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Management of wetland habitats in Biebrza National Park in the context of maintaining favourable conservation status

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Highlights

- Mid-forest grasslands on dunes constitute the year-round core habitat of semi-feral horses in wetlands.
- Horses preferentially use fen meadows during periods of young vegetation, particularly in spring and after mowing.
- Human management practices, such as mowing regimes, indirectly shape habitat selection by semi-feral horses.

Abstract: The protection of wetlands encompasses traditional, extensive human management practices, including mowing and grazing. This study analyses the seasonal patterns of space use and habitat selection of semi-feral Konik horses in the Biebrza National Park over a one-year period. Based on 1,351 GPS location fixes, home (95%) and core ranges (50%) were estimated using kernel density methods, and habitat selection was assessed with Jacobs' index in relation to habitat availability. The horses utilised approximately 620 ha, with marked seasonal variation in range size. Home and core ranges were smallest in summer, when food availability was highest, and largest in winter. Regardless of season, the mid-forest grasslands located on dunes constituted the core of the utilised area and were consistently selected throughout the year. Fen meadows were used more intensively in autumn and spring, particularly following mowing. Forest habitats, although frequently visited, were avoided relative to their availability. Habitat use also varied diurnally, with grasslands on dunes being used more frequently during the morning and midday, while meadows were visited more often later in the day. Results demonstrate that vegetation dynamics and land management practices influence the spatial behaviour of semi-feral horses. Extensive grazing by Konik horses may support the maintenance of open wetland habitats and contribute to land management in river valley wetlands.

Keywords: fen meadow, habitat selectivity, Konik horses, mid-forest dunes, semi-feral grazing

INTRODUCTION

Wetland ecosystems, being highly dynamic, vulnerable, and under strong long-term human influence, are among the most endangered ecosystems in the world (Mérő, Lontay and Lengyel, 2015; Biró *et al.*, 2020). Their protection under the Convention on Wetlands (2025) includes their restoration and conservation. Across Europe, traditional, extensive human management practices such as mowing and grazing played a crucial role in shaping these ecosystems (Kulik *et al.*, 2023). Thus, the

abandonment of these practices threatens the biodiversity of wetlands, leading to their progressive overgrowth with shrubs and reeds.

Grazing of cattle, horses or geese on wetlands at low stocking densities reduces tall wetland vegetation, creating a mosaic of vegetation heights and contributing to an increase in plant and animal biodiversity (e.g., Biró *et al.*, 2020; Kulik *et al.*, 2023). Within these practices, primitive breeds are increasingly used due to their high adaptability and low management requirements. In addition, marginal areas such as wetlands can serve as a place of reintroduction for large domestic herbivores, like cattle or horses, whose wild ancestor herds were part of European ecosystems in the past (Batáry *et al.*, 2015). An example of such activities is the presence of Polish primitive horses (Konik horses) in Biebrza National Park (Pol.: Biebrzański Park Narodowy – BbPN), where one herd of semi-feral animals lives freely on wetlands, only with minimum human intervention. Due to their gregarious lifestyle, spending most of their time in open areas and a different diet, horses can affect habitats in a different way than wild animals (like elk, deer) (Borowik *et al.*, 2019; Padilla *et al.*, 2023). It is therefore crucial to understand their habitat preferences, along with the factors that shape them, which can then be used to plan the assessment of the impact of animals on plant communities and further conservation activities. The majority of studies on the behaviour and habitat preferences of horses bred in reserves are based on direct observations of the animals (Auer *et al.*, 2021). Currently, the Global Location System (GLS) is increasingly used to monitor the distance travelled by animals, assess the size of their territory, and evaluate their spatial utilisation of habitats. In the case of horses, they are mainly concerned with wild-roaming animals from arid climate zones in short-term projects (ranging from 6.5 days to several weeks), e.g., in Mongolia – Przewalski's horses (Kaczensky *et al.*, 2008) or Australia – brumby (Hampson *et al.*, 2010).

In this context, the aim of this study is to describe the habitat selectivity of semi-feral Konik horses living in European wetlands, based on one-year GPS data. The main research questions are: Does the use of land by horses and their home range vary depending on the season? Could this have further implications for the conservation of habitats used by horses? The subject matter fills the existing knowledge gaps about their whole year behaviour and management, aimed at protecting habitats.

MATERIALS AND METHODS

STUDY SITES

The study was conducted in the largest national park in Poland, Biebrza National Park, over the course of one year (June 2022–May 2023), where in the Middle Basin in the Grzędy forest district (53°61'88 N, 22°76'54 E) is situated the Centre of Conservation Breeding of Konik Polski Horses and Rehabilitation of Wildlife. The climate in the Biebrza Valley is temperate continental, with an average annual air temperature of 6.8°C and a mean annual precipitation of 555 mm. The growing season in this region lasts approximately 200–205 days (Górniak, 2021). The average temperatures during the study were 8.2°C, with the highest temperature in September, and the lowest in December (Fig. 1). In particular seasons, the highest temperature was noted during the summer (average 18.2°C), with 40 days exceeding 25.0°C. On the other hand, the coldest period was winter (average 0.2°C), with 43 days with temperatures below 0°C. The winter period was characterised by 29 days with snow cover, but during only 10 days did this cover receive more than 10 cm. The sum of precipitation during the study year (Fig. 1) was 7.2 mm lower than the characteristic for the Biebrza Valley (Górniak, 2021). Despite the fact that spring flooding is typical for the meadows located in the Middle Basin BbPN, in 2023, the fen meadows in the study area were not flooded.

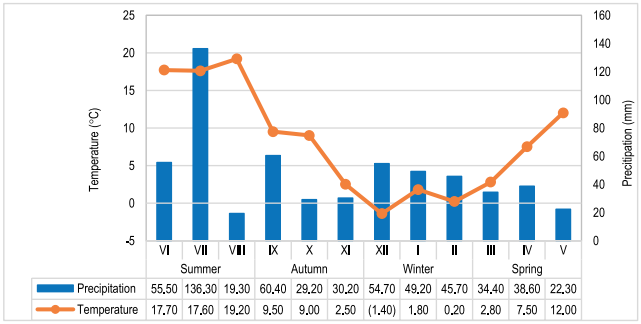

Fig. 1. The total monthly precipitation and average monthly temperature since 1st June 2022 till 31st May 2023; source: own elaboration on the basis of data from weather station Biebrza (IMGW, no date)

The structure of the land in the Middle Basin of Biebrza River valley is characterised by: meadows, mid-forest grasslands on dunes, meadows overgrown by willow-birch thickets, and forest. Detailed descriptions and shares of individual habitat types have been included in Chodkiewicz *et al.* (2023). During the study, active protection tasks (mowing of two fen meadows) were performed in the research area. The north meadow was cut from 8th until 15th August (summer) and the south meadow from 15th until 26th September (autumn).

STUDY METHODS

The herd of Konik horses (14 animals: 1 stallion, 10 mares, and 3 foals) has been moving freely within the territory of the Grzędy forest district since 2022. During the present study, a mare was randomly selected and fitted with a collar containing a GPS receiver (ECOTONE). The device gave information about their location at six-hourly intervals (four times a day starting at 00:00 a.m.). Due to animal behaviour, the data from one receiver represents the location of the herd. All collected location points were assigned to habitats (mid-forest grassland on dunes, mowed or overgrown with willow-birch thicket meadows, and forest) using QGIS 3.18.2 software, based on the orthophoto map for Poland (Geoportal, 2025). The home (95%) and core (50%) ranges were developed for data from the entire study period and specific seasons. The range sizes were defined using the Kernel Density (KD) method. Correspondence analysis (CA) was used to evaluate the differences in the frequency of Koniks' locations in individual parts of their home range (meadows, east, south, north, and centre) or habitats, during the seasons and at different times of the day. For this analysis, we used the FactoMineR and factoextra packages in the R 4.2.1 software. The habitat preferences of horses were calculated according to Jacobs' index (*JI*) of selection (Jacobs, 1974), defined as:

$$JI = (o_i - p_i)/(o_i + p_i) \quad (1)$$

where: o_i = proportion of use of the habitat (% of locations in a given habitat), p_i = proportion of availability.

The area of each habitat was determined using QGIS 3.18.2 software, based on the orthophotomap for Poland (Geoportal, 2025). JI ranges between +1, which means maximum preference, and −1 for maximum avoidance.

RESULTS

In our study, we collected and analysed 1351 fixes that showed horses' location. For particular seasons – summer, autumn, winter and spring – it was respectively 365, 334, 287 and 365. The lower number of horses' locations in autumn and winter was due to the breeding inspection carried out at that time. At the turn of November and December, horses spent almost four weeks in a fenced area close to the forester's lodge. The animals were finally released on 18th December. The area used by horses covered about 620 ha (Tab. 1, Fig. 2). The size of their home range varied by season, being the smallest in summer (approximately 376 ha) and the largest in winter (516 ha). That also corresponds to their core range, which in the harsh part of the year was almost twice as much as in summer.

Regardless of the season, horses roamed almost all over their home range (Fig. 2) but were mainly located in areas with the highest share of dunes. In summer, winter and spring, their core range includes scattered dunes primarily in the centre of their range and in the south. In autumn, they focus mainly on the southern meadow and southern dunes. The animals use the available area most evenly in winter and spring (Fig. 3a). In the summer, the highest percentage of fixes (58.4%) was noted in the centre of their area, situated between the Woźnawiejski Canal and mowed sedge meadows. In contrast, in autumn, horses stayed mainly in the southern part of their home range. The frequency of horse locations in the northern part exhibits two distinct peaks, one in summer and one in winter. In the southeastern part, the frequency of horses' locations increased from summer through the coldest part of the year and was highest in spring. The percentage of fixes in mowed meadows was the highest in autumn (Fig. 3a and b), when horses stayed in the southern meadow, and winter (when, in contrast, animals were located mainly in the northern one). Even though the animals live in this area for several vegetative seasons, they weren't located in the dense forest to the east of the mowed meadows. The frequency with which horses stayed in different habitats was related to time of day (Fig. 3c). Horses were more often located on the mid-forest grasslands on dunes in the morning and at noon than in other

Table 1. Home range and core range estimated by Kernel density for individual seasons and the whole period (1st June 2022–31st May 2023)

Range	Estimated area (ha)				
	summer	autumn	winter	spring	1st June 2022–31st May 2023
Home range (95%)	376.1	491.7	516.8	481.7	620.9
Core range (50%)	60.1	88.1	112.0	111.0	136.7

Source: own study.

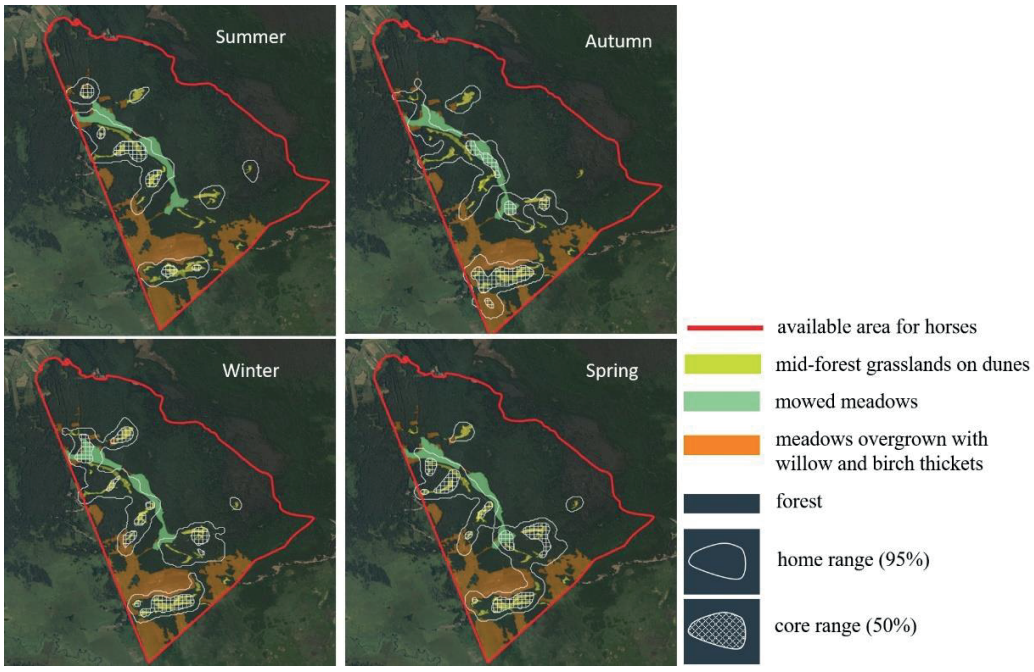

Fig. 2. Home (95%) and core (50%) range of Konik horses in Biebrza National Park (BbPN) in different seasons; source: own study

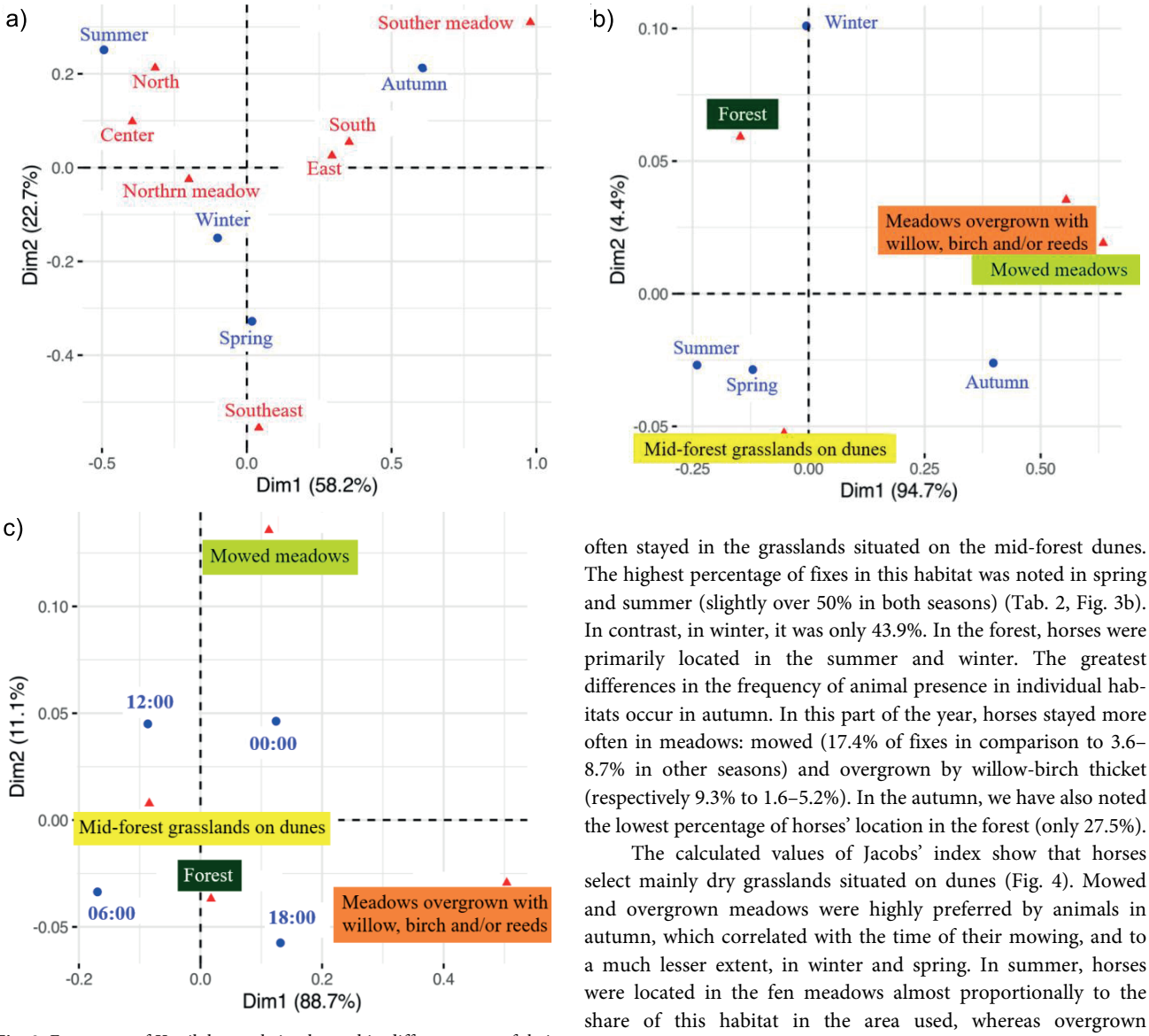

Fig. 3. Frequency of Konik horses being located in different parts of their home range (a) and habitats, depending on season (b), and in habitats depending on time of day (c); source: own study

parts of the day. On the other hand, there were relatively more fixes in the mowed meadows in the middle of the day and at midnight, whereas the overgrown ones were more often visited by the animals at 18:00 h.

Horses were most often located in open areas – on average, 62% of fixes (Tab. 2). Regardless of the seasons, the horses most often stayed in the grasslands situated on the mid-forest dunes. The highest percentage of fixes in this habitat was noted in spring and summer (slightly over 50% in both seasons) (Tab. 2, Fig. 3b). In contrast, in winter, it was only 43.9%. In the forest, horses were primarily located in the summer and winter. The greatest differences in the frequency of animal presence in individual habitats occur in autumn. In this part of the year, horses stayed more often in meadows: mowed (17.4% of fixes in comparison to 3.6–8.7% in other seasons) and overgrown by willow-birch thicket (respectively 9.3% to 1.6–5.2%). In the autumn, we have also noted the lowest percentage of horses' location in the forest (only 27.5%).

The calculated values of Jacobs' index show that horses select mainly dry grasslands situated on dunes (Fig. 4). Mowed and overgrown meadows were highly preferred by animals in autumn, which correlated with the time of their mowing, and to a much lesser extent, in winter and spring. In summer, horses were located in the fen meadows almost proportionally to the share of this habitat in the area used, whereas overgrown meadows were avoided. Although the percentage of fixes in the forest was high, the animals avoided this habitat.

DISCUSSION

According to studies from various regions, the areas used by horses can be highly diverse, ranging from more than 6 km^2 to over 300 km^2 (Miller, 1983; Bakaloudis *et al.*, 2024). The primary

Table 2. The percentage of fixes (horses' location) on the different habitats

Habitat	Season				1st June 2022–31st May 2023
	summer	autumn	winter	spring	
Mid-forest grasslands on dunes	52.6	45.8	43.9	51.5	48.8
Mowed meadows	3.6	17.4	8.7	5.2	8.5
Overgrown meadows	1.6	9.3	5.2	4.1	37.7
Forest	42.2	27.5	42.2	39.2	5.0

Source: own study.

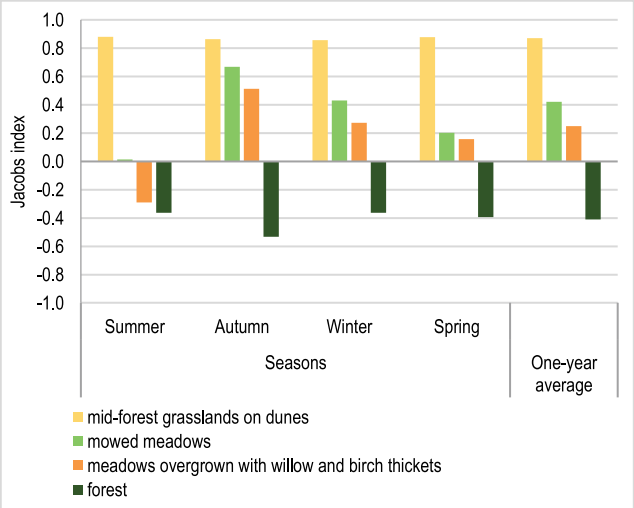

Fig. 4. Habitat preferences of Konik horses in Biebrza National Park (BbPN) in the period of 1st June 2022–31st May 2023; source: own study

factors determining the activity of horses, including the habitats they choose and their home range area are the availability of food and water (King, 2002). Horses are highly selective grazers, spending most of their time in habitats offering the most nutritious plant communities (Duncan, 1983). Throughout the year, the most important habitat type in Biebrza National Park (BbPN), are grasslands situated on mid-forest dunes. It is also confirmed by the estimated home and core ranges, which – independently of the seasons – cover mainly dunes and the adjoining forest edge. This suggests that plant communities in these semi-dry habitats provide higher nutritional value than sedge-dominated fen meadows. The home range of Konik horses in BbPN (generally about 620 ha, which is approximately 6.2 km^2) can result not only from the low nutritional value of plant communities but also from the high level of habitat patchiness, as the most preferred mid-forest grasslands are situated on dunes scattered over a large area. In the case of wild animals like elk, the habitat patchiness of available habitats even determines their migratory or sedentary strategy (Borowik *et al.*, 2019). The size of the used area can also depend on the size of a harem (King, 2002). We cannot exclude the possibility that the home range of Konik horses in BbPN will increase as the number of horses grows. However, this also means that an increase in the animal population in this area will not necessarily lead to an increase in their environmental impact.

The size of Konik horses' home and core range changes in seasons and is the smallest in summer. In addition to food availability, weather conditions and insect harassment significantly affect horse grazing behaviour and habitat choice (Chodkiewicz *et al.*, 2023). The summer of 2022 was marked by very warm weather. On hot days with temperatures above 25°C, the activity of horses is limited, and animals spend more time in the forest and on the dunes (Chodkiewicz *et al.*, 2023). Previous research conducted on horses in Poland, based on direct observations of their movement, shows that animals exhibit relatively low mobility in winter (Kownacki *et al.*, 1978) or even in autumn (Pikuła *et al.*, 2022). In such enclosures, in line with the rules of reserve breeding, horses are fed during the colder part of the year, which means that they do not have to wander in search of food and spend more time close to the laid hay. In BbPN, the lack of such supplementary feeding in winter causes the animals to move within their area more evenly. A similar pattern is also observed in the case of wild animals, such as elk (Padilla *et al.*, 2023). Due to the limited data presented, it is not possible to assess whether the height and duration of snow cover affect the use of habitats by horses during the winter. The horses did well and remained in good condition all the time, even in the period when the snow reached over 20 cm (own observations). As shown in the case of ungulate animals, snow cover exceeding 12.5 cm can significantly affect animal mobility, resulting in a narrowing of their core range and avoidance of open areas (Potapov *et al.*, 2011). However, it should be noted that this group of animals, unlike horses, is more closely related to the forest environment, and the basis of their diet is tree shoots (Scasta, Beck and Angwin, 2016).

Konik horses in BbPN exhibited a shift in preferences towards mowed and overgrown meadows between summer and autumn. Similar observations were made by Pikuła *et al.* (2022). In the Kliniska forest district, where coniferous and mixed forests prevail, horses stayed more in the forest in summer and winter, whereas in spring and autumn, they were more often localised in meadows. Although the herbaceous species constitute the basis of the Konik horses' diet, as the growing season passes and the nutrient values of plants decline, horses tend to browse more (Duncan, 1983). In BbPN, fen meadows and some mid-forest grasslands on dunes are mowed late due to the requirements of habitat and bird protection. A regrowing, young sward in autumn is a good source of feed for horses. For this reason, both the mowed southern meadow and the overgrown meadows located in the south, in the area where bush clearing began, belonged to the habitats preferred in this part of the year. These suggest that human management may indirectly influence the frequency of semi-feral horses in a given area.

The number of horses in BbPN in relation to the area that they use makes grazing very extensive; however, their presence may support the preservation of open areas, particularly meadows on mid-forest dunes, which are the most common places where these animals reside. Horses grazing at a low stocking rate can contribute to increasing the biodiversity of the sward – both the plants and animals – and its nutrient content (e.g., Ringmark, Skarin and Jansson, 2019). The question remains open as to the importance of equines in transporting nutrients between habitats. Inland mid-forest dunes belong to very dry and nutrient-poor habitats, where overgrowth is prevented by nitrogen and phosphorus deficiency (Sparrius, Sevink and Kooijman, 2012). Horses often used them for grazing and as resting places, where they also left more droppings (own observations). Elevated nitrogen deposition from faeces can accelerate the succession of *Corynephorion canescentis* communities. Another aspect is the influence of horses' presence on forest habitats, as the animals can cause damage, primarily resulting from browsing, bark stripping, and breaking branches, as well as selective grazing and leaving faeces (Boiko *et al.*, 2019). In comparison to the diets of European bison and cattle (Cromsigt *et al.*, 2018) or ungulates (Scasta, Beck and Angwin, 2016), horses have the lowest share of woody plants in the diet. Based on the home range of Konik horses in BbPN, it is evident that their presence is primarily restricted to the forest edge, particularly around mid-forest dunes with communities from *Alnetalia-glutinosae* (BDL, 2025) dominated by rather avoided by horses, *Alnus glutinosa* and more preferred by them

Betula pendula (Klich and Grudzień, 2013). Thus, in our opinion, the issue of the role of free-living horses in forest habitats requires further research.

CONCLUSION

Semi-feral horses on wetlands utilise a variety of habitats, but regardless of the season, the core of their home range is constituted by the grasslands on mid-forest dunes. The size of the area used by animals depends on the season and, therefore, the availability of food. Horses stay in fen meadows more often when there is young vegetation, which occurs in spring and after mowing. Thus, human activity can affect the habitat selectivity of horses.

CONFLICT OF INTERESTS

All authors declare that they have no conflicts of interest.

INSTITUTIONAL REVIEW BOARD STATEMENT

Ethical approval was not sought for this study because it did not involve capturing and anaesthetising animals to attach the collar. Wearing collars was not harmful to the animals.

RERERENCES

Auer, U. *et al.* (2021) "Activity time budgets – A potential tool to monitor equine welfare?" *Animals*, 11(3), 850. Available at: https://doi.org/10.3390/ani11030850.

Bakaloudis, D.E. *et al.* (2024) "Home range and habitat selection of feral horses (*Equus ferus f. caballus*) in a mountainous environment: A case study from Northern Greece," *Land*, 13(8), 1165. Available at: https://doi.org/10.3390/land13081165.

Batáry, P. *et al.* (2015) "The role of agri-environment schemes in conservation and environmental management." *Conservation Biology*, 29(4), pp. 1006–1016. Available at: https://doi.org/10.1111/cobi.12536.

Biró, M. *et al.* (2020) "Conservation and herding co-benefit from traditional extensive wetland grazing," *Agriculture, Ecosystems and Environment*, 300, 106983. Available at: https://doi.org/10.1016/j.agee.2020.106983.

Boiko, S. *et al.* (2019) "Polish pony changes lower layer biodiversity in old growth Scots pine stands," *Forests*, 10(5), 417. Available at: https://doi.org/10.3390/f10050417.

Borowik, T. *et al.* (2019) "The level of habitat patchiness influences movement strategy of moose in Eastern Poland," *PLOS One*, 15(3), e0230521. Available at: https://doi.org/10.1371/journal.pone.0230521.

Chodkiewicz, A. *et al.* (2023) "Habitat use by semi-feral horses on wetlands – three-year GPS study," *Environmental Monitoring and Assessment*, 195, 1033. Available at: https://doi.org/10.1007/s10661-023-11605-y.

Convention on Wetlands (2025) *Global Wetland Outlook 2025: Valuing, conserving, restoring and financing wetlands*. Gland, Switzerland: Secretariat of the Convention on Wetlands. Available at: https://doi.org/10.69556/GWO-2025-eng.

Cromsigt, J.P.G.M. *et al.* (2018) "Rewilding Europe's large grazer community: how functionally diverse are the diets of European bison, cattle and horses?" *Restoration Ecology*, 26(5), pp. 891–899. Available at: https://doi.org/10.1111/rec.12661.

Duncan, P. (1983) "Determinants of the use of habitat by horses in a Mediterranean wetland," *Journal of Animal Ecology*, 52, pp. 93–109. Available at: https://doi.org/10.2307/4590.

BDL (2025) *Bank Danych o Lasach [Forest Data Bank]*. Available at: https://www.bdl.lasy.gov.pl/portal/mapy (Accessed: December 1, 2025).

Geoportal (2025) *Mapy Geoportal [Geoportal maps]*. Available at: https://mapy.geoportal.gov.pl/imapnext/imap/index.html?moduleId=modulPD (Accessed: December 1, 2025).

Górniak, A. (2021) *Klimat województwa podlaskiego w czasie globalnego ocieplenia [The climate of the Podlaskie Voivodeship during global warming.]*. Białystok: Wydawnictwo Uniwersytetu w Białymstoku. Available at: http://hdl.handle.net/11320/12295 (Accessed: December 1, 2025).

Hampson, B.A. *et al.* (2010) "Distance travelled by feral horses in 'outback' Australia," *Equine Veterinary Journal*, 42(38), pp. 582–586. Available at: https://doi.org/10.1111/j.2042-3306.2010.00203.x.

IMGW (no date) *Dane pomiarowo-obserwacyjne 2022, 2023 [Measurement and observation data 2022, 2023.]*. Warszawa: Instytut Meteorologii i Gospodarki Wodnej. Available at: https://danepubliczne.imgw.pl/data/dane_pomiarowo_obserwacyjne/ (Accessed: December 1, 2025).

Jacobs, J. (1974) "Quantitative measurements of food selection," *Oecologia*, 14, pp. 413–417. Available at: https://doi.org/10.1007/BF00384581.

Kaczensky, P. *et al.* (2008) "Resource selection by sympatric wild equids in the Mongolian Gobi," *Journal of Applied Ecology*, 45(6), pp. 1762–1769. Available at: https://doi.org/10.1111/j.1365-2664.2008.01565.x.

King, S.R.B. (2002) "Home range and habitat use of free-ranging Przewalski horses at Hustai National Park, Mongolia," *Applied Animal Behaviour Science*, 78, pp. 103–113. Available at: https://doi.org/10.1016/S0168-1591(02)00087-4.

Klich, D. and Grudzień, M. (2013) "Selective use of forest habitat by Biłgoraj horses," *Belgian Journal of Zoology*, 143(2), pp. 95–105. Available at: https://doi.org/10.26496/bjz.2013.132.

Kownacki, M. *et al.* (1978) "Observation of the twenty-four hours rhythm of natural behaviour of Polish primitive horse breed for conservation of genetic resources in a forest reserve," *Genetica Polonica*, 19(1), pp. 62–77.

Kulik, M. *et al.* (2023) "Is grazing good for wet meadows? Vegetation changes caused by white-backed cattle," *Agriculture*, 13(2), 261. Available at: https://doi.org/10.3390/agriculture13020261.

Mérő, T.O., Lontay, L. and Lengyel, S. (2015) "Habitat management varying in space and time: the effects of grazing and fire management on marshland birds," *Journal of Ornithology*, 156(3), pp. 579–590. Available at: https://doi.org/10.1007/s10336-015-1202-9.

Miller, R. (1983) "Seasonal movements and home ranges of feral horse bands in Wyoming's Red Desert," *Journal of Range Management*, 36(2), pp. 199–201. Available at: https://doi.org/10.2307/3898162.

Padilla, B.J. *et al.* (2023) "Seasonal variation in size and composition of elk (*Cervus canadensis*) home range in central Appalachia," *Canadian Journal of Zoology*, 101(6), pp. 448–461. Available at: https://doi.org/10.1139/cjz-2022-0099.

Pikuła, R. *et al.* (2022) "An analysis of the annual mobility of Polish Konik horses depending on habitat, season, and time of the day," *Archives Animal Breeding*, 65, pp. 239–247. Available at: https://doi.org/10.5194/aab-65-239-2022.

Potapov, E. *et al.* (2011) "Impact of snow cover on movements and habitat choice by suburban white-tailed deer," *Bulletin of the New Jersey Academy of Science*, 56(2), pp. 5–8. Available at: https://brynathyn.edu/_media/documents/Potapov-Deer-Snow.pdf (Accessed: December 1, 2025).

Ringmark, S., Skarin, A. and Jansson, A. (2019) "Impact of year-round grazing by horses on pasture nutrient dynamics," *Animals*, 9(8), 500. Available at: https://doi.org/10.3390/ani9080500.

Scasta, J.D., Beck, J.L. and Angwin, C.A. (2016) "Meta-analysis of diet composition and potential conflict of wild horses with livestock," *Rangeland Ecology & Management*, 69(4), pp. 310–318. Available at: https://doi.org/10.1016/j.rama.2016.01.001.

Sparrius, L.B., Sevink, J. and Kooijman, A.M. (2012) "Effects of nitrogen deposition on soil and vegetation," *Plant and Soil*, 353 (1–2), pp. 261–272. Available at: https://doi.org/10.1007/s11104-011-1029-y.