Praca oryginalna *Original paper*

Spatial activity of sheep under extensive grazing conditions in relation to habitat type

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Received 13.05.2026 *Accepted 25.06.2026*

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Summary

The aim of the study was to analyse the grazing behaviour and spatial activity of Świniarka sheep in relation to habitat type under extensive grazing conditions. It was hypothesised that habitat type influences the organisation of sheep activity, as reflected in differences in habitat use and in the proportion of locomotor activity and non-locomotor behaviour. The study was conducted in the "Kózki" Nature Reserve using telemetry collars. The study sample consisted of a flock of 300 sheep, of which 10 randomly selected individuals were fitted with telemetry collars. Observations were carried out over a 10-day period during the grazing season, and 16 complete telemetry recordings comprising a total of 135 hours of observations were selected for further analysis. Based on the habitat map, four habitat types (H1-H4) differing in vegetation composition were identified. The analysis included the time spent by sheep within individual habitats, locomotor activity, non-locomotor behaviour, and distance travelled. A significant effect of habitat type on the organisation of grazing activity in sheep was demonstrated ($p < 0.05$). The highest proportion of time spent by animals, as well as non-locomotor behaviour associated mainly with resting and grazing, was recorded in habitats dominated by vegetation of the *Molinio-Arrhenatheretea* class (H1 and H4). In contrast, habitats associated with sandy grassland communities of the *Koelerio glaucae-Corynephoretea canescentis* class were characterised by a higher proportion of locomotor activity, which may suggest that these areas were used mainly during movement between other pasture fragments. The results indicate that habitat structure and vegetation composition may have been associated with differences in the way sheep utilised space under semi-natural conditions. The use of GPS telemetry monitoring proved to be a useful tool for assessing the spatial and behavioural activity of sheep under natural conditions.

Keywords: Świniarka sheep, pasture activity, GPS telemetry, habitat

The domestic sheep (*Ovis aries*) was one of the first domesticated livestock species and has played an important role in animal production and in shaping of agricultural landscapes (12). The domestication process, which began during the Neolithic period, led to the development of numerous breeds adapted to diverse environmental conditions. Among these, primitive breeds hold a special position, as they have retained many characteristics of their wild ancestors, including high resistance, adaptability, and low nutritional requirements (3, 22, 26, 39). One such breed is the Świniarka sheep, considered one of the oldest native sheep breeds in Poland, characterised by an exceptional ability to thrive in harsh environmental conditions (17).

Nowadays, the role of sheep extends beyond their use for production. They are increasingly being used in extensive farming systems and in active nature conservation, where they play a significant role in maintaining biodiversity and preventing secondary succession (41). Thanks to their mobility, selective feeding habits, and ability to utilise low-nutritional-value, sheep are able to effectively exploit habitats with diverse vegetation structure and sward quality (21, 40). Their activity influences not only vegetation structure, but also soil properties and ecosystem dynamics, making them an important factor in the management of protected areas (24). From an animal welfare perspective, grazing systems provide opportunities for the expression of natural behavioural patterns, such as grazing, locomotion, and social interactions (4, 40). Sheep are a highly gregarious species, and their behaviour is based on maintaining group cohesion and synchronizing their actions. Eye contact with other individuals, a stable social structure, and the opportunity to display affiliative behaviour are crucial to their welfare (2, 5). Life in a group offers many benefits, including support in caring for offspring and protection from predators, as well as more efficient foraging (11). The tendency to graze and gather in groups is one of the most characteristic features of sheep (29, 36). Foraging and feeding largely determine the daily activity pattern of sheep on pasture (14).

Sheep grazing behaviour results from complex interactions between environmental, social and individual factors. The most important factors determining pasture use include the botanical composition of the sward (7, 10, 13), forage availability and quality, terrain characteristics, weather conditions, shelter availability, and the presence of other animals (19, 32). By selecting particular food resources, animals simultaneously select habitats, aiming to maximise energy intake whilst minimising the costs associated with resource acquisition. This process involves behavioural decision-making related to forage availability, habitat structure, and flock organisation (7, 19, 37). In highly heterogeneous environments, sheep may face a conflict between their preference for higher-quality forage and the need to maintain contact with the group. As a result, different spatial use strategies may emerge, including intensive utilisation of selected pasture areas or movement over longer distances in search of resources (30). Previous studies have demonstrated that the spatial distribution of sheep grazing on heterogeneous vegetation mosaics is influenced not only by forage availability, but also by social behaviour, flock cohesion, and environmental features such as shelter availability and terrain organisation (32, 37).

The analysis of grazing behaviour in relation to habitat type is important both from the perspective of animal welfare and effective pasture management and nature conservation. It enables a better understanding of the mechanisms underlying habitat selection, the identification of preferred areas, and the assessment of resource utilisation. Such knowledge may be applied in practice to optimise grazing management, reduce excessive habitat exploitation, and improve animal husbandry conditions (9, 19). Despite numerous studies on sheep grazing behaviour, the number of studies analysing the relationship between habitat type and the structure of animal activity under semi-natural pasture conditions with heterogeneous vegetation remains limited. Previous studies have focused mainly on feeding preferences or general grazing patterns, whilst less attention has been paid to the spatial differentiation of sheep behaviour within habitats used for active nature conservation (30, 37). In addition, relatively few studies have combined GPS-based spatial analysis with habitat heterogeneity assessment under semi-natural grazing conditions. In studies of grazing behaviour, increasing attention has been paid to methods that enable the objective and continuous recording of animal activity under natural conditions. Although traditional direct observations provide valuable information, they are time-consuming and may be affected by observer-related limitations, including perceptual bias and the observer's influence on animal behaviour (6, 34). Consequently, modern telemetry tools, including GPS positioning systems, are increasingly being used to precisely track animal movement and analyse pasture use (30). GPS-based approaches are currently regarded as valuable tools for evaluating grazing distribution, habitat preferences, and spatial behaviour of livestock kept under extensive conditions (33). The application of such technologies makes it possible to obtain detailed data on animal location, distances travelled, movement speed, and time spent in particular habitat types. Spatial analyses based on grazing distribution may additionally provide information regarding vegetation heterogeneity and uneven pasture utilisation patterns (16). These parameters enable indirect inference regarding locomotor activity and non-locomotor behaviour under natural conditions (6, 34). The aim of the study was to analyse the grazing behaviour and spatial activity of Świniarka sheep in relation to habitat type under extensive grazing conditions. It was hypothesised that habitat type influences the organisation of sheep activity, as reflected in differences in habitat use and in the proportion of locomotor activity and non-locomotor behaviour.

Material and methods

The study was approved by The Local Ethics Committee for Animal Experimentation in Lublin, Poland (License No 104/2015).

The study involved a flock of 300 Świniarka sheep kept under a semi-extensive grazing system within the "Kózki" Nature Reserve (approximately 82 ha) located in the Mazowieckie Voivodeship, Poland. The animals were released for grazing by the farmer at approximately 7:00 a.m. onto the reserve area, where they remained until approximately 7:00 p.m. Afterwards, they were returned to the sheepfold, where they spent the night. The reserve area was characterised by considerable landscape heterogeneity and a specific arrangement of natural boundaries. The northern boundary of the area was formed by the Bug River, whereas the southern boundary was defined by marshy oxbow lake structures.

Field observations were conducted over a period of 10 days during the grazing season, between July and September. Before the flock was released onto pasture, GPS collars were fitted to 10 randomly selected sheep (Fig. 1). Animal location monitoring was performed using a Garmin Astro 320 GPS receiver combined with Garmin DC™ 50 telem-

Fig. 1. Świniarka sheep in the "Kózki" Nature Reserve; a GPS telemetry collar used for monitoring the spatial activity of the animals is visible

etry collars. The system enabled real-time tracking of animal positions. Data were recorded daily on the receiver device and subsequently exported for further analysis. According to the manufacturer, the maximum communication range between the receiver and collar was up to 14.5 km in open terrain without obstacles; however, the actual range depended on terrain configuration, vegetation cover, and environmental conditions. The DC™ 50 collars were equipped with a GPS receiver recording animal position and a lithium-ion battery providing approximately 26-54 h of operation, depending on the selected position update frequency. Recording of Świniarka sheep activity was conducted continuously between 7:00 a.m. and 7:00 p.m. The collected material included several dozen route recordings. However, only 16 recordings that met the main quality criteria – including the completeness of the recording and the absence of major interruptions in satellite signal reception – were selected for further analysis. In cases where the flock gathered near the reserve exit, the farmer decided to end grazing early. All changes in grazing duration were due to weather conditions. The average duration of a single recording was 507 minutes. In total, 135 hours of material analysed by a single observer were included in the study.

A habitat map of the study area was prepared using QGIS software, taking into account the distribution of vegetation within the reserve. Based on this, four main habitat types were distinguished. Habitat 1 (H1) was defined as grassland dominated by species of the *Molinio-Arrhenatheretea* class. Habitat 2 (H2) included grasslands dominated by species of the *Koelerio glaucae-Corynephoretea canescentis* class with the presence of species belonging to the *Molinio-Arrhenatheretea* class. Habitat 3 (H3) consisted of loose sandy grasslands of the *Koelerio glaucae-Corynephoretea canescentis* class. Habitat 4 (H4) was defined as grassland dominated by species of the *Molinio-Arrhenatheretea* class with the presence of species belonging to the *Koelerio glaucae-Corynephoretea canescentis* class.

The habitat map was imported into the BaseCamp software, where sheep movement routes were analysed in relation to the individual habitat types. GPS recordings were analysed in the BaseCamp with respect to the following parameters: locomotor activity [min], non-locomotor behaviour [min], time spent in particular habitat types [min], and distance travelled [m]. Due to the limitations of telemetry-based assessment, non-locomotor behaviour was interpreted as periods associated mainly with grazing, rumination, or resting performed without substantial displacement within the pasture area. Mean values obtained for individual habitat types from all GPS tracks were subsequently expressed as percentages of the total recorded values during the observation period.

Data analysis was performed using two levels of interpretation. In the first stage, the overall time budget of the animals was evaluated for the entire observation period, taking into account the proportion of particular behavioural activities and the time spent in specific habitat types. In the second stage, the behavioural structure within individual habitat types was analysed by comparing the proportion of locomotor activity and non-locomotor behaviour associated mainly with resting, rumination, and grazing within each habitat. Statistical analysis was performed using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA). Data analysis was performed using the GLIMMIX procedure, with Holm-Tukey correction applied to p-values. A fixed habitat effect was included in the model. Results are presented as least squares means (LS Means) with standard error (SE). Differences were considered statistically significant at $p < 0.05$.

Results and discussion

Analysis of the selected parameters revealed significant differences in sheep activity between habitats (H1-H4) ($p < 0.05$), both in relation to the entire observation period and when considering individual habitat types (Tab. 1, Fig. 2). The total time spent by sheep was highest in habitat H1, whereas the lowest proportion was observed in habitat H2, where it did not exceed 1%. Habitats H3 and H4 were characterised by intermediate values (Tab. 1). A similar distribution pattern was observed for locomotor activity, expressed

Tab. 1. Proportion of analysed behavioural parameters and distance travelled by sheep within individual habitats H1-H4 (LS Means ± SE)

Parameter	H1	H2	H3	H4
Dailytime spent in habitat [min]	69.45 ± 10.40^{a}	0.90 ± 0.14^{b}	2.98 ± 0.45^{c}	26.74 ± 3.96^{d}
Locomotor activity [min]	56.52 ± 7.00^{a}	2.42 ± 0.31^{b}	4.56 ± 0.55^{c}	36.76 ± 4.55^{d}
Non-locomotor behaviour [min]	74.90 ± 10.70^{a}	0.52 ± 0.11^{b}	2.84 ± 0.45^{c}	22.56 ± 3.22^{d}
Distance travelled [m]	55.68 ± 7.25^{a}	2.57 ± 0.35^{b}	5.12 ± 0.67^{c}	36.79 ± 4.79^{d}

Explanations: H1 – grassland dominated by species of the *Molinio-Arrhenatheretea* class; H2 – grassland dominated by species of the *Koelerio glaucae-Corynephoretea canescentis* class with the presence of species belonging to the *Molinio-Arrhenatheretea* class; H3 – loose sandy grasslands of the *Koelerio glaucae-Corynephoretea canescentis* class; H4 – grassland dominated by species of the *Molinio-Arrhenatheretea* class with the presence of species belonging to the *Koelerio glaucae-Corynephoretea canescentis* class. Differences between means within rows marked with different lowercase letters (a-d) are statistically significant at $p < 0.05$.

as locomotion time and distance, as well as for non-locomotor behaviour associated with resting and grazing. The results suggest differences in sheep space use may have been related to the floristic composition and functional characteristics of the analysed habitats (1, 8). The mosaic arrangement of habitats differing in forage quality and vegetation structure may therefore have contributed to the observed spatial differentiation of sheep activity. Studies conducted on sandy grasslands in the Bug River valley have highlighted that plant communities containing species from the *Molinio-Arrhenatheretea* class are characterised by higher forage value and greater attractiveness to livestock (18, 41). In contrast, typical sandy grasslands dominated by *Corynephorus canescens* and *Cladina mitis* are regarded as habitats of lower productivity and lower forage attractiveness (41). The highest proportion of total time spent by sheep in habitat H1 may indicate that these areas represented the main grazing zones for the studied animals. This is further supported by the activity structure observed within this habitat, where non-locomotor behaviour associated mainly with grazing and resting predominated. This pattern may reflect selective habitat use associated with the availability and distribution of forage resources, although the present study did not directly assess forage quantity or quality within the analysed habitats. Similar relationships were described by Perotto-Baldivieso et al. (28) and Mysterud et al. (25), who reported that ruminants kept in extensive systems prefer habitats that enable efficient forage intake whilst simultaneously reducing the energy costs associated with movement. Under conditions of high availability of valuable forage resources, animals tend to reduce locomotion and concentrate their activity on grazing and rumination (23).

Analysis of behavioural structure within individual habitats revealed significant differences ($p < 0.05$) in the proportions of the analysed activities (Fig. 2). In habitat H1, non-locomotor behaviour associated mainly with resting and grazing predominated, accounting for more than 75% of activity, whereas locomotor activity represented approximately 25% of activity. An opposite pattern was observed in habitat H2, where locomotor activity predominated (approximately 89%) and the proportion of non-locomotor behaviour was markedly lower. Habitats H3 and H4 were characterised by a more balanced proportion of both analysed behavioural categories, although in H4 non-locomotor behaviour associated with resting and grazing still predominated. The predominance of locomotion in habitat H2 may suggest that these areas primarily served a transit function and were mainly used during movement between other grazing sites, particularly since the total time spent in this habitat throughout the day was the lowest. Moscatelli et al. (23) demonstrated that sheep travel longer distances in habitats characterised by lower NDVI values, which was interpreted as a consequence of limited availability or lower quality of forage resources. The authors emphasised that animals increase the intensity of space exploration under conditions of lower vegetation productivity in order to optimise energy intake. A similar mechanism may also have been involved in the present study, although forage availability and quality were not assessed directly within the analysed habitat types. This interpretation is further supported by studies on the grazing behaviour of small ruminants in heterogeneous habitats. Pontes et al. (31) demonstrated that sheep utilise areas characterised by a higher proportion of high-quality forage components more intensively, whereas a decline in forage quality and availability results in an increased range of movement and diversification of grazing strategy. The authors also emphasised that the organisation of flock activity depends not only on the amount of available biomass, but also on its spatial and qualitative structure. Similarly, Sibbald et al. (37) reported that the spatial distribution of sheep within heterogeneous vegetation mosaics is strongly associated with both habitat structure and social organisation within the flock. The more balanced proportion of locomotor activity and non-locomotor behaviour observed in habitats H3 and H4 may indicate a different pattern of habitat use compared with H1 and H2. Previous studies have demonstrated that sheep grazing behaviour in complex grasslands is strongly influenced by vegetation heterogeneity and the spatial distribution of forage resources (7). In the case of habitat H4, the presence of species belonging to both the *Molinio-Arrhenatheretea* and *Koelerio glaucae-Corynephoretea canescentis* classes may have encouraged a more varied use of space by sheep. Previous studies conducted on sandy grasslands have indicated that the mosaic arrangement of plant communities influences the organisation of grazing activity and the selection of grazing sites by animals (18).

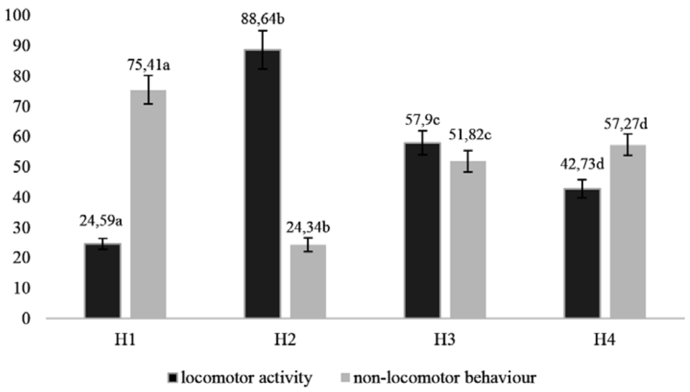

Fig. 2. Mean (± SE) proportion of locomotor activity and non-locomotor behaviour within individual habitats (H1-H4)
Explanation: Different lowercase letters indicate statistically significant differences between habitats within the analysed parameter ($p < 0.05$)

The results obtained are also significant in the context of active conservation of sandy grasslands. The literature highlights that the abandonment of extensive grazing leads to the accumulation of litter, a reduction in open grassland structure, and secondary succession associated with the encroachment of shrubs and woody plants (42). At the same time, an excessive concentration of animals within individual habitats may result in uneven grazing pressure. Therefore, understanding the spatial preferences of sheep is important for planning conservation grazing and assessing its impact on vegetation structure. Selective habitat utilisation may contribute to uneven grazing pressure, potentially influencing vegetation dynamics and long-term habitat conservation outcomes (9). In the present study, the higher use of grasslands characterised by a greater proportion of species from the *Molinio-Arrhenatheretea* class (H1) may indicate that these areas were used more intensively by sheep during grazing. In contrast, the limited use of habitat H2 suggests that typical sandy grasslands may have primarily served as transit areas between other pasture fragments. Similar relationships were previously observed in the "Kózki" Nature Reserve, where sheep preferred habitats characterised by higher sward productivity, whereas poorer habitats were mainly utilised during flock movement (41).

The use of GPS telemetry collars enabled the assessment of space utilisation by animals under natural conditions. Integration of telemetry data with habitat maps made it possible to determine relationships between vegetation structure and the organisation of sheep grazing activity. GPS monitoring has also been successfully applied in studies evaluating movement patterns and daily activity organisation in free-grazing sheep (30). This approach may represent a useful tool supporting both grazing management and the evaluation of the effectiveness of active sandy grassland conservation. At the same time, certain limitations of the methodology used should be taken into account. Telemetry systems using GPS signals are susceptible to positioning errors and temporary signal loss, particularly in areas with varied terrain or dense vegetation cover (15, 23). In practice, this necessitates additional data processing and the removal of records affected by significant errors, resulting in a reduction in the amount of data available for analysis. In the present study, the final analysis was conducted on the basis of 16 complete telemetry recordings; therefore, the results obtained should be interpreted with caution. In addition, although GPS collars were fitted to randomly selected sheep, individual animals were not identified across consecutive observation days. Therefore, repeated monitoring of the same individual cannot be completely excluded.

Due to the high frequency of GPS position recording and the continuous nature of movement trajectories, the potential temporal and spatial autocorrelation of telemetry data should also be taken into account when interpreting the results. Weather conditions may also be an important factor affecting the way in which sheep utilise space. Temperature, solar exposure, and the availability of shaded habitat fragments may influence both locomotor activity and the organisation of behaviours related to resting and grazing (27, 38). In the present study, this factor was not included in the analysis, although it could provide additional information regarding grazing behaviour.

Interpretation of the results should also take into account the potential influence of the area occupied by individual habitats. Differences in the time spent by sheep in particular habitats may have resulted not only from habitat-related differences in vegetation characteristics, but also from the proportional area occupied by each habitat within the pasture. Precise determination of the area proportions of individual habitat types could enable a more accurate assessment of spatial preferences in the studied animals.

The present study demonstrated differences in the organisation of sheep activity between habitat types under extensive grazing conditions. Habitats dominated by vegetation of the *Molinio-Arrhenatheretea* class (H1 and H4) were characterised by the highest proportion of behaviours associated with grazing and resting, indicating that these areas represented the main zones of grazing activity. In contrast, habitats associated with sandy grassland communities of the *Koelerio glaucae-Corynephoretea canescentis* class (H3) were characterised by a markedly higher proportion of locomotor activity, suggesting that these areas were used mainly during movement between grazing sites. The observed differences suggest that habitat structure and vegetation composition may have influenced the organisation of daily activity in grazing sheep. The integration of GPS telemetry with habitat analysis proved to be a useful tool for assessing habitat-related behavioural activity under natural conditions and may support both grazing management and active conservation of semi-natural grasslands.

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