because of the higher moisture content, the resulting forest succession and the association typical of the beaver meadows result in wet forest types (Larsen et al., 2021) and contribute to the formation of marshy, peaty areas (Johnston and Naiman, 1990). Based on all this, it can be concluded that there is a shortcoming in the current research direction, which minimally examines the cause-and-effect relationship in connection with the appearance of certain plant species that require specific conditions. The research examines a less explored subject area of Eurasian beaver knowledge with the aim of finding an answer to the question of whether soil moisture conditions in beaver meadows influence the composition of the plant community established in the area.

2. Materials and methods

The essence of our method is to analyse the cause-effect relationship between the measured changes in the state of soil moisture in a selected study area under beaver influence, as well as the composition of the formed vegetation, using soil moisture measurements and plant mapping. The investigated area is located in Hungary, in Vas County, within the Vas-hegy and Kőszeghegyalja small region, in the Őrség-Vas hilly flora district. The ground cover layer is made up of Pleistocene sediments, as well as a layer of quartz and gravel brought down from the Kőszeg Mountains, and the gravel sediment of the Gyöngyös stream is also considered a soil-forming layer. In addition to this, Ice Age loam also appears in places. Brown forest soil forms the majority of the ground cover in the area, 91.0 % (Dövényi, 2010). The vegetation of the small region can be estimated at approximately 800-1,000 species, of which the number of protected species is between 60 and 80. According to Kulcsár et al. (2022), the number of plant species observed in Vas County can be considered exceptionally high, amounting to 272 species.

2.1 Measurement sites and sampling points

The study sites required for flora mapping and soil moisture measurement were designated in the section of the Ablánc-stream where beaver activity was intense, and identifiable beaver dams as a result of beaver activity were directly connected to individual beaver dams. The measurements were preceded by continuous monitoring, which took place weekly in 2022 and 2023 through field visits and camera traps. During the survey fieldwork before the measurements, we selected a total of 10 test locations that are suitable for both vegetation testing and soil moisture distribution analysis. The measurement locations all met the following criteria: 1) fresh, active beaver activity was observed near the sampling sites, 2) the beaver dam located near the beaver meadows was free of anthropogenic effect (there are no agricultural activities in the area's surroundings) and 3) the plant cover of the individual quadrates is uniform, no anthropogenic influence was effect.

2.2 Vegetation mapping and plant association analysis

The quadrat-based mapping method was used to reveal the direct and indirect effects on the plant communities of the beaver meadows along the dam system along the Ablánc-stream built by Eurasian beavers (*Castor fiber*). In the study area, ten 10 m x 10 m were designated, on which the plant taxa occurring in the given square were mapped, and parameters such as the frequency values within each square, the evenness distribution, and the value of Shannon's biodiversity index. The purpose of the flora mapping is to determine, along the ecological needs of each species, whether taxa that occur in large numbers only in the case of special markers characteristic of wetlands have appeared in the plant communities due to the appearance, expansion and environment-shaping activities of the Eurasian beavers (*Castor fiber*).

2.3 Soil moisture measurement and the used instrument

In order to examine the soil moisture status, several measurement points were designated for each quadrat. The number of soil moisture measuring points used within a quadrat was one hundred sampling locations. During the measurements carried out, the upper 0.3 m zone of the vertical soil moisture distribution of each soil profile, i.e. the moisture content of the root zone of the vegetation, was analysed. The obtained data were evaluated, taking into account the characteristics of each sampling point. In addition to the averaging of individual values for squares, their vertical and horizontal distribution was evaluated. During the examination of the distributions, the outliers, their frequency and possible causes were identified. The individual measurements were carried out in a standard way, with a PMS710 type, capacitive soil moisture content measuring instrument. During field visits, the device measures every 0.1 m layer from the soil surface and provides data for the upper 0.3 m soil zone of the examined soil profile, which expresses the moisture content of the given layer as a percentage of volume (φ%). The volume percentage of moisture content (φ%) expresses the amount of volume of moisture in the soil as a percentage of the volume of the given soil medium. In addition, in parallel with the data generated through flora mapping, the markers of the ecological needs of the vegetation occurring in the given survey section were also evaluated. This made it possible to explore the relationships and quantify the relationships between the results of the soil moisture status survey and plant mapping.

3. Results

In the measuring sites, 10 squares of 10 m x 10 m were designated according to the pre-determined area delimitation criteria. The number of plant species identified in the examined quadrates varied between 16-22. The mosaic method helped identify plant species, their distribution, and coverage by describing and examining the dominant species in each area. Table 1 shows Shannon's diversity index and distribution value determined based on the plant species found during the examination of the 10 squares (Q-01; Q-02; ...; Q-10). Based on the results of Shannon's biodiversity index calculation, it can be established that the distribution value of the square with the identification number Q-01 of the examined beaver was 0.83, which, considering the interval scale between 0.00 and 1.00, indicates a moderately high distribution value.

Table 1: Diversity, distribution and ecological demand values of the examined quadrats

Square ID	Diversity	Distribution	T*	W*	R*	N*	Z*
			0-7	0-11	0-5	0-5	0-5
Q-01	2.33	0.83	4	6	3	3	4
Q-02	1.87	0.61	5	8	3	3	3
Q-03	2.16	0.79	4	6	3	3	4
Q-04	1.89	0.65	4	6	3	3	4
Q-05	2.14	0.76	5	7	3	3	4
Q-06	1.92	0.68	4	6	3	3	4
Q-07	2.32	0.81	4	7	3	3	4
Q-08	2.15	0.78	4	6	3	3	4
Q-09	1.92	0.68	4	7	3	3	4
Q-10	2.03	0.72	5	8	3	3	3
Average:	2,07	0,73	4	7	3	3	4

Data from Simon and Seregélyes (2000)

*Notation: T-temperature requirement of plant species; W-water requirement of plant species; R-pH requirement of plant species; nitrogen requirement of plant species; Z-degradation tolerance of plant species

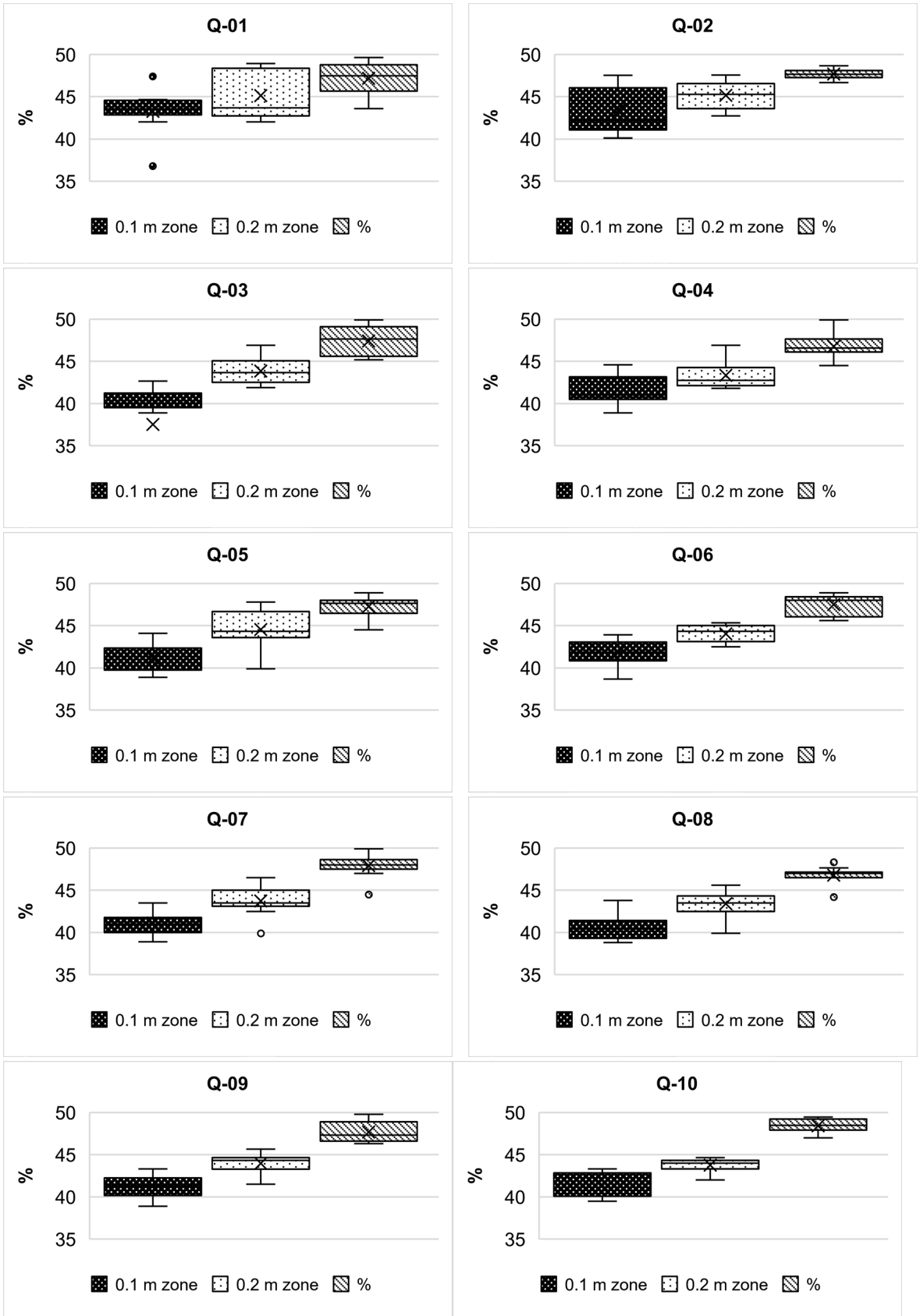

Figure 1: Vertical soil moisture distribution of the quadrats of the investigated beaver meadows in the upper 0.3 m soil zone (%, Q-01 – Q-10); Data from: based on own measurement results; own editing

The Q-07 square had a similar value (0.81). Parallel to the higher distribution values, a higher diversity value is also characteristic, which was 2.33 in the case of Q-01, while 2.32 in the case of Q-07. Q-02 had the lowest distribution value (0.61), and its diversity value was also the lowest, 1.87. The reason for this is that the examined square is an area under direct influence, the majority of its vegetation was made up of Petasites hybridus with high water requirement. After establishing the plant diversity, based on the values of the ecological needs of each plant species, it can be determined what main needs prevail in the given area in terms of the composition of the vegetation. As can be seen from the data in the table, the number of deviations in the values of temperature requirements (T), pH requirements, nitrogen requirements, and degradation characteristics was negligible, but this cannot be clearly established for water requirements as well. It can be seen that, for example, the value of Q-01 is 6 (moderately wet growing area), while the value of Q-02 is 8 (moderately wet growing area). Based on the averaging of the values obtained in this way, it can be said that the habitat characteristics of the plant communities of the studied beaver meadow are the climate zone typical of coniferous and deciduous mixed forests (average value: 4), wet growing area (average value: 7), soil type with an almost neutral pH (average value: 3), plant species with medium nitrogen demand (average value: 3) and degradation tolerance are typical.

Plant species such as Phragmites australis (W value: 10), Myosoton aquaticum (W value: 9), Carex acutiformis (W value: 10) and Petasites hybridus (W value: 9) were decisive in determining the value of the wetland. In other words, among the identified plant species, some species are not, or only to a small extent, characteristic of forest associations, and due to their natural needs, they have a rather wet, very wet growing area requirement. Beaver meadows are typically under constant, permanent water influence, which serves as the basis for the establishment and appearance of plant species with high water demand in individual plant communities. To explore the relationships between the changes in the soil moisture distribution caused by environmental changes caused by the needs of plants and the effects of beavers, we measured the soil moisture distribution in the upper 0.3 m soil zone (root zone) in every 0.1 m zone at each quadrat. Figure 1 illustrates the vertical soil moisture distribution of the quadrats through quartiles.

Based on the measured values and the obtained secondary results, it can be said that the examined soil profiles had a high soil moisture value. The average value of the examined beaver is 45.4 φ% for the entire 0.0-0.3 m zone. The value of soil moisture in the 0.0-0.1 m zone of the examined soil profile was 41.3 φ%, 44.1 φ% between 0.1-0.2 m and 47.5 φ% between 0.2-0.3 m. As can be seen, the Q-02 quadrat has consistently higher values than the other quadrats. Its average value characteristic of the 0.0-0.3 m zone is higher than the average value of the beaver meadow (46.1 φ%). The significant difference was also detectable in the individual subzones, 43.3 φ% between 0.0-0.1 m, 45.2 φ% between 0.1-0.2 m and 47.7 φ% between 0.2-0.3 m. Based on the obtained results, it can be said that a higher-than-average soil moisture distribution was experienced in those quadrats whose plant communities contained more plant species with higher water demand.

4. Conclusions

This paper examines the relationships between the composition of the plant communities of beaver meadows and the distribution of soil moisture influenced by the constant water effect because of the dam-building and environment-shaping activities of the Eurasian beaver (*Castor fiber*) to shed light on the relationship between beaver activity, soil moisture, and vegetation.

During the research, we carried out flora mapping, plant community analysis based on the quadrat and mosaic method, and soil moisture tests in the 10 squares in the upper 0.0-0.3 m soil zone of the beaver meadow. Throughout the investigations, we established that among the identified plant species, there were a significant number of taxa - such as Phragmites australis, Myosoton aquaticum, Carex acutiformis, and Petasites hybridus - whose primary living conditions and ecological requirements are a constant wet environment and high water demand. Given the characteristics of that particular habitat, the presence of permanent water effects and continuous or periodic flooding, which is realised through water damming by beavers, play a significant role in the occurrence of these taxa. All of this is supported by the typically high soil moisture values, which varied between 39.0 φ% and the maximum 50.0 φ%.

We confirmed some assumptions and hypotheses with quadrates by finding plants with high water demand and soil moisture. In our opinion, the research results can be used by environmental and ecological researchers and nature conservation specialists to expand scientific knowledge about the direct and indirect effects of beavers and to lay the foundation for future research. For this reason, it is necessary to expand the research to additional habitats and beaver meadows in the future.

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