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Assessment of the occurrence of the pond turtle *Emys orbicularis* in Polesie National Park based on drone monitoring

Abstract. This study aimed to determine the habitat preferences of the pond turtle *Emys orbicularis* L. in Polesie National Park and assess the effectiveness of drone use across different seasons. Monitoring was conducted with three DJI drone models (Mavic Air 2, Air 2S and Air 3), which carried out surveys on 27 selected sites covering a total area of 49.73 ha, using optical cameras and orthophoto software. Turtle activity was highest in spring, especially during mating, when individuals are more likely to come to the surface for thermoregulation and reproduction. As temperatures rose and drought progressed, the number of sightings decreased, which was associated with the drying of water bodies and a change in turtle behaviour. Most turtles were observed in sedge meadows and drainage ditches, which acted as migration corridors and places of refuge during the drought. The survey confirmed the high usefulness of drones in monitoring the species, especially in hard-to-reach areas.

Keywords: European pond turtle, *Emys orbicularis*, drone monitoring, wetland habitats

INTRODUCTION

The pond turtle (*Emys orbicularis* L.) is the only native turtle species in Poland and is classified as a high-risk, endangered species. It is listed in both the *Polish Red Book of*

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Animals and the *Red List of Threatened and Endangered Animals in Poland* with an EN (Endangered) status [Głowaciński 2001, 2002]. The species is protected under the EU Habitats Directive 92/43/EEC (Annexes II and IV) and the Bern Convention [Najbar 2012]. In Poland, it is strictly protected and subject to active conservation measures under the Regulation of the Minister of the Environment of 16 December 2016 [Najbar 2012]. While it occurs throughout the country, its largest population is found in the Lublin Polesie region. It is considered one of Poland's most distinctive and well-studied reptile species [Dziedzic 2002, Kosik et al. 2013]. Pond turtles inhabit a variety of habitats across extensive park areas, including bogs, sedge meadows, alder thickets, ponds, drainage ditches and peat bogs [Mitrus 2006]. Eleven breeding sites have been identified in the park and its buffer zone. The population size is estimated at 350–450 adult individuals; based primarily on the number of females laying eggs in a given year. A systematic increase in the number of females at breeding sites, including the appearance of previously unmarked individuals, suggests that active protection efforts by park staff are effective. The exact number of males and juveniles remains unknown [Olszewski 2024].

In recent years, drones have gained popularity as a tool for monitoring wildlife in natural environment, especially in hard-to-reach areas where traditional ground-based methods prove insufficient [Chamoso et al. 2014, Rey et al. 2017, Ezat et al. 2018, Kellenberger et al. 2018, Prosekov et al. 2020, Rančić et al. 2023, Czyżowski et al. 2024]. Their use in turtle population inventories surpasses the effectiveness of classic techniques based on direct observation [Wójcik et al. 2024]. Drones allow monitoring areas inaccessible to humans without disturbing wildlife. When equipped with optical and thermal cameras, and combined with deep learning technology, they enable the automatic processing and identification of captured images [Rey et al. 2017, Ezat et al. 2018, Prosekov et al. 2020, Rančić et al. 2023].

The main objective of this study was to determine the habitat preferences of the pond turtle in Polesie National Park using consumer drones and to assess the seasonal effectiveness of using drones for turtle monitoring.

MATERIALS AND METHODS

The research was conducted with the consent of the Director of Polesie National Park (permit no 24/2024), authorising scientific research and movement within the park. Additionally, permission for exemptions from prohibitions related to research on the European pond turtle in Polesie National Park was granted under DOP-WOPPN.61.74.2024.MŚP.

Preliminary field surveys, along with information from the park service and the literature allowed the selection of probable turtle habitats. The size of the areas monitored varied, usually limited by the natural features of the habitats, such as a group of mid-forest bogs, sedges bounded by drainage ditches, fishponds, etc. Monitoring was carried out in six study periods: 1 (13–28 IV), 2 (5–15 V), 3 (17–29 V), 4 (18–21 IV), 5 (10–21 VII) and 6 (19–23 VIII). Monitoring hours were adapted to the time of turtle activity, typically from 9 am to 2 pm, adjusting for weather conditions. Habitat preference was determined by recording the number of turtles observed in specific habitats relative to the total number of turtles. Drone monitoring was carried out on 27 separate survey plots covering a total area of 49.73 ha (Fig. 1). Taking into account the six countings in each plot (with a few exceptions), a total area of 246.72 ha was surveyed, within which turtles were photographed and counted.

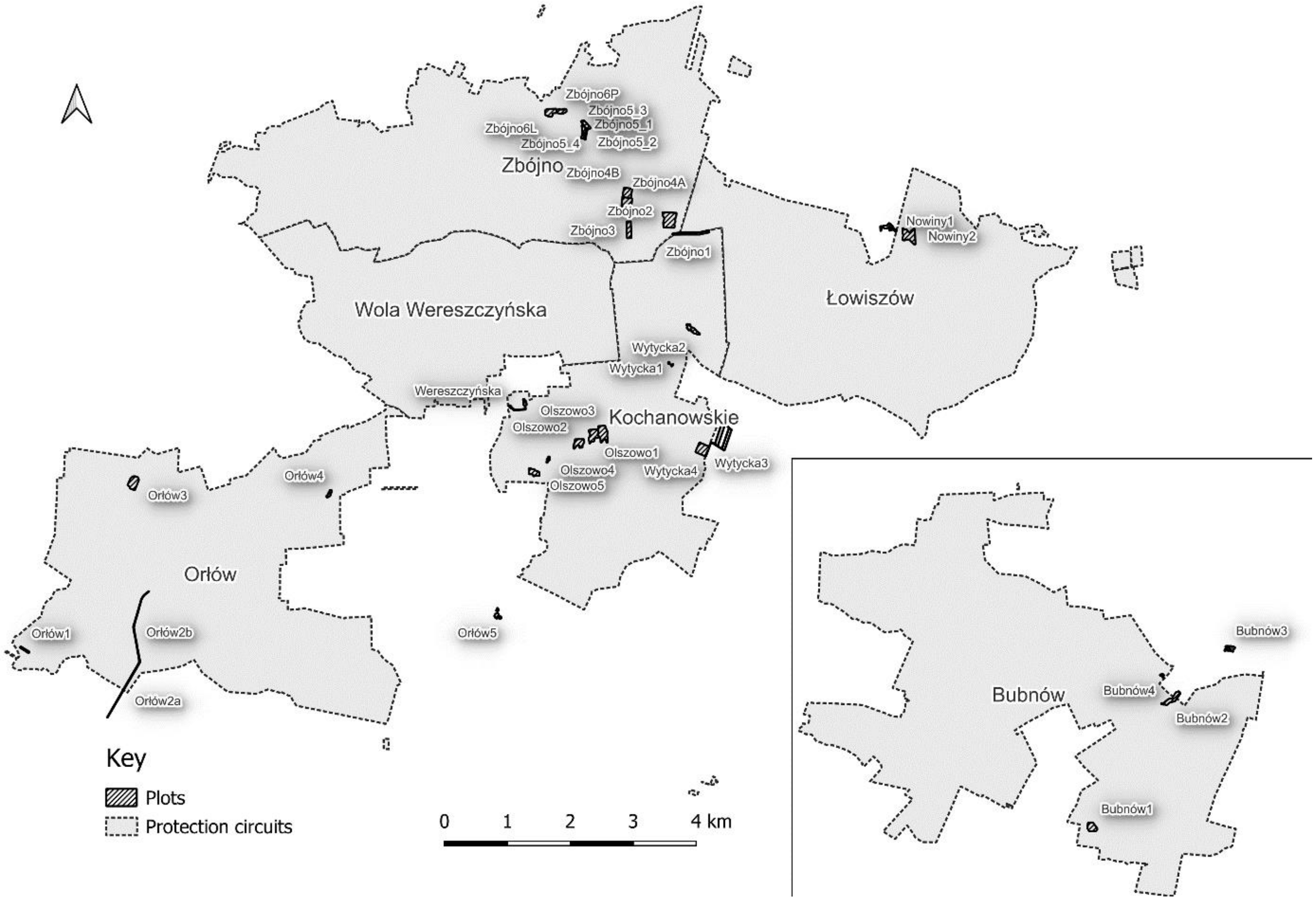

Fig. 1. Location of monitoring plots within the park and buffer zone surveyed using drones

Three consumer drone models were used for monitoring: the DJI Mavic Air 2, the DJI Air 2S and the DJI Air 3 (SZ DJI Technology Co., Ltd.). The DJI Mavic Air 2 drone features a 1/2″ Quad Bayer sensor with 48 Megapixel resolution. The DJI Air2s is equipped with a 1″ CMOS sensor with 20 Megapixel resolution. The DJI Air 3 has dual cameras – 24 and 70-mm supported by a 48-megapixel sensor. Depending on the terrain conditions and the presence of obstacles such as trees, the drone flight altitude was adjusted and ranged from 17 to 25 m, resulting in a photo resolution of 0.3–0.6 cm/pixel depending on the drone model. Dji Mavic Air2 and Air2S were used together on 24 plots with predominantly low grass or scrub vegetation due to the ease of flight path planning in Grid Mission Designer and Litchi for DJI Drones software. Both models enabled the capture of high-resolution images and efficient recognition of turtle silhouettes. For three sites with tall trees, the newer and more advanced DJI Air3 model was employed. Its 70 mm telephoto lens, flown at approximately 50 m altitude provides magnification comparable to that of a 24 mm lens flown at 17 m. However, planning and executing missions with this model is only possible with the original DJI Fly software using Waypoints which is significantly more difficult and less precise.

The response of turtles to drone presence has been tested in previous studies, which reported no signs of disturbance when drones were flown at altitudes above 15 m [Wójcik et al. 2024].

The work started by determining the drone's flight paths on the monitoring plots. The Mission Grid Designer tool (https://ancient.land) was used to determine the initial flight parameters. The flight template thus prepared was imported into the Litchi Mission Hub (https://flylitchi.com/), where the flight parameters were adjusted in detail. Aerial inspections of several areas were complemented by visual monitoring using binoculars.

Drones were also used to produce area-based maps to show turtles' locations in the most current habitat. Using WebODM (Web Open Drone Map) version 2.5.5 software, orthophotos were taken in WGS 84 / UTM zone 34N projection (EPSG:32634) at 3 cm per 1-pixel resolution. Pearson's chi-square (χ^2) test of independence was used to assess the relationship between the number of turtles observed and factors such as the date of observation, habitat type and air temperature range. Calculations were made for contingency tables covering the respective combinations of levels of these factors (date × habitat, habitat × temperature range). Results with a significance level of $p < 0.05$ were considered statistically significant. The relationship between the minimum daily temperature during the season and the decline in the number of turtles observed was assessed using the Pearson correlation coefficient calculated in Statistica 13.3.

RESULTS AND DISCUSSION

An analysis of turtle abundance over six consecutive research periods (Fig. 1) revealed a decline in the number of observed individuals, particularly noticeable during the latest research seasons. The highest number of observations was recorded in the first and second research periods (second half of April – first half of May), likely reflecting seasonal patterns in the species' biology. After their winter dormancy, turtles begin to move actively in search of food and breeding partners; additionally, they are more likely to appear at the water surface or on the banks and overgrowing vegetation, basking in the sun for thermoregulation [Najbar and Mitrus 2001]. The decline in observed individuals can also be attributed to the specific meteorological conditions during the study period. The low rainfall and high temperatures in the summer of 2024 caused a hydrological drought, manifested by reduced river flow, lower river levels, and the drying of small water bodies. As poikilothermic animals, turtle activity is strongly influenced by ambient temperature. During the study period, an increase in minimum daily temperature was significantly correlated with a decrease in the number of observed individuals ($r = -0.8151$, $p = 0.048$; Fig. 2). The decrease in the number of turtles observed on successive dates (April to August) with increasing minimum air temperature may be due to a change in their behaviour during the warmer months. At low spring temperatures, turtles spend more time in the sun, basking multiple times a day. During summer, with high temperatures, they reduce basking activity and spend less time in warm water [Bodie and Semlitsch 2000, Cash and Holberton 2005] .

During the season, an increase in vegetation cover is also correlated with a rise in temperature, which in turn reduces the visible area of observation. At the same time, the water level decreases during summer, and this factor was particularly intensified in the study season and resulted in a significant reduction in the surface area of the water table. Turtles can survive prolonged periods of drought by hiding under moss, ferns or alder roots [Roe and Georges 2008, Roe et al. 2009].

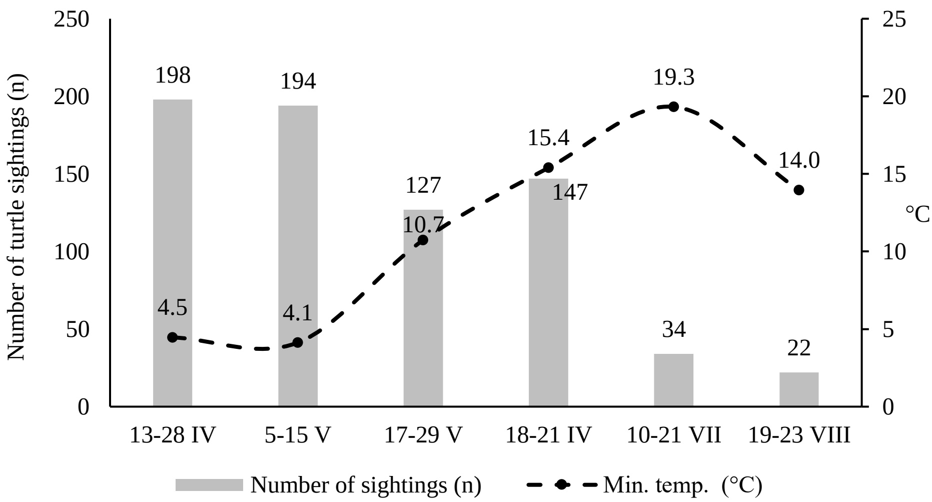

Fig. 2. Number of turtle sightings in successive survey periods (n) against changes in mean minimum air temperature

Throughout the study, there was an apparent variation in the number of turtle observations depending on the characteristics of the water bodies in each study period (Figs. 3 and 4). The notable decrease in turtle sightings on successive dates in habitats that dry out periodically (such as sedge meadows, reed beds, willow thickets, and peat bogs) is attributed to the drying of these bodies of water caused by the ongoing drought. The turtles will likely have reduced their activity and moved to deeper, more stable aquatic habitats or hidden under vegetation. The increase in sightings in ditches and reservoirs in June and July, coinciding with the drought period, results from migration to areas where water lasted longest. Ditches act as migration corridors, while permanent water bodies provide the last refugia during the dry season. Short-term desiccation of water bodies does not significantly affect turtle survival or the rate of movement between habitats [Owen-Jones et al. 2016]. However, long-term desiccation, e.g. due to habitat reclamation, significantly reduces the survival of the species. According to Ficetola et al. [2004], the annual probability of a turtle leaving one water body in favour of a neighbouring one does not exceed 15% and declines sharply with increasing distance. Most of these movements are limited to within 1 km, while occasional movements up to 2 km probably corresponded to male dispersal behaviour. The connectivity between ponds influenced movements. This highlights the importance of aquatic corridors, such as ditches, drainage lines and culverts for supporting natural intra-population exchange, as turtles tend to follow these when available [Rees et al. 2009].

Preferred habitat types where turtles were recorded most frequently were sedge meadows and drainage ditches (35.4% and 25.2% observed turtles). Turtles were most abundantly recorded in sedge meadows (Fig. 3), which in spring turned into floodplains with overhanging, tufted vegetation on which turtles can bask, and the presence of water facilitated their movements, especially during the breeding season. Similar habitat preferences have been confirmed in studies from other European countries [Segurado and Araújo 2004, Thienpont et al. 2004, Drechsler et al. 2018]. However, the local sedge meadows are being overgrown by willow or alder thickets as a result of succession. Drainage ditches in the park area currently act as water storage reservoirs, so as water levels drop in shallower habitats, turtles use them as migration routes and permanent habitats. Like the sedge meadows, the ditches are also subject to overgrowth and shallowing.

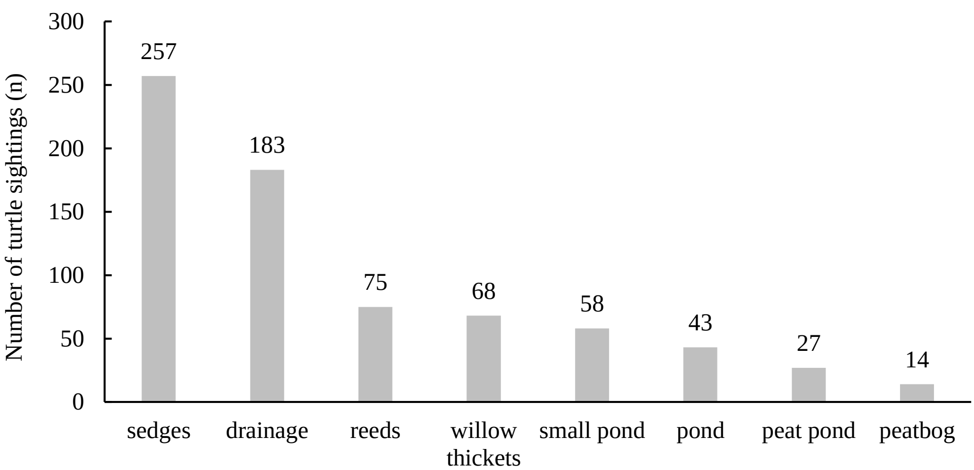

Fig. 3. Number of turtle sightings per habitat (n)

Spring is a critical period in the life cycle of turtles, particularly for breeding. At moderate temperatures of 16 to 25°C, the highest number of individuals was observed on sedge meadows, suggesting that this habitat plays a vital role during this time (Fig. 4). Their shallow waters warm up more quickly, enhancing food availability, providing suitable resting sites , and offering conditions conducive to mating. Statistical analysis confirmed the relationship, with Pearson's χ^2 test showing a statistically significant relationship between habitat type and air temperature range for the number of turtles observed (χ^2 = 255.77; df = 21; p < 0.0001). At cooler temperatures below 5°C, the number of turtles in the sedge habitats was much lower, indicating that their activity was still much reduced in early spring. As the air warmed, they became more active, and sedges became their primary habitat. However, as temperatures exceeded 25°C, the sightings decreased again, which may indicate that on hot days, the turtles do not leave the water or choose more sheltered environments. On hot summer days, the turtles are often submerged in the water with only their heads protruding above the surface, a behaviour visible through binoculars but undetectable by drones. At air temperatures above 25°C most individuals were found near drainage ditches in the study area. In a study by Marchand et al. [2021], conducted using temperature recording sensors, it was observed that the activity of mud turtles significantly increased in the morning, decreased at midday and peaked in the evening. At midday, turtles were more likely to rest than to bask, suggesting a strategy of avoiding exposure to excessive heat during the period of maximum sunshine.

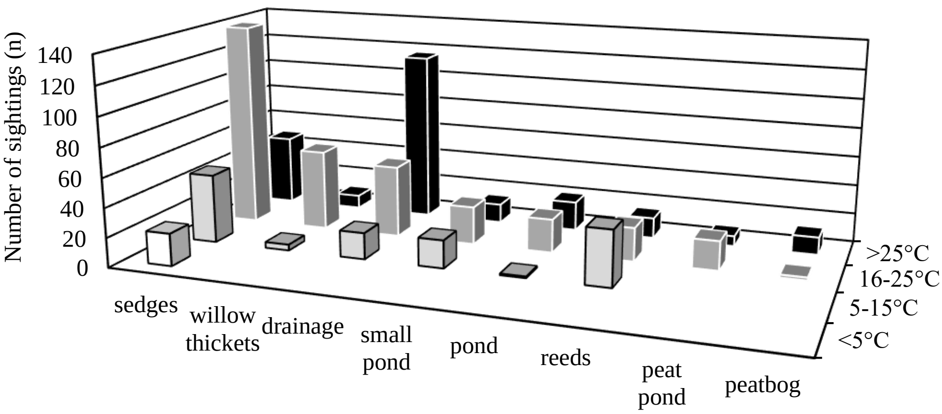

Fig. 4. Number of turtle sightings (n) in each habitat according to the range of air temperature

However, it is important to note that the observed patterns of turtle activity may largely reflect the specific weather conditions during the study period. The highest number of individuals observed was recorded in periodically drying habitats (mainly sedge meadows) during spring with the lowest mean minimum air temperatures (Fig. 5). As the temperature increased in successive monitoring periods, the number of turtles observed in shallow water bodies declined, likely due to desiccation, in favour of drainage ditches. Pearson's χ^2 test confirmed a statistically significant relationship between the number of turtles observed and the interaction between observation date and habitat type (χ^2 = 195.94, df = 10, p = 0.001). Similar patterns were reported by researchers in other central European countries,who also observed high basking activity of pond turtles in spring [Novotený et al. 2008, Vamberger and Kos 2011, Erdélyi et al. 2019].

After emerging from hibernation in March or April, depending on weather conditions, turtles gradually increase their activity while remaining relatively close to the nesting ground and water bodies where they overwinter. Early in the spring season, turtles are more sedentary and restrict their movements to familiar habitats, staying close to bodies of water where they mate. Males become more mobile from April to May, searching for females to copulate, whereas female turtles move most extensively from May to June to lay eggs [Cadi et al. 2004, Mignet et al. 2014]. During the egg-laying period, females undertake migrations to locate suitable nest sites. They choose well-known sites for nesting, often those where they hatched, with adequate sunlight. Research indicates strong nest site fidelity [Mitrus 2006, Najbar and Szuszkiewicz 2007]. Turtles migrate by water and land, travelling various distances, often reaching several hundred metres or even several kilometres [Paul and Andreas 1998, Zufi and Rovina 2006, Liuzzo et al. 2023].

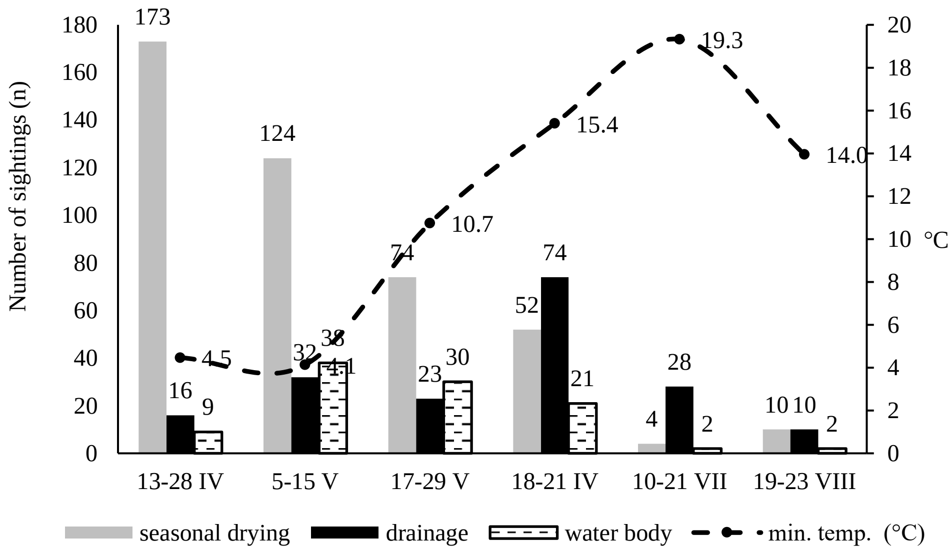

Fig. 5. Number of turtle sightings (n) according to the presence of water in the habitat on successive survey dates

Towards the end of summer and into autumn, turtles may once again increase their movement range, particularly evident on the sixth observation period (August), when a sharp increase in distance from nesting sites was recorded. This may be related to migration to overwintering sites, where they select suitable hibernation habitats, often distant from summer foraging sites [Owen-Jones et al. 2016] (Fig 6). Alternatively, this movement may be a response to environmental stress and a defence strategy against habitat drying [Cash and Holberton 2005].

While adult turtles are well-adapted to overland movement and, contrary to popular belief, are not slow, as they can easily cover several hundred metres during a single day, land migration poses greater challenges for juveniles. It not only requires more physical effort but is also associated with the threat of land-based predators. Proximity to water is beneficial, and the closer the site is to a water source, the more juveniles are observed (Fig. 7). In contrast, more remote sites are typically inhabited only by adults. As confirmed by previous studies [Escoriza et al. 2020], juvenile turtles, unlike adults, restrict their movements to a small area. After leaving the nest, young turtles move over land until they reach the nearest body of water and remain there for several years – these habitats are characterised by low water levels and dense vegetation [Vignoli et al. 2015].

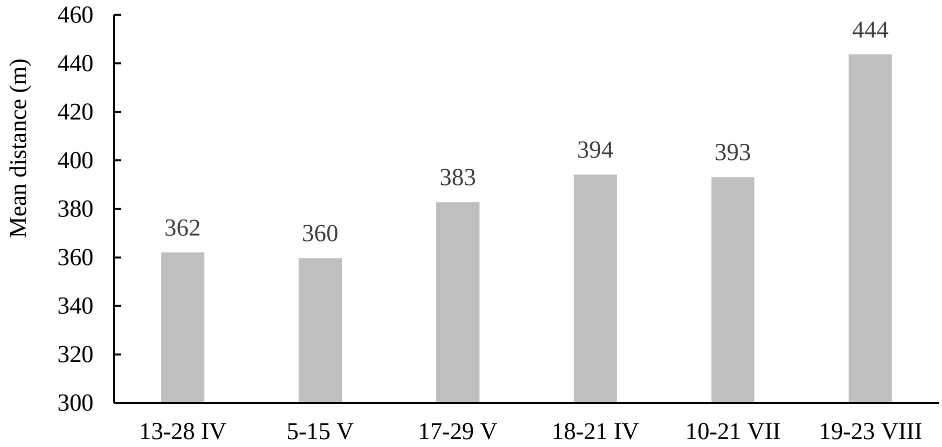

Fig. 6. Mean distance (m) of turtles observed from the nesting site across successive survey periods

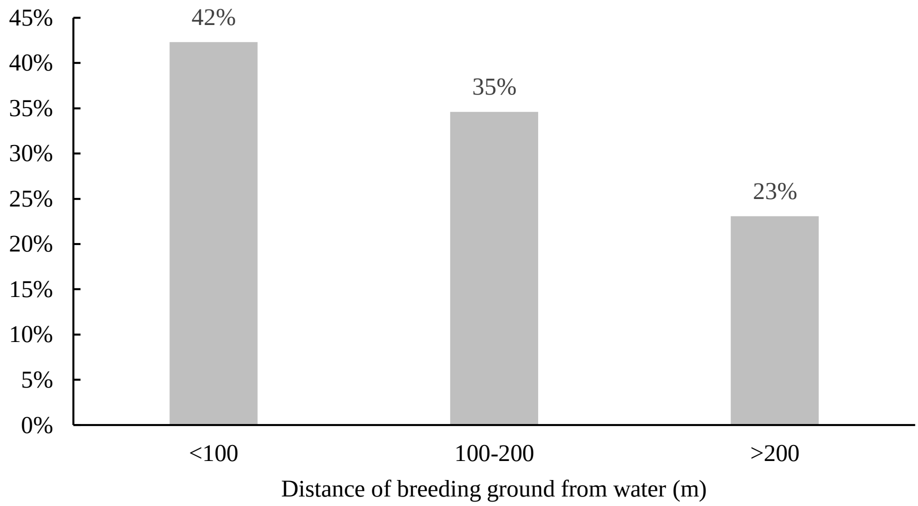

Fig. 7. The proportion of sites (%) where juvenile turtles were observed depending on the distance of the bed from the water body

Considering the size of the plots monitored relative to the number of turtles, the highest densities, above 40 individuals/ha, occurred in the Bubnów study plots (Fig. 8). This may have been attributed to the fact that turtles concentrated in selected locations, such as drainage ditches and peat bogs. Surprisingly, although the Zbójno area is known for its numerous nesting sites and high turtle abundance, the vastness of the area makes their population density low. The distribution of individuals is also the most distant from the nesting sites (Fig. 9). The Nowiny area supports only a few turtles, hence the lowest observed densities (Fig. 10). These findings confirm previous observations of the strong dependence of pond turtles on specific habitat types, especially canal habitats, which have been identified, among others in Italy, as critical nesting sites [Zuffi and Rovina 2006]. The observed distribution of individuals in relation to known breeding sites may indicate the existence of established migratory routes and high fidelity to breeding grounds, as previously noted by Rovero and Chelazzi [1996], among others.

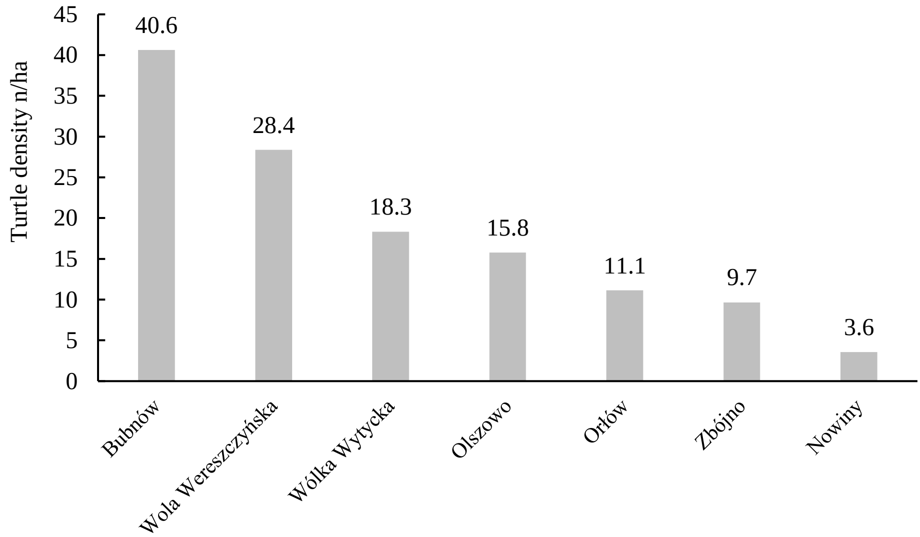

Fig. 8. Density (n/ha) of individuals observed at individual study sites in conservation districts

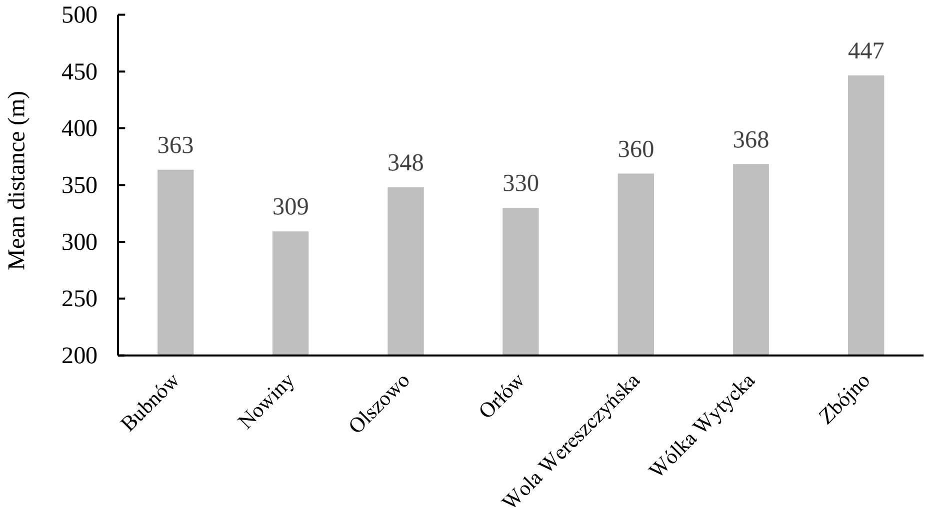

Fig. 9. Average distance (m) of observed turtles from the breeding ground in individual areas (protective perimeters)

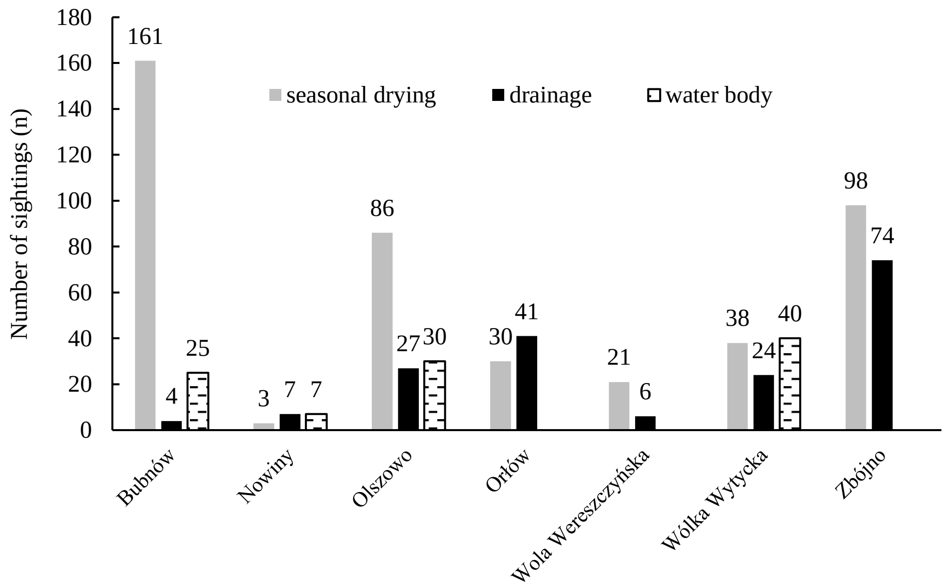

Fig. 10. Number of turtle observations (n) depending on the presence of water in a given habitat in individual protection areas

SUMMARY AND CONCLUSIONS

The study confirms the high value of drone technology in protected species monitoring. The use of drones has proved highly effective – it has made it possible to monitor hard-to-reach habitats without disturbing the animals and to document the presence of turtles precisely. However, certain environmental and climatic factors limit its effectiveness. Dense, tall forests can obstruct visibility, and during hot summers, turtles often submerge in warm water or restivate beneath silt or vegetation, making detection more difficult.

Turtle activity was closely related to weather conditions – the number of observations decreased with rising temperatures and intensifying drought. Research on the occurrence of the pond turtle in the Polesie National Park has shown that the most significant activity of these reptiles occurs in spring.

The preferred habitat types are sedge meadows and drainage ditches, which accounted for 60.7% of all recorded observations. Their exposed surfaces provide access to the sun, vital for thermoregulation. However, sedge meadows are increasingly being replaced by willow or alder thickets due to succession. Drainage ditches in the park area act as water storage reservoirs, so as the water level drops in the shallower habitats, turtles use them as migration routes and permanent habitats. These ditches, however, are also subject to overgrowth and shallowing. Seasonal migrations were observed, resulting from reproductive needs, foraging and preparations for wintering.

The conservation of semi-aquatic species such as the European pond turtle requires a comprehensive understanding of their habitat requirements and the need to protect periodically flooded habitats, which play a key role in the life cycle of the turtle. Maintaining connectivity between water bodies, such as through drainage ditches, facilitates natural migrations and increases the chances of population survival. In the context of climate change and increasing drought frequency, it is especially important to implement conservation measures aimed at maintaining stable water sources within the species' habitats.

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The impact of the European beaver on the environment of selected water reservoirs in the Ciechanów Forest District – a case study

Abstract. The European beaver (*Castor fiber*) has long been considered an ecosystem engineer, exerting a profound influence on the habitats it occupies. Its activities significantly shape water conditions, terrain, and biodiversity. Research conducted in the Ciechanów Forest District aimed to assess the impact of beavers on the local environment. Observations took place from August 2024 to March 2025 and involved documenting beaver activities such as browsing trees, creating burrows, and building lodges. It was found that the tree species most frequently selected by beavers in the study area was gray alder (*Alnus incana*). Beavers most frequently browsed trees with a diameter of 1–20 cm and a hardness of 2.1 on the Brinell scale. Their most intense impact occurred at the end of the growing season, from August to November. The most preferred species were young trees with soft wood, which may indicate that less effort and energy are required to cut them down, or that they are more palatable, juicy, and tender than older plants.

Keywords: *Castor fiber*, environmental impact, food preferences

INTRODUCTION

The European beaver (*Castor fiber*) is currently a common species in Poland, with an estimated population of over 149,900 individuals [GUS 2024]. Its population has fluctuated significantly over recent centuries, a result of hunting, changes in conservation status,

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and habitat availability [Rakowska and Stachurska-Swakoń 2021]. This species exerts a significant influence on the environment. Beavers' ability to transform their environment has led to their classification as ecosystem engineers [Jones et al. 1994]. While European beavers are viewed positively by some, they may be considered pests in areas of high population density or where their activities negatively affect human interests. Negative perception of this species stems from the damage they cause to agricultural crops, flood embankments, and orchard trees and shrubs, as well as from the flooding of forest areas and the potential transmission of parasites and diseases to livestock [Giżejewski and Goździewski 2016].

Despite their impact on human activity, beavers play a significant role in restoring the natural balance of forest ecosystems. By constructing dams, they retain water during summer droughts while also contributing to its purification. Above all, their environmental influence enhances the attractiveness of landscapes not only for their aesthetic quality but also for their educational and recreational value. In areas transformed by these rodents, numerous species of waterfowl, fish, amphibians, and invertebrates can be observed, and the areas surrounding floodplains become havens for various species of birds of prey and mammals [Konopka and Erenc 2002, Janiszewski and Misiukiewicz 2012, Janiszewski and Hanzal 2015].

Beavers feed primarily at night, but can occasionally be observed active during the day, especially at noon [Czech 2001]. As semi-aquatic animals, they inhabit areas close to water bodies [Tranda and Jaroniewski 1999]. Their foraging is usually limited to a 20-meter zone along the shoreline, which strongly influences the diversity of food they consume [Czech 2007].

Areas where beavers create floodplains can extend over several dozen hectares. They act as a natural sponge, storing water in spring and gradually releasing it in summer. By building dams, beavers increase the water retention capacity of the catchment area. Its level depends on the shape of the catchment area, the density of beaver habitats, and soil conditions. Beaver reservoirs can also mitigate peak flood waves. In their vicinity, groundwater levels stabilize and rise, erosion is reduced, and the deposition of mineral and organic particles increases significantly. As a result, natural marsh-forming processes are initiated. Following heavy rainfall or spring snowmelt, floodwaters spread over a larger area, thereby losing their force [Naiman 1988].

Due to beavers' high adaptability, they can occupy areas modified or degraded by humans, which is frequently a source of conflict. In some countries – including Lithuania, Sweden, and Finland – beaver populations have recovered to such an extent that hunting has been reinstated. In other countries, the species remains endangered and strictly protected, for example, in France, Hungary, Slovakia, and Germany [Czech 2000].

Beavers are herbivores that feed on a wide range of aquatic and riparian plant species. Their diet includes 100 species of woody plants and over 200 species of herbaceous plants. The composition of a beaver's diet depends on food availability and habitat conditions, and changes depending on the season [Dzięciołowski and Goździewski 1996]. The species' population growth and expanding range prompt an analysis of the animal's impact on its environment and the surrounding area. Therefore, this study aimed to assess the impact of the European beaver (*Castor fiber*) on the environment of reservoirs located within the Ciechanów Forest District.

MATERIAL AND METHODS

Observations were carried out in the vicinity of water reservoirs located within the Ciechanów Forest District: the Dziady reservoir, the Krubin water complex, and a reservoir located in the village of Nużewko. The Ciechanów Forest District lies in the northern part of the Mazovian Voivodeship and covers a total area of 11,300.37 ha, of which 11,116.93 ha is forested. The study areas are located within the Bardonki and Gołoty Forest. The predominant forest habitat types in this region are fresh mixed coniferous forest and fresh mixed deciduous forest. The pine is the dominant species, accounting for over 70% of the tree stand composition [https://ciechanow.olsztyn.lasy.gov.pl/]. In terms of area, the most abundant species in the Ciechanów Forest District are Scots pine (7789.23 ha), oak (1166.53 ha), alder (1154.10 ha), birch (739.06 ha), and others (171.77 ha) [Plan urządzania lasu Nadleśnictwo Ciechanów 2024].

Observations were conducted once per month from August 2024 to March 2025, along with a damage inventory. Tree species were identified, and the trunk diameter of all trees at felling height was measured to the nearest 1 cm using a caliper. Additionally, photographic documentation of animal habitats and environmental changes was collected.

The hardness of browsed trees was determined using the Brinell scale [PN-EN ISO 6506-1: 2008, PN-EN ISO 6506-1: 2002].

Statistical analysis of the results was performed using the Statistica 13.1 statistical package. The analysis included the frequency of felled tree species, the distribution of felled trees by diameter at the measurement point, wood hardness, and the month of observations across the three study sites. To determine the correlation between the analyzed number of trees and wood hardness, as well as between tree diameter and wood hardness, Pearson correlation coefficients were calculated, and linear regression equations were presented.

RESULTS

It was shown that the most frequently selected tree species by beavers was grey alder (*Alnus incana*), with selection rates of 50%, 28% and 18% in the vicinity of the water reservoir in the village of Nużewko, the Dziady reservoir and the Krubin water complex, respectively. Less frequently beavers selected aspen (*Populus tremula* L.) and sycamore maple (*Acer pseudoplatanus* L.) near the Nużewko reservoir, at 27% and 18%, respectively (Fig. 1).

Beavers showed the highest preference forbrowsing trees with a diameter of 1–20 cm, notably, 63% of trees felled near the Nużewko water reservoir had a diameter of less than 10 cm (Fig. 2).

The observed rodents most often chose tree species with hardness of 2.1, especially in the Dziady reservoir and in the village of Nużewko (56%), and 1.3 and 1.5, 14% each (Fig. 3).

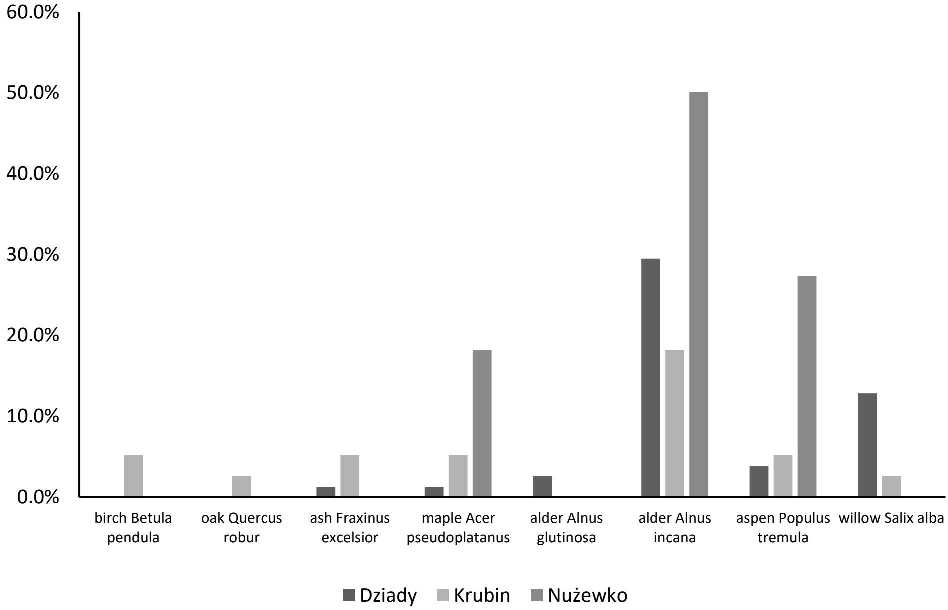

Fig. 1. Percentage of tree species cut down in the vicinity of water reservoirs: Dziady, Krubin and in the village of Nużewko

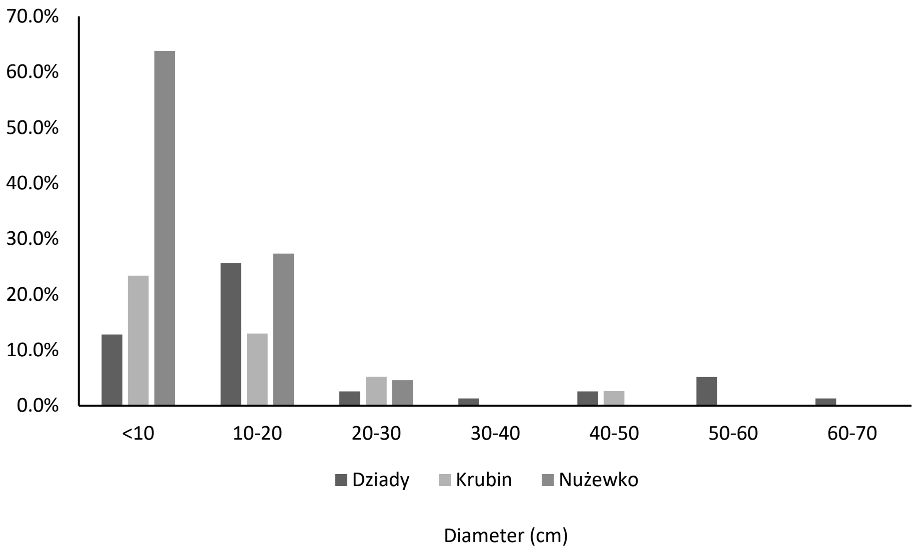

Fig. 2. Percentage distribution of felled trees depending on diameter at the site of logging in the area of water reservoirs: Dziady, Krubin and in the area of the village of Nużewko

The period of most intensive tree browsing by the observed animals was from August to November (17–20%). Beaver activity decreased in December and January (5%) – as in Figure 4.

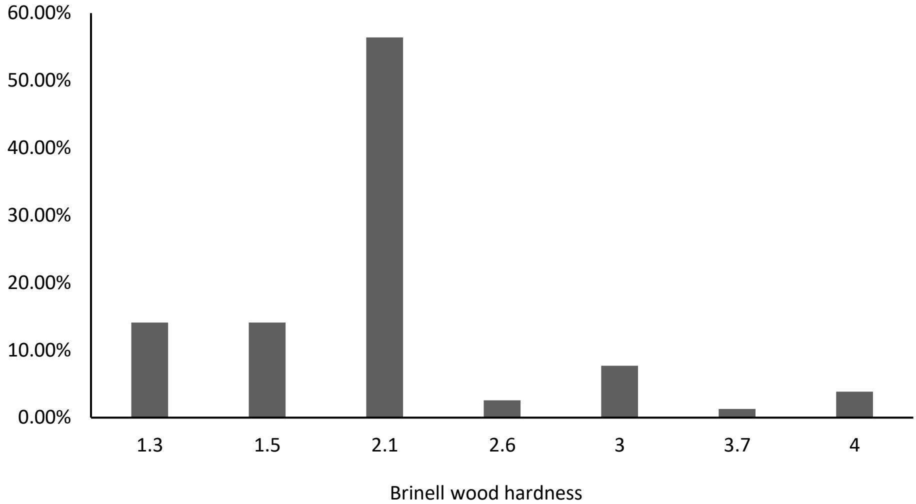

Fig. 3. Percentage distribution of felled trees depending on hardness in the studied water bodies

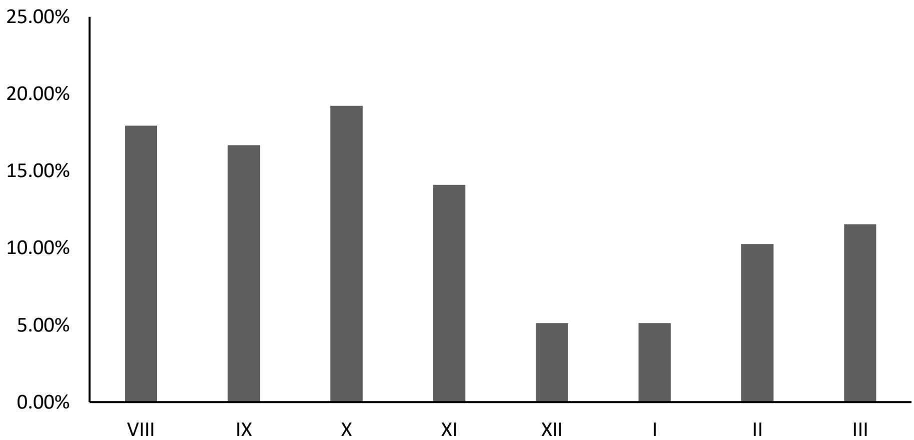

Fig. 4. Percentage distribution of cut trees depending on the month of observations

The correlation between the number of damaged trees and wood hardness was analyzed and found to be inversely proportional to the wood hardness of the analyzed tree species. The calculated correlation between the number of browsed trees and wood hardness was negative and statistically insignificant (Pr = 0.33) – as in Figure 5. In general, the number of damaged trees decreased with increasing wood hardness.

The correlation between the diameter and hardness of the wood of the browsed trees was positive and also insignificant (Pr = 0.43) – as in Figure 6.

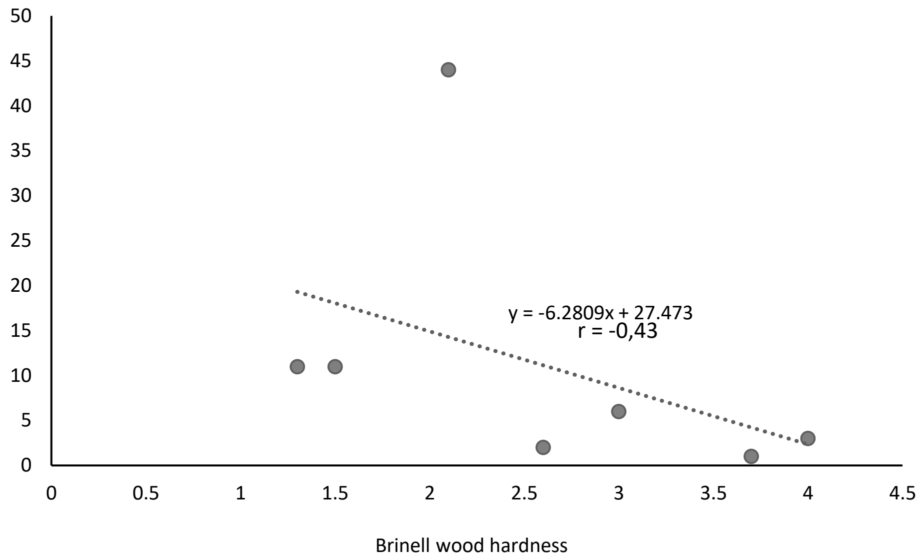

Fig. 5. The correlation between the number of felled trees and the hardness of wood of the analyzed species

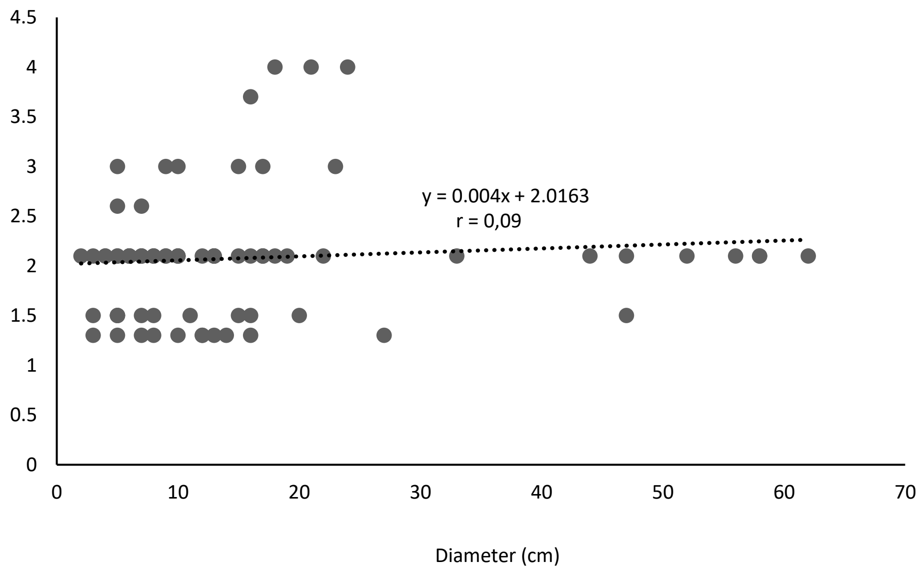

Fig. 6. Correlation between diameter and hardness of wood of browsed trees

DISCUSSION

Beavers feed on marsh and aquatic vegetation, buds, fresh twigs, and leaves from spring to autumn. From late autumn to early spring, their diet consists primarily of bark and twigs of trees and shrubs [Dzięciołowski 1996]. They most frequently choose species of trees from the genera *Salix* sp., *Populus* sp., *Betula* sp., and other deciduous trees [Czech 2007, Tajchman et al. 2018].

As the current observations show, the selection of plant species that constitute potential food or building material for beavers depended primarily on the abundance of vegetation growing in their habitat, which is also confirmed by previous studies [Tajchman et al. 2018]. They most often chose pioneer, fast-growing tree species, i.e., gray alder and first-age aspen, and less frequently, sycamore maple or white willow. This is confirmed by studies conducted in the Czech Republic, where a strong preference for poplar was also demonstrated [Brenner 1962, Belovski 1984, Derwich 2001, Fustec et al. 2001, John 2001, Ficek 2003]. Beavers digest aspen more efficiently than other tree species, and their daily consumption of other plants was inversely proportional to their digestibility. A strong preference for alder or poplar may slow the succession of these species in wet floodplains. However, because beavers eagerly feed on these species, they contribute to the transformation of tree stands and promote the development of other vegetation species, thereby creating favorable living conditions for the aquatic fauna [Valachovič and Gímeš 2003, Janiszewski et al. 2017].

Some researchers argue that the interest in willow is due to its low resin and essential oil content, which beavers tend to avoid [Nolet et al. 1994, Dzięciołowski 2004]. The number of tree species in the diet increases at the end of the growing season, when beavers store up for winter, a pattern also confirmed by our results. During this period, beavers typically browse species of the genera *Populus* spp. and *Salix* spp. [Danilov and Kanshiev 1983, Nolet et al. 1994, Kostkan 2000, Ficek 2003]. However, when their numbers are limited, beavers may feed on *Betula* spp., *Acer* spp., as well as *Tillia cordata*, *Corylus avellana*, and *Quercus robur* [Doucet and Ball 1994, Doucet et al. 1996]. Similar patterns were recorded in Polesie National Park, where a notable consumption of alder buckthorn (26%) and common oak (17%) was described [Janiszewski et al. 2017]. In addition, studies conducted in three reservoirs in the Ciechanów Forest District showed that sycamore maple and common ash may also be components of beaver diets. As reported by Nolet et al. [1994], beavers may select plant species to supplement specific nutrients that are deficient in their preferred species.

This study showed that beavers select tree species with a trunk diameter ranging from 1 to 20 cm, consistent with findings from the Czech Republic, where 78% of trees had diameters below 20 cm (78%). The diameter of the most frequently damaged tree species was in the range of 2.6–6 cm and 6.1–12 cm, and the third most frequently selected group were trees with a diameter below 2.5 cm [Dvořák 2013]. Observations in the Ciechanów Forest District confirm this tendency: beavers were most interested in young trees with a diameter of up to 10 cm (63%).Similar results were reported by Janiszewski et al. [2017], who showed a preference for trees with a diameter of up to 15 cm, with an average percentage share of such trees at the level of 88%.

In studies conducted within the Ciechanów Forest District, a negative but statistically insignificant correlation ($r = -0.43$) was found between the number of browsed trees and wood hardness, consistent with results obtained in the Lubaczów and Chotyłów Forest

Districts [Tajchman et al. 2018]. Similar results were reported by Czyżowski et al. [2009] in studies conducted in the Lublin and Nadwieprzański Landscape Parks (r = –0.321). Overall, the number of damaged trees decreased with increasing wood hardness.

Beavers most often inhabit areas around lakes and rivers, gravel and peat pits, marshes, mountain streams, and small brooks. Key factors influencing their habitat selection include the depth of the water body and the availability and quantity of woody food resources [Gałek and Woch 2011]. Beavers avoid areas with strong currents due to the risk of burrow erosion and the potential drowning of their young [Czech 2000]. They are highly territorial and family-oriented animals that can occupy a given area for several generations [Wąs and Gorczyca 2022].

It is worth noting that in the Krubin water complex, where the municipal swimming pool is located, beavers did not build lodges but inhabited burrows dug in the shores. This is a natural phenomenon, as in bodies of water where water levels do not fluctuate significantly, beavers usually dig residential burrows [Dzięciołowski 2004]. On the other hand, in flowing waters, they build tree dams, which cause the water to accumulate above the structure and create better living conditions for the species. By doing so, they contribute to increasing the water depth and reducing its flow, and as a result, they gain better access to vegetation, i.e., building material and food [Wąs and Gorczyca 2022]. Again, on elevated areas surrounded by water, they build dome-shaped lodges, which serve both as a protective and breeding function. The lodges are constructed of tree branches and soft vegetation, covered with mud and clay. These structures can reach up to 3 meters in height [Panfil 1984].

Observations conducted in the Ciechanów Forest District also showed that beavers primarily inhabited small reservoirs located in close proximity to farmland and buildings. Their impact on the environment was significant, as they improved water retention, created floodplains, and raised groundwater levels. Despite these benefits, many people in the study area viewed them as pests, since they flood farmland, fell trees, and undermine banks. In the Krubin reservoir and Dziady reservoir, at the request of residents, the municipality protects trees by wrapping them in netting, enhancing safety and minimizing potential infrastructure damage.

Due to the observed increase in the number of species studied, this type of analysis may have an applied nature, e.g. in planning the planting of suitable tree species near streams and water reservoirs.

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Znaczenie ekstensywnego systemu utrzymania koni dla bioróżnorodności i funkcjonowania ekosystemów lądowych

The importance of extensive horse husbandry systems for biodiversity and the functioning of terrestrial ecosystem

Abstrakt. Celem pracy jest przedstawienie ekstensywnego systemu utrzymania koni, który stanowi model użytkowania zwierząt gospodarskich łączący harmonijnie cele produkcyjne z ochroną środowiska oraz wspieraniem bioróżnorodności. Poruszono tematykę wpływu wypasu koni na zmiany składu runi pastwiskowej, oddziaływania końskich odchodów na mikroflorę gleby i cykle biogeochemiczne, znaczenie wypasu dla ornitofauny i entomofauny oraz wpływ na stabilność ekosystemów. Przeanalizowano zmienność fitosocjologiczną oraz sukcesję roślinności, a także potencjalne korzyści wypasu koni w kontekście ochrony przyrody i polityki rolnośrodowiskowej. Stwierdzono, że wypas koni, mimo pewnych ograniczeń, może być skutecznym narzędziem wspierającym bioróżnorodność, retencję wody oraz sekwestrację węgla, wpisując się w strategię zrównoważonego rolnictwa i adaptacji do zmian klimatu przy jednoczesnym uwzględnieniu potrzeb dobrostanowych tych zwierząt.

Słowa kluczowe: konie, bioróżnorodność, ekstensywny wypas, rolnictwo zrównoważone, mikrobiota gleby, pastwiska

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WSTĘP

Zrównoważone zarządzanie zasobami naturalnymi jest nie tylko podstawowym założeniem ekologii stosowanej, lecz także jednym z filarów Europejskiego Zielonego Ładu i strategii ochrony różnorodności biologicznej w Unii Europejskiej: EU Biodiversity Strategy 2030 [Commission Regulation 2019, European Commission 2020]. W tym kontekście system ekstensywnego wypasu koni domowych (*Equus caballus*) stanowi interesujący przykład praktyki rolniczej, która może jednocześnie wspierać dobrostan zwierząt, utrzymywać funkcjonalność krajobrazu rolniczego i poprawiać stan przyrodniczy agrocenoz [Thulin i in. 2025]. Użytkowanie łąk poprzez wypas koni może wspierać utrzymanie siedlisk z priorytetowych zbiorowisk przyrodniczych, w tym łąk podmokłych, o zmiennym poziomie wilgotności i termofilnych, które są przedmiotem ochrony w ramach sieci obszarów Natura 2000 [Council Directive 92/43/EEC 1992, Török i in. 2011].

Ekstensywny system utrzymania koni oparty jest na zapewnieniu zwierzętom wolności przemieszczania się, dostępu do paszy naturalnej, możliwości schronienia i życia w warunkach zbliżonych do naturalnych. Charakteryzuje się on ograniczoną obsadą zwierząt, minimalną ingerencją człowieka w cykle paszowe oraz dużą zależnością od zasobów naturalnych takich jak pastwiska czy łąki. W odróżnieniu od intensywnego chowu, systemy ekstensywne sprzyjają utrzymywaniu różnorodności biologicznej, zarówno na poziomie gatunkowym, jak i ekosystemowym [Kapás i in. 2020]. Konie jako duzi roślinożercy wpływają na strukturę roślinności poprzez selektywne żerowanie, udeptywanie gleby oraz rozsiewanie nasion. Ich presja pokarmowa zmienia skład gatunkowy zbiorowisk roślinnych i może sprzyjać utrzymaniu gatunków światłolubnych, które w warunkach sukcesji wtórnej ustępowałyby roślinom ekspansywnym lub drzewiastym [Cromsigt i in. 2018]. Szczególne znaczenie mają tu strefy przybrzeżne, śródpolne enklawy roślinności półnaturalnej oraz nieużytki, gdzie koński wypas może stanowić efektywną alternatywę dla kosztownego wykaszania mechanicznego [van Klink i in. 2016]. Konie często preferują inne gatunki traw i ziół niż bydło, co prowadzi do powstawania mozaikowego układu runi. Taka heterogeniczność siedliskowa jest korzystna dla wielu grup organizmów, w szczególności bezkręgowców i ptaków stepowych [Lovász i in. 2024].

Oddziaływanie koni na środowisko wykracza poza strukturę roślinności. Odchody zwierząt są źródłem zasobów pokarmowych dla licznych gatunków saprotrofów i koprofagów, w tym chrząszczy z rodzin *Scarabaeidae* i *Geotrupidae*. W miejscach intensywnie użytkowanych przez konie wzrasta aktywność entomofauny związanej z rozkładem materii organicznej. Rozkład odchodów przez chrząszcze koprofagiczne przyczynia się do przyspieszenia obiegu składników pokarmowych w glebie, ograniczenia presji patogenów oraz zmniejszenia liczby pasożytów [Tonelli i in. 2021, Thomassen i in. 2023].

Celem niniejszej pracy jest wieloaspektowa analiza wpływu ekstensywnego chowu koni na komponenty ekosystemów lądowych – od mikroorganizmów glebowych, przez zespoły entomofauny i ornitofauny, aż po zmiany sukcesyjne w strukturze roślinności. Analiza ta opiera się na aktualnym stanie wiedzy naukowej, z uwzględnieniem badań prowadzonych w Europie Środkowej i Północnej, gdzie tradycje wypasu mają silne podstawy historyczne i kulturowe.

ROLA WYPASU KONI W KSZTAŁTOWANIU ROŚLINNOŚCI I MIKROHABITATÓW

W warunkach niskiej lub umiarkowanej presji zwierząt wypas może przyczyniać się do zwiększenia bogactwa gatunkowego roślin oraz wzrostu złożoności przestrzennej siedlisk [Pringle i in. 2023]. Analiza przeprowadzona przez zespół badaczy pod kierownictwem Tälle [2016] wykazała, że ekstensywny wypas wykazuje bardziej pozytywny wpływ na bioróżnorodność niż koszenie. Ciągła selektywna presja, którą zwierzęta wywierają na roślinność, prowadzi do tworzenia mikromozaik zróżnicowanej wysokości i składu gatunkowego. W przeciwieństwie do jednolitego charakteru siedlisk koszonych, wypas sprzyja powstawaniu różnorodnych mikrohabitatów oraz występowaniu organizmów o zróżnicowanych wymaganiach ekologicznych [Teague i in. 2011, Socher i in. 2012]. Na pastwiskach wypasanych przez konie obserwuje się wzrost liczebności roślin światłolubnych oraz ograniczenie dominacji gatunków ekspansywnych i wysokich traw [Chodkiewicz 2020, Bonavent i in. 2023]. Utrzymywanie niższego pokrycia roślinnego wpływa pozytywnie na występowanie wielu gatunków owadów, w tym zapylaczy [Kleijn i in. 2015]. Szczególne znaczenie wypas koni odgrywa w siedliskach objętych ochroną w ramach sieci Natura 2000, takich jak łąki o dużej wilgotności z klasy *Molinio Arrhenatheretea*, łąki zmiennowilgotne oraz murawy kserotermiczne, które wymagają ochrony przed zarastaniem przez krzewy i drzewa [Council Directive 92/43/EEC 1992]. Przywracanie użytkowania pastwiskowego z udziałem dużych roślinożerców jest skutecznym i ekonomicznie opłacalnym narzędziem ochrony czynnej siedlisk łąkowych [Török i in. 2011].

Oddziaływanie koni na strukturę roślinności to także efekt ich specyficznych preferencji pokarmowych [Cromsigt i in. 2018]. Wykazano, że konie preferują trawy o niskiej zawartości celulozy, unikając jednocześnie roślin trujących i o silnym aromacie, co wpływa na skład florystyczny i sprzyja utrzymaniu wysokiej heterogeniczności w przestrzeni pastwiska [van Klink i in. 2016, Mutillod i in 2024]. Ponadto konie przyczyniają się do powstawania ścieżek, placów wydeptywanych i miejsc intensywnej defekacji, elementów istotnych dla przestrzennej organizacji zbiorowisk roślinnych i zwierzęcych [Ostermann-Kelm i in. 2009, Ringmark i in. 2019]. Niektóre rasy koni chętnie korzystają również z dostępnych zarośli i drzewostanów, a stopień wykorzystania danego środowiska zmienia się w czasie i zależny jest od dostępności pożywienia [Lamoot i in. 2005]. Przykładem są koniki polskie, w Polsce utrzymywane na terenach otwartych w obsadzie wynoszącej ok. 0,32 sztuki na hektar, które przez większość roku bytują na łąkach, jednak wykorzystują również tereny zakrzaczone i leśne jako ochronę przed niekorzystnymi czynnikami zewnętrznymi (m.in. wysokie temperatury, dokuczliwe ataki owadów). W przypadku hodowli ekstensywnej otwarty dostęp do drzewostanów może wywierać wpływ na jakość drzew i tempo ich odnowienia, co ma istotne znaczenie dla gospodarki leśnej na danym obszarze [Doboszewski i in. 2017]. Przebywanie koni w lasach wywiera duży wpływ na roślinność drzew i krzewów poprzez: zgryzanie liści i pędów, łamanie gałęzi w wyniku ocierania się, spałowanie kory oraz ścinanie siewek i odrostów, niemniej odpowiednio ukierunkowany wypas koni sprzyja ochronie terenów otwartych przed sukcesją drzew i krzewów [Klich 2009].

ZNACZENIE WYPASU KONI DLA BEZKRĘGOWCÓW I MIKROORGANIZMÓW GLEBOWYCH

Wpływ wypasu koni nie ogranicza się wyłącznie do roślinności i owadów zapylających. Istotnym elementem ich oddziaływania na środowisko jest tworzenie zasobów pokarmowych oraz siedliskowych dla saprotrofów i bezkręgowców glebowych [Nichols i in. 2008, Sun i in. 2024]. Istotnym elementem krajobrazu pastwiskowego są odchody koni, zwłaszcza w systemach ekstensywnych, gdzie nie są one usuwane ani przemieszczane. Stanowią zasobne źródło materii organicznej, bogatej w azot, fosfor, potas oraz mikroelementy. Poprzez wprowadzenie tej materii do środowiska glebowego następuje wzmożenie aktywności mikroorganizmów saprofitycznych, przyspieszenie procesów mineralizacji i zwiększenie tempa cyklów biogeochemicznych [Sitters i Andriuzzi 2019]. Odchody końskie, charakteryzujące się dużą zawartością niestrawionej materii organicznej, są szybko kolonizowane przez koprofagiczne chrząszcze, muchówki i grzyby. Różnorodność chrząszczy związanych z odchodami jest skorelowana z obecnością dużych roślinożerców oraz częstotliwością ich defekacji w terenie [Tonelli i in. 2018, Ríos−Díaz i in. 2020]. Działalność bezkręgowców i mikroorganizmów jest ściśle związana z obecnością presji wypasu, jej brak prowadzi do homogenizacji środowiska i zaniku grup specjalistycznych [van Klink i in. 2016]. Żerowanie, przemieszczanie się i defekacja koni powodują powstawanie mikrohabitatów różnorodnych zarówno przestrzennie, jak i funkcjonalnie. Wpływa to nie tylko na strukturę pokarmową środowiska, ale również na mikroklimat i dynamikę rozkładu materii organicznej. Systematyczne rozprzestrzenianie nawozu przez zwierzęta i jego wtórne przetwarzanie przez bezkręgowce odgrywa istotną rolę w obiegu składników mineralnych. W efekcie gleba na wypasanych powierzchniach odznacza się wyższą aktywnością biologiczną i enzymatyczną w porównaniu z glebami nieużytkowanymi [Gedgafova i in. 2023].

Badania mikrobiologiczne wykazały, że intensywność wypasu wpływa na skład mikrobiomu glebowego, w szczególności na obecność promieniowców (*Actinobacteria*), które stają się przeważające, co stymuluje procesy mineralizacji i poprawia produktywność gleby. Umiarkowana intensywność wypasu sprzyja także zwiększeniu zawartości węgla i azotu w glebie, poprawia skład i strukturę agregatów glebowych, co sprzyja lepszej stabilności i produktywności ekosystemu [He i in. 2011, Xun i in. 2018]. Pod wpływem wypasu koni poprawiają się również właściwości fizyczne gleby, takie jak porowatość, zdolność infiltracyjna oraz przepuszczalność. Proces ten przyczynia się do odbudowy mikrobioty glebowej i wspiera odbudowę siedlisk na gruntach porolnych oraz marginalnych [Kenny i in. 2023]. Intensywność wypasu modyfikuje strukturę bakterii glebowych, w tym grup odpowiedzialnych za przemiany azotu i węgla. Umiarkowana presja wypasu zwiększa udział grup promujących mineralizację, co przekłada się na poprawę parametrów żyzności gleby. Ponadto aktywność i przemieszczanie się koni wpływa na ugniatanie gleby i tworzy przestrzenną różnorodność mikrośrodowisk, zwiększając retencję wody w glebie i ułatwiając rozwój mikroorganizmów [Qu i in. 2016].

Wypas koni nie tylko wpływa na florę i faunę bezkręgowców, ale może również modyfikować warunki życia i zasiedlania siedlisk przez awifaunę łąkową. Badania prowadzone w Europie Środkowej wykazały, że naturalny wypas koni i bydła przyczynia się do wzrostu liczebności i różnorodności gatunkowej ptaków zasiedlających otwarte siedliska, w tym gatunków lęgowych. W warunkach ekstensywnego wypasu obserwuje się większe zagęszczenie ptaków łąkowych oraz większy sukces lęgowy w porównaniu z obszarami niewypasanymi lub koszonymi [Lovász i in. 2024]. Równocześnie utrzymywanie pastwisk poprzez wypas wspomaga rozwój siedlisk zgodnych z wymaganiami ochrony gatunków i siedlisk Natura 2000 [Council Directive 92/43/EEC 1992].

W systemach rolniczych, gdzie zrezygnowano z użytkowania ekstensywnego, obserwuje się szybkie zarastanie powierzchni roślinnością krzewiastą i drzewiastą, co skutkuje wypieraniem gatunków typowych dla otwartych użytków zielonych [Lovász i in. 2024]. Utrzymanie odpowiedniego poziomu presji roślinożerców (np. koni) zapobiega zamknięciu siedlisk i pozwala na długoterminowe utrzymanie bogactwa florystycznego i funkcjonalnego [Herrero-Jáuregui i Oesterheld 2017]. Pozytywny wpływ koni na różnorodność biologiczną dotyczy także stawonogów, a w tym bezpośrednio zapylaczy. Ich bioróżnorodność nie zależy wyłącznie od obecności roślin kwitnących, ale także od struktury siedliska i jego ciągłości przestrzennej. Wypas koni, poprzez modyfikację struktury runi, tworzy warunki korzystne dla wielu gatunków owadów. Przerwy w pokrywie roślinnej, tzw. place wypasowe, sprzyjają występowaniu pszczół samotnic i muchówek zapylających, które wymagają otwartych, nagrzewających się powierzchni do rozrodu [Kleijn i in. 2015]. Obecność koni sprzyja wzrostowi różnorodności stawonogów w siedliskach trawiastych, w tym gatunków saproksylicznych, chrząszczy, roztoczy i nicieni, co poprawia odporność ekosystemów na różne zaburzenia. Występowanie zróżnicowanych mikroklimatów w obrębie pastwisk, od ciepłych, suchych mikrosiedlisk po wilgotniejsze enklawy, tworzy warunki dla współwystępowania licznych grup troficznych [van Klink i in. 2016].

ZNACZENIE OCHRONNE I KRAJOBRAZOWE WYPASU KONI

Z punktu widzenia praktyki ochrony przyrody i rolnictwa ekologicznego, ekstensywny wypas koni może być z powodzeniem integrowany z celami polityki rolno-środowiskowej. Programy rolno-środowiskowo-klimatyczne (PROW) przewidują wsparcie dla rolników utrzymujących łąki i pastwiska w sposób tradycyjny, bez intensywnego nawożenia oraz z ograniczonymi zabiegami mechanicznymi [Rozporządzenie… 2023]. W tym kontekście konie stają się naturalnym narzędziem przywracania równowagi przyrodniczej na terenach zdegradowanych oraz siedliskach wymagających czynnej ochrony. Odpowiednio dobrana obsada pastwiskowa (maksymalnie pięć sztuk, a optymalnie dwie sztuki na hektar), sezonowość wypasu oraz kontrola długości wypasu w sezonie wegetacyjnym mają kluczowe znaczenie dla uzyskania pozytywnych efektów ekologicznych. Zbyt intensywny wypas prowadzi do obniżenia liczby gatunków i degradacji struktury runi, natomiast brak wypasu powoduje sukcesję w kierunku siedlisk zdominowanych przez roślinność drzewiastą lub ekspansywną. Równowaga pomiędzy nadmierną eksploatacją, a jej całkowitym zaniechaniem stanowi fundament skutecznego zarządzania przyrodą w systemach pasterskich [Schmitz i Isselstein 2020]. Na szczególną uwagę zasługuje fakt, że wypas koni sprzyja nie tylko gatunkom chronionym, ale również tym o statusie wskaźnikowym dla siedlisk półnaturalnych. Utrzymanie obecności roślin runi pastwiskowej takich jak *Centaurium tenuiflorum*, *Cirsium vulgare*, *Ranunculus ophioglossifolius*, *Trifolium ornithopodioides*, *Trifolium squamosum* wymaga nie tylko ochrony prawnej, ale też konkretnych działań w terenie, a wypas ekstensywny umożliwia nasionom roślin rzadkich dotarcie do gleby i kiełkowanie, co jest kluczowym czynnikiem ich wzrostu [Schmitz i Isselstein 2020]. Nie każde siedlisko trawiaste będzie reagować w taki sam sposób na presję wypasu – należy uwzględnić żyzność gleby, uwilgotnienie, występowanie gatunków wskaźnikowych, a także wcześniejszą historię użytkowania. Sukces ochrony siedlisk zależy od wyważonego dostosowania presji roślinożerców do konkretnej mozaiki przyrodniczej. W niektórych przypadkach wymagane jest łączenie wypasu z okresowym wykaszaniem części powierzchni lub regulacją dostępu zwierząt do określonych fragmentów [Török i in. 2011].

Ekstensywny wypas koni odgrywa również istotną rolę w kontekście ochrony krajobrazu kulturowego. Tradycyjne formy użytkowania ziemi, w tym pasterstwo i chów wolnowybiegowy, stanowią nieodłączny element mozaiki kulturowo-przyrodniczej wielu regionów Europy [Jaworski i in. 2018]. W Polsce na obszarach takich jak Bieszczady, Podlasie czy Roztocze wypas koni przyczynia się do utrzymania struktur historycznych. Jednym z istotnych walorów wypasu koni jest ich mobilność i zdolność do użytkowania trudno dostępnych siedlisk, np. terenów pagórkowatych, nieużytków porolnych czy obszarów bagiennych, gdzie użytkowanie mechaniczne jest nieefektywne [Topczewska i in. 2022]. Co więcej, wiele ras koni nie wymaga ani instalacji specjalistycznych urządzeń do zadawania paszy, ani wysokiej jakości paszy, na przykład prymitywne konie huculskie, co czyni je rasą szczególnie przydatną do działań ochronnych prowadzonych na dużych ekstensywnie użytkowanych obszarach Topczewska i in. 2022]. W Europie przytoczyć można o wiele więcej przykładów chowu ekstensywnego, gdzie konie odgrywają ważną rolę w kształtowaniu krajobrazu kulturowego i ochronie przyrody. W Hiszpanii konie Cabalo Galego utrzymywane są w systemach półdzikich, gdzie pełnią funkcję naturalnych regulatorów roślinności w górskich ekosystemach Galicji. W Portugalii rasa Garrano wypasana w Parku Narodowym Peneda-Gerês przyczynia się do ograniczania sukcesji drzewiastej oraz zmniejszania ryzyka pożarów. We Francji konie Camargue, żyjące swobodnie w deltach Rodanu, wspierają utrzymanie mozaiki siedlisk bagiennych i pastwiskowych. Z kolei w Anglii populacje półdzikich kuców, takich jak Exmoor, Dartmoor czy New Forest pony, są kluczowe dla zachowania bioróżnorodności wrzosowisk i łąk [Rewilding Europe 2012]. W kontekście zmian klimatycznych i utraty siedlisk półnaturalnych, wypas koni zyskuje na znaczeniu jako metoda wspierająca odporność ekosystemów. Obecność dużych roślinożerców może pełnić funkcję tzw. bufora ekologicznego, zmniejszającego ryzyko jednoczesnego zaniku wielu gatunków zależnych od otwartych mało przekształconych siedlisk. Różnorodność funkcjonalna bezkręgowców i mikroorganizmów jest ściśle związana z obecnością presji wypasu, jej brak prowadzi do homogenizacji środowiska i zaniku grup specjalistycznych [van Klink i in. 2016].

ETOLOGICZNE ZNACZENIE EKSTENSYWNEGO WYPASU KONI

Ekstensywny system utrzymania koni, oparty na wypasie w środowisku zbliżonym do naturalnego, oferuje zwierzętom warunki umożliwiające realizację szerokiego repertuaru zachowań specyficznych dla danego gatunku. W odróżnieniu od systemów intensywnych, ograniczających przestrzeń i kontakty społeczne, systemy ekstensywne wspierają dobrostan psychiczny i fizyczny koni, co znajduje potwierdzenie w etologii oraz badaniach z zakresu zoopsychologii [Hausberger i in. 2012]. Konie jako gatunek wybitnie społeczny w naturze funkcjonują w grupach rodzinnych lub tzw. tabunach i bandach, w których obserwuje się złożone relacje dominacyjne, afiliacyjne i komunikacyjne. W warunkach wypasu ekstensywnego, gdzie dostęp do przestrzeni i swoboda ruchu nie są ograniczone, konie mogą nawiązywać i utrzymywać stabilne więzi społeczne, tworzyć grupy stabilne składowo i dynamicznie kształtować hierarchie społeczne [Ransom i Cade 2009]. Zachowania społeczne obserwowane w stadach koni wypasanych w systemie ekstensywnym obejmują m.in. zabawy młodych osobników, wspólne żerowanie oraz formowanie koalicji w sytuacjach stresowych. Sprzyja to rozwojowi poznawczemu koni oraz pozytywnie wpływa na odporność fizjologiczną tych zwierząt [McGreevy 2012]. Konie utrzymywane w systemach wypasowych przejawiają większą stabilność emocjonalną i łatwiejszą adaptację do nowych bodźców. Osobniki pochodzące z ekstensywnych warunków utrzymania są mniej reaktywne na nieznane dźwięki i obiekty, co może przekładać się na wyższe bezpieczeństwo użytkowania tych zwierząt w rekreacji i pracy [Lansade i Bouissou 2008]. Ponadto konie utrzymywane w systemie wolnowybiegowym cechują się wyższą odpornością i mniejszym zapotrzebowaniem na interwencje weterynaryjne. Naturalna selekcja środowiskowa sprzyja utrzymywaniu osobników zdrowych i dobrze przystosowanych, co jest istotne z punktu widzenia zarówno ekonomiki chowu, jak i ochrony lokalnych ras koni prymitywnych [Topczewska i in. 2022].

Jedną z ras chętnie utrzymywanych w systemie bezstajennym są koniki polskie, objęte w naszym kraju programem ochrony zasobów genetycznych. Hodowla tych prymitywnych koni w systemie rezerwatowym umożliwia zapewnienie im warunków jak najbardziej zbliżonych do naturalnych i podtrzymywanie ich charakterystycznych cech rasowych w sposób naturalny, a nie poprzez zootechniczną selekcję. W praktyce oznacza to, iż koniki przez cały rok przebywają w rezerwacie leśnym, a ingerencja człowieka, zgodnie z założeniem programu hodowlanego, jest ograniczona do minimum [Polski Związek Hodowców Koni 2020]. Taki system utrzymania koników pozwala na pełne uzewnętrznienie ich wrodzonych zachowań, których najwyraźniejszym przejawem są stosunki utworzone w grupie koni wraz z determinującym je systemem hierarchii. Zatem koniki polskie, oprócz ich roli w pielęgnacji obszarów cennych przyrodniczo, są również doskonałym modelem do badania behawioru w populacjach koni dziko żyjących [Łuczyńska i in. 2008].

WADY I OGRANICZENIA EKSTENSYWNEGO WYPASU KONI

Choć wolnowybiegowy system utrzymania koni jest często oceniany jako bardziej naturalny i zgodny z etologią gatunku, jego stosowanie wiąże się również z istotnymi ograniczeniami. Jednym z najczęściej podkreślanych problemów jest trudność w systematycznej kontroli stanu zdrowia tych zwierząt. Konie utrzymywane na rozległych terenach są mniej dostępne do codziennej obserwacji, co może skutkować opóźnioną diagnozą urazów, infekcji i chorób metabolicznych, a tym samym pogorszeniem rokowania, wydłużeniem procesu leczenia, a nawet zagrożeniem życia, utrudniona jest również kontrola rodzaju i ilości paszy pobieranej przez zwierzęta [Raspa i in. 2024]. W szczycie sezonu pastwiskowego często pasza ma bardzo wysoką wartość energetyczną, co zwiększa u koni ryzyko rozwoju otyłości, insulinooporności oraz wtórnych powikłań, takich jak ochwat, stanowiący jedno z najpoważniejszych zagrożeń zdrowotnych w tym modelu utrzymania, zimą zaś niektóre zwierzęta wymagają indywidualnego dokarmiania [Geor 2010].

Kolejnym wyzwaniem jest wpływ wypasu na środowisko glebowe i roślinne. Przy zbyt dużym zagęszczeniu zwierząt (powyżej pięciu sztuk na hektar) obserwuje się intensywną akumulację azotu w glebie, co prowadzi do zaburzeń równowagi ekosystemu, degradacji runi pastwiskowej oraz zwiększonej presji na lokalne zasoby przyrodnicze [Baumgartner i in. 2021]. Brak rotacji w użytkowaniu pastwisk dodatkowo nasila te zjawiska, skutkując zadeptywaniem powierzchni gleby, utratą darni, wzrostem udziału gatunków mniej pożądanych i w efekcie spadkiem wartości paszowej roślinności oraz różnorodności mikrobiologicznej pastwisk [Williams i in. 2020]. Może to prowadzić do przyspieszonej erozji gleby na tych terenach. Zdarzają się sytuacje, kiedy wypas koni traktowany jest jako proces ekologiczny o znaczeniu równym naturalnym zaburzeniom, takim jak pożary, powodzie czy sukcesje pierwotne [Mirzabaev i in. 2016].

PODSUMOWANIE

Ekstensywny system utrzymania koni stanowi model użytkowania zwierząt gospodarskich, który harmonizuje cele produkcyjne z ochroną środowiska oraz wspieraniem bioróżnorodności. Jego wdrożenie przyczynia się do zachowania integralności funkcjonalnej ekosystemów lądowych poprzez aktywowanie mechanizmów ekologicznych nieobecnych lub silnie ograniczonych w systemach intensywnych. Obecność koni na trwałych użytkach zielonych wspiera dekompozycję materii organicznej, obieg pierwiastków i tworzenie mikrosiedlisk, co w konsekwencji przekłada się na wzrost jakości gleby, zwiększenie jej pojemności wodnej i stabilizację procesów biogeochemicznych. Jednocześnie obecność koprofagicznej i zapylającej entomofauny, wzbogaconej przez mozaikową strukturę pastwisk, prowadzi do wzmocnienia usług ekosystemowych takich jak zapylanie, rozkład resztek organicznych i biologiczna kontrola populacji szkodników. Z kolei urozmaicona struktura runi i siedlisk sprzyja zachowaniu populacji ptaków łąkowych i drapieżnych, których obecność świadczy o wysokiej wartości przyrodniczej użytkowanych terenów. Kluczowe znaczenie ma również wpływ systemu na fitosocjologię poprzez dynamiczne przekształcanie roślinności – wypas koni przeciwdziała sukcesji drzewiastej, zachowując półnaturalne zbiorowiska o wysokim wskaźniku różnorodności gatunkowej. Na podstawie analizy dostępnych opracowań naukowych można stwierdzić, że ekstensywny wypas koni pełni funkcję nie tylko użytkową, ale i konserwatorską, szczególnie w odniesieniu do siedlisk cennych przyrodniczo. Model ten znajduje zastosowanie jako narzędzie czynnej ochrony przyrody w obszarach Natura 2000, parkach krajobrazowych czy strefach buforowych wokół obszarów chronionych. Dodatkowo wypas ten wpisuje się w działania adaptacyjne do zmian klimatu poprzez wspieranie sekwestracji węgla, retencję wody i łagodzenie skutków ekstremalnych zjawisk pogodowych. W obliczu nasilających się procesów degradacji gleb, uproszczenia krajobrazów rolniczych oraz utraty siedlisk półnaturalnych rekomenduje się szerokie wdrażanie systemów ekstensywnego wypasu koni jako praktyk o strategicznym znaczeniu dla ochrony różnorodności biologicznej, przeciwdziałania zmianom klimatu i utrzymania funkcjonalnych, stabilnych agroekosystemów. W wielu regionach Europy wypas koni jest stosowany jako element biologicznego zarządzania glebami zdegradowanymi lub narażonymi na erozję. W kontekście zmian klimatycznych i utraty siedlisk półnaturalnych wypas koni zyskuje na znaczeniu jako metoda wspierająca odporność ekosystemów – może pełnić funkcję tzw. bufora ekologicznego, zmniejszającego ryzyko jednoczesnego zaniku wielu gatunków zależnych od otwartych, mało przekształconych siedlisk. Badania etologiczne potwierdzają, że systemy ekstensywne wspierają zarówno ochronę środowiska i bioróżnorodność, jak i dobrostan koni, odpowiadając ich potrzebom gatunkowym, fizjologicznym oraz społecznym. Ekstensywny chów wymaga oczywiście starannie zaplanowanego nadzoru weterynaryjnego, monitorowania kondycji zwierząt oraz odpowiedniego zarządzania pastwiskami, aby zminimalizować ryzyka zarówno zdrowotne, jak i środowiskowe. Niemniej jednak w dobie wzrastających oczekiwań społecznych wobec dobrostanu zwierząt gospodarskich wolnowybiegowy wypas koni stale zyskuje na znaczeniu jako etyczna i ekologiczna forma użytkowania terenów zielonych.

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Summary. The aim of this work is to present an extensive horse husbandry system, which is a model for livestock farming that harmoniously combines production goals with environmental protection and biodiversity support. The topics covered include the impact of horse grazing on changes in pasture vegetation composition, the impact of horse manure on soil microflora and biogeochemical cycles, the importance of grazing for ornithofauna and entomofauna, and the impact on ecosystem stability. Phytosociological variability and vegetation succession were analysed, as well as the potential benefits of horse grazing in the context of nature conservation and agri-environmental policy. It was found that, despite certain limitations, horse grazing can be an effective tool for supporting biodiversity, water retention and carbon sequestration, contributing to the strategy of sustainable agriculture and adaptation to climate change, while taking into account the welfare needs of these animals.

Keywords: horses, biodiversity, extensive grazing, sustainable agriculture, soil microbiota, pastures

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The importance of horses' senses in a nutritional context

Abstract. The horse's senses are very acute and geared to constantly analyse the stimuli coming from the environment. Their role in choosing the right feed is very important and often underestimated by their caretakers. Compared to their wild ancestors, nowadays horses are generally not free to choose the type and amount of feed. Instead, they are provided with feed selected and prepared by humans. It is not uncommon to encounter the phenomenon of so-called food neophobia, i.e. horses' refusal to eat feed with an unfamiliar taste or smell. This also applies to the consumption of supplements, medication and sometimes even water, which can be quite a problem for horse users and can even lead to health disorders for these animals. Therefore, this paper explores the topic of the role of horses' senses in terms of their nutrition.

Keywords: equids, sense organs, horse nutrition, diet selection, food preferences

INTRODUCTION

Horses were domesticated about 5,500 years ago [Orlando 2020]. Since then, their living conditions and the type and amount of food they consume have been dependent on humans. The diet of domesticated horses gradually changed because horses used by humans needed feed that was richer in nutrients. Nevertheless, their general nutritional needs, determined by the specific structure of their digestive system and fermentation mainly in

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the cecum and large colon, remained unchanged [Ralston 2021]. Nowadays, it is very rare to find horses living in the wild – this is generally in nature reserves and other conservation areas [Naundrup and Svenning 2015]. Through evolution, horses have adapted to selectively choose and consume a wide range of plant species [Van den Berg et al. 2016b]. Horses are herbivores with a constant secretion of acid in the stomach, so they need to eat regularly in small portions to avoid digestive problems [Roig-Pons et al. 2025]. They spend 16–20 hours a day grazing, which consists of taking a small amount of forage and then moving a few steps to the next feeding station [Sarrafchi and Blokhuis 2013, Van den Berg et al. 2015]. This natural foraging behaviour also occurs in stabled horses when they are offered a variety of feeds [Goodwin et al. 2005b]. This way, equines can select the best food source based on visual cues, odour, taste, texture, availability and variety [Goodwin et al. 2005a, Chodkiewicz 2020, Rørvang et al. 2020]. Van den Berg et al. [2016a] indicated that horses are primarily guided by nutritional value, followed by taste and smell, when choosing a food source. Previous studies have shown that free-roaming horses eat up to 50 different plant species [Van den Berg et al. 2015]. Because poisonous plants are an integral part of many horse pastures around the world, it is important that horses be able to make appropriate dietary choices to avoid fatal poisoning [Pfister et al. 2010]. Optimal feeding is crucial for survival and functioning of the organism and is shaped by both the characteristics of the available feed and the animal's selective feeding strategies [Culda and Stermin 2019, Sahu et al. 2020]. Therefore, gathering information about potential food using various sensory modalities makes them extremely important in equine nutrition.

Horses living in stable conditions consume a variety of plant-based fed, depending on the climatic zone, availability of different plant species and storage method: hay, haylage, oats, barley, corn, alfalfa and others [Murray et al. 2015, Harris et al. 2017]. The use of complete industrial feeds, feed concentrates and supplements is also becoming more widespread. Currently, horses consume roughage selected and prepared by humans, so they do not make full use of their ability to selective choose [Stegelmeier 2011]. Because of their natural feeding pattern, which involves foraging and feeding for most of the day, horses may become bored or frustrated if they are unable to perform this behaviour [Roig-Pons et al. 2025]. A lack of adequate daily forage provision can lead to behavioural disorders, and is one of the frequently mentioned reasons for a reduced rejection of toxic plants [Sarrafchi and Blokhuis 2013, Sroka et al. 2022]. In reality, limited free search in domesticated horses may be the reason for a gradual decline in the ability to recognise noxious or poisonous plants [Stegelmeier 2011].

Horses evolved as flight animals, which is why they are very sensitive to environmental stimuli [Marliani et al. 2021]. Their alertness allows rapid detection and identification of the stressor which was crucial to survive in the wild [Apfelbach et al. 2005]. Horses' cautiousness also manifests itself in neophobia, i.e. fear of novelty that can be associated with various stimuli, including tastes or smells [Lansade et al. 2008a]. This means that there are situations when horses refuse to eat feed with an unfamiliar odour or taste or when they prefer the taste of one feed and do not want to take another. Combined with additional individual preferences, this can lead to problems in keeping horses in an adequate nutritional state [Van den Berg et al. 2016b, Merkies et al. 2024]. For this reason, this article analyses the role of the various senses of horses in the processes of feed selection and consumption. Each sensory organ, due to its characteristic biological and neurophysiological conditions, has a different contribution to make in delivering the received stimuli to the brain [Narloch 2016]. Horses' willingness to consume feed is influenced by its taste, smell, texture and visual cues [Goodwin et al. 2005a, Chodkiewicz 2020, Krueger and Flauger 2011]. Therefore, the senses of taste, smell, touch, and sight play the most significant role in assessing the suitability of feed and are discussed in this article.

This is a review article and aims to discuss the importance of taste, smell, touch and sight in the context of feed selection by horses. The paper refers to numerous scientific studies and other review articles, discussing the aspects of the functioning of the senses, nutrition, biology and the welfare of horses. The selection of scientific research for this paper was conducted with databases such as Google Scholar, Scopus, and Web of Science. The keywords applied included the expressions „horse senses", „horse nutrition", „feeding behavior of horses", „sense of smell and taste in horses", „touch in horses," and „food selection by horses".

Sense of taste and smell

Chemical senses, which include taste and the functionally related sense of smell, are considered one of the oldest forms of animal adaptation [Krueger and Flauger 2011]. They are closely related and much more acute than in humans. The sensory properties of feed are usually perceived by domestic animals in the following order: appearance, aroma, texture and taste. However, horses rely most on odour and taste, when selecting feed or plants in a pasture [Perry et al. 2024]. Horses perceive their environment differently than humans, and sensory abilities in humans and horses also differ [Stachurska et al. 2022]. The choice of feed for horses is largely based on olfactory and taste sensations, while for humans it is mainly based on visual sensations [Francis et al. 2020]. Taste is a sense that allows humans to evaluate the chemical properties of a substance in terms of its suitability for consumption. Taste information is received only in the oral area. However, most of the taste sensations experienced by horses while eating are simultaneously perceived as olfactory information from the nasal cavity area [Van den Berg et al. 2016b]. Horses usually smell before eating. This activity is due to the clear connection between taste and olfactory sensations. Before food reaches the mouth, the horse examines it thoroughly using its olfactory receptors and vibrissae [Perry et al. 2024]. The surface of the horse's tongue is covered with numerous structures called taste buds, which are responsible for the sensation of taste. In the central part of the taste buds are taste receptors, which are equipped with special projections called microvilli. Taste nerve cells are concentrated in the taste buds of the mouth and throat. They react to food or drink mixed with saliva. These surface cells send taste information to nearby nerve fibres and then to the brain. In herbivorous mammals, i.e. also in equines, taste perception is better developed than in predators. Herbivores have a significantly higher number of taste buds than predators, which is related to the need to detect toxic substances in the plants they eat [Lunceford and Kubanek 2015].

Taste perception in horses is highly developed and plays a key role in their daily life, especially during food selection. Taste sensations provide the body with information about nutritional values and help to identify harmful or spoiled feed, protecting the horse from consuming poisonous or stale food [Tomczynski et al. 2002a, Rørvang et al. 2020]. Before domestication, horses used their sense of taste to select food rich in essential nutrients and to avoid eating poisonous plants. Nowadays, they are able to select vegetation in the pasture and forage provided by humans, thus rejecting what does not suit their taste preferences [Van den Berg et al. 2016b]. Horses can detect four out of five types of taste: sweet, sour, salty and bitter. There is currently very little information on whether horses can detect umami, known colloquially as meat or dry taste [Van den Berg et al. 2016a]. The vast majority of horses prefer sweet and salty tastes and avoid bitter and sour tastes [Janczarek et al. 2018]. The sweet taste of food often indicates the content of a simple source of energy, while a salty taste indicates the content of sodium and potassium cations. Food perceived as bitter may signal the presence of poisonous substances, while a sour taste may indicate possibly spoiled food [Van den Berg et al. 2016b]. Feed flavour is not limited to taste sensations alone, but is a combination of both taste, smell and texture [Tomczynski et al. 2002a]. Horses may avoid not only indigestible or poisonous plant species, but also those perceived by them as unpalatable [Janczarek et al. 2018].

The taste of feed affects horse's appetite, and thus the acceptance of feed by horses and the time of its consumption. Appetite is determined by so-called pre-gastric factors, which include the taste, smell and texture of the feed [Van den Berg et al. 2016b, Rørvang et al. 2020]. Horses often reject feed that doesn't match their individual taste preferences. As shown by Stachurska et al. [2022], moistening and sweetening feed has a potential to increase the horses' willingness to eat. Horse breeders often add various flavored supplements to the food (e.g. apple flavor) to encourage horses to eat. This is a very good solution when introducing a new feed to the diet or administer oral medications [Van den Berg et al. 2016a]. Masking tastes and odours that are unpleasant for horses (e.g. oral medications) increase the palatability and intake of feed. This method allows for „smuggling" medication in a feed when the horse refuses to take it [Stachurska et al. 2022]. Even if the nutritional value of a given feed seems to outweigh taste and smell in the horse's choice of food, individual taste preferences may be more relevant to horses [Van den Berg et al. 2016b, Merkies et al. 2024].

Like many other animal species, horses are characterised by variable and individual responses to specific tastes [Goodwin et al. 2005b]. It has been found that the taste preferences of horses depend on their breed and sex [Janczarek et al. 2018]. In the mentioned study, the greatest variation in individual taste preferences was found in purebred Arabian horses, while the mares perceived the selected treats as more palatable than the geldings. Taste and odour preferences during food selection change also with the age of the horse. Foals between 2 and 5 months of age readily accept feed with a milky taste and vanilla aroma. This preference was not observed in younger foals [Tomczyński et al. 2002b]. In adult horses, interest in feed enriched with flavour and aroma additives occurred only after four days of adaptation. It was also observed that the introduction of the scent of alfalfa and vanilla into the feed had a positive effect on the interest of adult horses in the feed [Tomczyński et al. 2002a]. According to the study conducted by Van den Berg et al. [2016b], a sweet taste or smell encourages horses to choose specific feed. The sense of taste is also important during horse training, especially in positive reinforcement. In horse training, reward (reinforcement) brings positive results and can positively influence the behavior of horses toward their trainers [Janczarek et al. 2018]. Popular treats include apples, carrots and special horse snacks. As shown by Janczarek et al. [2018], feeds with added apples or carrots were the favourite treats of all breeds studied, i.e. purebred Arabian, Anglo-Arabian, Polish Konik, and Polish cold-blooded horses. However, when introducing novel tastes and odours, the possibility of neophobia must be considered. In the study by Van den Berg et al. [2016b], most of the individuals studied showed aversion to smells that were new to horses, and consequently, to the food they were given. Considering the above, when choosing feed for horses or treats used during training, factors such as individual preferences, breed, sex and neophobia should be taken into account.

Humans are able to associate certain odours with a certain taste and vice versa, referring to the combined effect of smell and taste as taste sensations [Holcombe and Ducharne 2004]. Unlike humans, horses breathe only through the nostrils, and mouth breathing only occurs when the horse is physically deprived of the ability to breathe through the nostrils [Mellor and Beausoleil 2017]. In horses, the sense of taste is ontogenetically linked to the olfactory epithelium. During ontogenesis both organs develop from similar embryonic structures and thus share a common origin. The taste buds and the olfactory epithelium originate from the same germ layer – the ectoderm. However, it is not known whether horses can associate smell and taste and form a concept of a given taste, as is possible in humans [Goodwin et al. 2005a].

Olfaction is a key sense in most mammalian species and has a crucial role in their interactions with the environment, as well as in sexual and social behaviour [Rørvang et al. 2017]. Horses are very susceptible and sensitive to odours from their environment. Their olfactory organ consists of the olfactory epithelium which lines the inside of the upper part of the nasal cavity and connects via olfactory neurons in the nasal conchae, to the olfactory bulbs in the horse's brain [Rørvang et al. 2020]. In addition to the main olfactory system, horses have a highly developed accessory olfactory system [Rørvang et al. 2021]. It is called Jacobson's organ or the vomeronasal organ (VNO) and is located in the hard palate at the base of the nasal septum between the nasal and oral cavities, although in horses there is no connection between the VNO and the oral cavity. It enables the accurate analysis of volatile molecules (e.g. pheromones), commonly found in the body's bodily secretions. Jacobson's organ plays a key role in chemical communication [Buzek et al. 2022]. Such a highly developed olfactory apparatus implies that information from odours is relevant to horses [Rørvang et al. 2020].

The way horses respond to odours plays a key role in their daily lives, as they use olfactory cues in a variety of behavioral contexts, such as eating given food, forage search and grazing in the pasture, and aspects of herding behaviour and reproduction [Hothersall et al. 2010, Nielsen et al. 2015, Jezierski et al. 2018]. It also provides humans with valuable information regarding the welfare of the horses, for example by determining their response to food. Knowledge of horses' reactions to odours and the ability of humans to predict them are also essential to ensure safety when handling and training horses, especially when horses are exposed to many new odours [Sabiniewicz et al. 2023]. The presence of a familiar smell may increase the willingness to consume unknown foods, whereas novel odours may hinder feed intake [Stachurska et al. 2022]. For example, in the study conducted by Christensen et al. [2005], the horses had an increased number of eating bouts and became more vigilant towards their surroundings when eucalyptus oil (novel smell) was present. Horses can also be conditioned to associate a particular odour with positive stimuli, e.g. feeding, grooming. The same odour can then be used in stressful or fear-inducing situations, e.g. trailer loading or social isolation [Rørvang et al. 2021].

However, olfaction is of great importance in foraging, since it provides horses with first information about potential food before tasting it. Namely, horses often explore feed through olfactory investigation before ingestion. During such olfactory exploration, the horse sniffs and examines elements of the forage at close range, allowing it to assess chemical cues related to palatability and safety [Rørvang et al. 2022]. Wilk et al. [2024] showed that the horses' sense of smell has some potential for differentiating poisonous from non-poisonous plants without tasting, touching and seeing them. The authors observed that horses spent significantly more time on olfactory exploration of non-poisonous plants than poisonous plants. Poisonous plants might have elicited aversion in the horses and therefore they interacted with them less. The ability to recognise unpalatable, indigestible or poisonous plants by sense of smell alone without previous experience with them would be beneficial for horses. However, different food sensory characteristics (smell, taste and texture) and post-ingestive feedback (positive or negative) seems crucial in creating food aversion [Van den Berg et al. 2016a]. Horses can also recognise the scent of a predator, even if they have never encountered it before [Ahmadinejad et al. 2010]. Such skills increased the species' chances of survival in the wild and confirm how acute and well-developed sense of smell horses have [Nielsen et al. 2015, Sabiniewicz et al. 2023]. As studied by Rørvang et al. [2022], horses habituate to scent samples after repeated exposure to them, but presentation of a new odour restores an initial reaction. It shows that horses are vigilant to odours in their environment and that they recognise between them. The authors also concluded that horses naïve to the taste of a substrate may be able to link smell with taste, which is a new insight into the knowledge on horses' food intake. In the previous study Rørvang et al. [2021] observed that, similarly to the sense of taste, horses may have different odour preferences and that olfactory interest may vary with age and gestational status but not sex. Horse caretakers should therefore take these factors into account when offering new feed and treats to their horses.

Unfortunately, research on equine olfaction is sparse and primarily concerned with social recognition and reproduction [Rørvang et al. 2021, 2022]. As previously mentioned, horses are mainly guided by nutritional value, followed by taste and smell when choosing a food source. Horses can select the vegetation on the pasture and the feed given them by humans, rejecting what does not meet their taste preferences [Van den Berg et al. 2016a]. Taste sensations provide nutritional information to the body and protect the horse from consuming poisonous or spoiled food [Tomczyński et al. 2002a]. The sense of taste allows horses to assess the chemical properties of a substance in terms of its edibility. Taste information is only received in the oral cavity. However, the majority of the taste sensations that horses experience while eating are simultaneously perceived as olfactory information from the area of the nasal cavity [Van den Berg et al. 2016a]. The sense of smell and sight are the first to participate in the selection of plats that are to be eaten by horses. The appearance and smell of the plant are the first clues that are meant to encourage or discourage the animal from potential consumption. However, the taste and texture of the food determine whether the animal will continue to consume it or stop [Rørvang et al. 2021]. Toxic plants are usually characterized by a bitter taste and strong odour, and horses do not try to eat plats or other types of feed that have an unpleasant smell for them [Zeitler-Feicht 2014].

Sense of touch

From an evolutionary perspective, horses, as a species susceptible to predation, are animals with high tactile sensitivity. Horses vary in their tactile sensitivity, but individual levels of tactile sensitivity are relatively constant [Lansade et al. 2008b]. As a hunted species, horses are more sensitive to tactile stimuli, which was important for their survival. The horse's skin is equipped with many sensory receptors, and the most sensitive parts of the body are the head, neck, and withers. Delicate sensory receptors in these areas allow them to quickly respond to even subtle stimuli, such as an insect bite or a light touch from another animal, thus increasing their chances of escaping a predator in a natural condition [Saslow 2002]. Skin is the largest organ in both humans and horses. Therefore, considering the entire body, the skin is the largest sensory organ in horses. The most sensitive to touch are the snout, nostrils, and the area around the eyes, which is important for recognizing feed. Epidermal layer is thinner around the eyes, muzzle and nostrils, so sensitivity to tactile stimuli in these areas is particularly high [Rørvang et al. 2020].

The sense of touch in horses is important in the selection and intake of feed and plants [Saslow 2002]. As in many other mammalian species, horses have sensory hairs (vibrissae) around the muzzle and eyes [Mills and Redgate 2017]. These are long and stiff hairs that enable sensory evaluation of objects. Vibrissae have very different characteristics to follicles; they are thicker, do not undergo the moulting process and they are embedded in the nerves' endings. They are also a sensory organ, so their removal for aesthetic purposes is not compatible with welfare [Rørvang et al. 2020]. Vibrissae allow horses to select their feed, which helps them avoid prickly or contaminated plants in the pasture [Saslow 2002]. The horse's eyes are situated not at the front of the head, but more at the sides, its skull is quite long, so it cannot see the feed that is directly in front of its mouth. Therefore, the sensitive skin on the muzzle and the vibrissae on the lips and around the nostrils are very important when recognising feed [Rørvang et al. 2020].

Tactile perception of feed is inextricably linked to the sense of taste, because in order to know the taste of food, the horse must first take it into its mouth [Culda and Stermin 2019]. However, the decision to swallow the food placed in the mouth is also influenced by its texture, because in such a way the horses receive full information about the feed they are consuming [Janczarek et al. 2018]. Cairns et al. [2002] showed that horses had different preferences for pellets with different orosensory properties, e.g. in moisture content. The authors also state that other nutrients and overall taste and texture will change as the energy density of the food changes. Therefore, the orosensory characteristics (taste, odour, texture) of higher-energy pellets may have been perceived by horses as more palatable than lower-energy pellets.

Sense of sight

The vision of humans and animals is closely linked to their nature [Narloch 2016]. The biological structure of the visual organ plays a key role in determining the perception of the external environment [Sankey et al. 2011]. It is made up of the eyeball, optic nerve and accessory organs such as eyelids and eyelashes. Unlike the retina in the human eyeball, the equine retina has a so-called „visual stripe", which allows horses to see the entire horizon equally, but with a significantly smaller range at the top or bottom [Hanggi and Ingersoll 2009]. From an adaptive perspective, this had a huge advantage for horse living in open spaces, where they were not exposed to aerial predators. In order to sharpen a given object, the horse usually needs to raise or lower its head. Therefore, the position of the horse's head is crucial for their ability to see [Rørvang et al. 2020]. Horses also have many more rods in their retinas than humans, that allows them to see better at night [Roth et al. 2008].

During evolution, horses' sense of sight has developed significantly [Paul and Stevens 2020]. Life on the open steppes was quite challenging since horses were exposed to attacks from predators [Rørvang et al. 2020]. Horses' panoramic field of vision is due to the placement of their eyes on the sides of their skulls. As a result, horses have a very wide field of vision, approximately 330° [Ollivier et al. 2004]. Horses are characterised by a good scotopic vision, i.e., ability to see under low light conditions and have a color vision. Colour vision in horses is dichromatic, similar to that of people with red-green colour blindness.

Panoramic vision and the sharp eyesight of horses are a prime example of evolutionary adaptation to the conditions in which they lived before domestication [Paul and Stevens, 2020].

It is well known that the olfactory and taste systems play a large role in the selection of food by horses, while the visual system is less important [Van den Berg et. al 2016a]. However, research conducted by Culda and Stermin [2019] showed taking food into mouth does not mean it will be consumed. Findings showed that sight is the main sense in locating food, followed by the sense of smell involved in the choice of plants eaten and the sense of taste, which contributes less to the choice. However, in that study all four plants have been smelt and tasted, whereas only three of them were swallowed. The visual sense also played an important role in the orientation toward a certain species of the plant. These findings should be taken into account in horse nutrition since visual cues of a certain food may link to memory of prior experience. Consequently, they may reinforce the drive to seek food, or may result in food aversion [Van den Berg et al. 2016a, Fine and Riera 2019].

Unfortunately, scientific research on the importance of the sense of sight in horses in the context of food selection is scarce, previous research was conducted only by Culda and Stermin [2019]. However, the visual organ is one of the most frequently analyzed aspects in ethological studies on the senses and perception of horses [Ollivier et al. 2004]. Scientific research is primarily based on the way horses see color and perceive depth of field [Timney and Macuda 2001]. In the case of horses recognizing various objects or individuals, the horses' brain is able to integrate the cues from different sensory organs into unified information [Stone 2010]. All senses participate in processing information. When the sense of sight provides 90% certainty about the identify of a given individual, and the sense of smell confirms this information, the animal gains 99% certainty is a given situation [Breed 2010]. In study conducted by Próchniak et al. [2017], it was shown that the smell of a positively conditioned person had a more intense effect on horses than the sight of that person. Horses also showed more interest by touching, grasping, and licking the object that was the source of the smell. This indicates that during conditioning, the stimulus is more strongly associated with the smell of a human than their face.

According to the information available so far, sight is of least importance for horses when choosing food. Research and analysis on these topics are advisable. However, it should be remembered that horses use all their sensory organs in their daily functioning, which complement each other. It is likely that sense of smell, taste, and touch contribute more to the selection of food by horses. However, a better understanding of these mechanisms, and in particular a more precise knowledge of the role of the sense of sight in the selection of food, could in the future contribute to a more conscious diet for horses, which would promote their health and well-being.

SUMMARY

Horses' senses evolved to best adapt them to the environment in which they lived, to help them avoid danger from predators, and to facilitate their social life. They also play a key role in locating the source, choosing the right diet, appropriate for edibility, palatability and being non-poisonous. The senses of smell and taste, but also sight and touch, are particularly involved in food selection. Despite these facts, relatively little research has

addressed this topic. Horses are comprehensively utilised animals, so understanding the functioning of their senses and knowing how they react to new foods is important for their welfare and safe handling and use. Although horses currently have a limited ability to selectively ingest food, there are studies indicating that they have retained the ability to safely select an appropriate diet. The current state of knowledge would need to be completed with information on the relationship between the different sensory modalities in equine nutrition. Knowledge about how a horse's senses function in the context of feeding behaviour can help develop more effective strategies for introducing new feeds and reducing food neophobia. In practice, it is recommended to introduce new ingredients gradually, use methods to mask strong odours and monitor horses' reactions to changes in their diet. This approach can increase the effectives of feeding and facilitate the maintenance of proper health in horses.

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