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Space use of wintering Eurasian Tree Sparrows *(Passer montanus)* in a semi-urban area: a radiotelemetry-based case study

Attila Fülöp[1,2,3,*], Dóra Lukács[1] & Zoltán Barta[1]

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Abstract Space use, which includes the home range and habitat utilisation pattern of individuals for different activities (e.g. foraging, roosting), is one of the fundamental aspects of a species ecology. Hence, knowledge on the different aspects of space use in general is essential to understand the relationship between species and their habitat. Here, we investigated the home range size (using the minimum convex polygon method; MCP) and roosting site selection, using radiotelemetry, in a sedentary passerine species, the Eurasian Tree Sparrows *(Passer montanus)*. The study was carried out during the non-breeding period (i.e. wintering), in a semi-urban habitat where supplemental feeding was also available. We found that individuals had highly variable home ranges, both in shape and size (mean ± SD of 95% MCP: 6.89 ± 5.73 ha), the location of which was influenced by the presence of bird feeders. Roosting sites of the tracked individuals were largely consistent at an individual level, that is, all birds used the same locations for roosting during the whole tracking period, and the roosting sites of all individuals were located on buildings, except for a few rare occasions. Our results suggest that urbanised habitats can provide multiple benefits for the individuals during the winter in the form of easily accessible resources (e.g. food, roosting place), and individuals readily exploit these resources by adjusting their space use according to their availability.

Keywords: home range, roosting, radiotelemetry, *Passer montanus*

Összefoglalás A fajok ökológiájának egyik legalapvetőbb aspektusa a térhasználat, amely megadja az egyedek mozgásterületét és élőhelyhasználatát különböző tevékenységek (pl. táplálkozás, éjszakázás) közben. Emiatt az egyedek térhasználatának ismerete kulcsfontosságú a fajok és élőhelyek közötti kapcsolatok megértéséhez. Vizsgálatunkban mezei verebek *(Passer montanus)* mozgásterületét (minimum konvex poligon módszerrel; MCP), valamint éjszakázó hely választását vizsgáltuk rádiótelemetriás módszerrel a telelési időszakban, egy urbánushoz közeli élőhelyen. Az egyedek által használt terület mérete és alakja nagymértékű változatosságot mutatott (95%-os MCP, átlag ± szórás: 6.89 ± 5.73 ha), és az egyedi területhasználatot nagy mértékben befolyásolták a vizsgálati területre kihelyezett madáretetők. A nyomon követett egyedek éjszakázó helyei épületeken helyezkedtek el, és használatuk egyedi szinten konzisztens volt, azaz a teljes vizsgálati időszak alatt az összes egyed túlnyomó részt ugyanazt a saját éjszakázó helyet használta. Eredményeink azt mutatják, hogy az urbánushoz közeli élőhelyek a téli időszakban többféle előnnyel is szolgálhatnak az egyedek számára könnyen hasznosítható erőforrások (pl. élelem, éjszakázó hely) formájában, és hogy az egyedek ezeket az erőforrásokat sikeresen ki is aknázzák, módosítva „természetes” területhasználatukat.

Kulcsszavak: mozgásterület, éjszakázás, rádiótelemetria, *Passer montanus*

[1] *ELKH-DE Behavioural Ecology Research Group, Department of Evolutionary Zoology and Human Biology, University of Debrecen, 4032 Debrecen, Egyetem tér 1. Hungary*
[2] *Evolutionary Ecology Group, Hungarian Department of Biology and Ecology, Babeş-Bolyai University, str. Clinicilor 5–7, RO-400006 Cluj-Napoca, Romania*
[3] *Centre for Systems Biology, Biodiversity and Bioresources (3B), Babeş-Bolyai University, str. Clinicilor 5–7, RO-400006 Cluj-Napoca, Romania*
* *corresponding author, e-mail: fulop.attila@science.unideb.hu*

Introduction

Space use is one of the most fundamental aspects of a species ecology and includes the home range and habitat utilisation pattern of individuals. The home range of individuals can be defined as the total area they use for different activities that include, among others, reproduction, foraging, or roosting. Since individuals use parts of their home range for different purposes and with various intensities, mostly avoiding the edges of their home range, habitat utilisation refers to the frequency of usage of the different parts of the home range (Powell & Mitchell 2012). Knowledge on these different aspects of space use in general is therefore essential to understand species-habitat relationships both on individual-, and at species-level.

With the development of modern tracking technologies (e.g. global positioning system; GPS), the amount of information on the space use of numerous bird species has increased exponentially (e.g. Pérez-García *et al*. 2013, Mitchell *et al.* 2016, Gustin *et al.* 2017, Moskát *et al.* 2019, Heggøy *et al.* 2021, Zvidzai *et al.* 2022). Even though modern technology has become increasingly available, some limitations can still constrain their wide-range usage. For instance, for a long period the relatively large weight of the tags (> 5 g) made them unsuitable for small-sized birds (i.e. species with a body mass < 100 g; Barron *et al.* 2010, Bodey *et al.* 2018). Apparently, this issue was recently solved by a new archival GPS-based miniaturised tracking device, weighting only 1 g, and which was successfully deployed even on species with a mass of < 20 g (Hallworth & Marra 2015, see also e.g. Musseau *et al.* 2021). However, as data cannot be downloaded remotely from these miniaturised archival GPS tags, individuals have to be recaptured. Thus, these devices are optimal for species with high site-fidelity, and which can be easily trapped multiple times, but not for others. Also, the financial costs of GPS-based tracking devices are still relatively high. Hence, other tracking methods, as radiotelemetry, still represent a viable and affordable alternative to track the (local) movements of e.g. small passerines (see below).

Numerous studies investigated space use of small-sized birds using radiotelemetry, also attempting to describe the factors influencing individual-level variation in space use. A large proportion of studies focused on the space use of individuals during the reproductive season, when individuals are usually territorial and their movements are restricted around the nest site (e.g. Anich *et al.* 2009, Jirinec *et al.* 2016, Liu *et al.* 2020). During the winter, however, individuals can leave their breeding site and move around more freely to exploit resources from larger areas. Hence, the space use of individuals can be strongly influenced by seasonal effects, and can also be influenced by the type of habitat they use independently of season. For example, individuals of the same species inhabiting natural- or anthropogenic (i.e. urbanised) habitats can have different home range characteristics (reviewed by O'Donnell & del Barco-Trillo 2020). This is not surprising, as urbanisation is a global phenomenon with a strong impact on natural processes (Seress & Liker 2015). Overall, when studying space use of different individuals and/or species it is important to consider multiple factors which can shape the species-habitat relationship.

In this study, we investigated space use using radiotelemetry in Eurasian Tree Sparrows *(Passer montanus)*. Tree Sparrows are small sized passerines (17–25 g), feeding predominantly on seeds and grain during winter, but also on invertebrates during the breeding season (Summers-Smith 1995). At our study area, Tree Sparrows are year-round residents and breed in natural (e.g. trees) or artificial cavities (e.g. nest boxes, buildings). During the winter, Tree Sparrows form large, compact flocks (Mónus & Barta 2010), forage in the open parts of the study area, and they also readily use bird feeders (e.g. Barta *et al.* 2004, Mónus & Barta 2008, 2011, 2016, Mónus *et al.* 2017, Fülöp *et al.* 2019, 2022). Based on our field observations, Tree Sparrows are present in most parts of our study area (see Tree Sparrow Database at http://openbiomaps.org/projects/pasmon/; Bán et al. 2022). However, individual space use has not been investigated yet. Here, we studied home range size and roosting site selection of Tree Sparrows during winter, in a semi-urban study area where supplemental feeding is regularly available. A previous work studying space use in Japanese population of Tree Sparrows found that home range size can vary in the different seasons, being the largest (up to 11.5 ha) during the winter (Sano 1973). This is likely because foraging is one of the main activities of individuals during winter, hence, the spatial distribution of available food sources is expected to strongly influence the space use of individuals in this season (Sano 1973). Similarly, in our study, we expect space use of individuals to be variable on the individual-level, but depending on the habitat characteristics, we also anticipate space use to be influenced to a certain degree by the location of the bird feeders. Regarding the roosting behaviour of Tree Sparrows our knowledge is limited (Summers-Smith 1995). As documented previously, in the summer, Tree Sparrows roost communally in dense vegetation (e.g. trees, bushes, or reed beds), yet during the winter, individuals use mostly holes for roosting and roost in small numbers, usually alone or in pairs (Summers-Smith 1995). In our population, due to the heterogeneity of the habitat *(Figure 1)*, Tree Sparrows have multiple options available to choose from as their roosting site: natural cavities in trees, nest boxes, or building cavities. Whether individuals have a preference for one or another type of cavity, or they use all of these is unknown.

Materials and Methods

General setup

The study was carried out in the Botanical Garden (hereafter 'Garden') and on the Central Campus (hereafter 'Campus') of the University of Debrecen (N 47.55366, E 21.62164; Debrecen, Hungary) between January and March 2017. The study site is a relatively open area with scattered trees and shrubs, also containing some buildings of various sizes forming a heterogeneous semi-urban landscape mosaic (Barta *et al.* 2004, Fülöp *et al.* 2019) *(Figure 1)*.

During the study period we provided *ad libitum* food for the birds, consisting of sunflower seeds, on a daily basis, on five different bird feeders scattered over the study area. The feeders were wooden platforms made of oriented strand board (i.e. "feeding platform"; 120 × 120 cm) that were placed on the ground in the following setup: three in the Garden (*Figure 1*, feeders BG1, BG2 and BG4) and two in the Campus (*Figure 1*, feeders C1 and C2). All feeders were located near at least one larger bush and/or tree which provided shelter for the birds, as Tree Sparrows have a preference for similar feeding habitats (Barta *et al.* 2004).

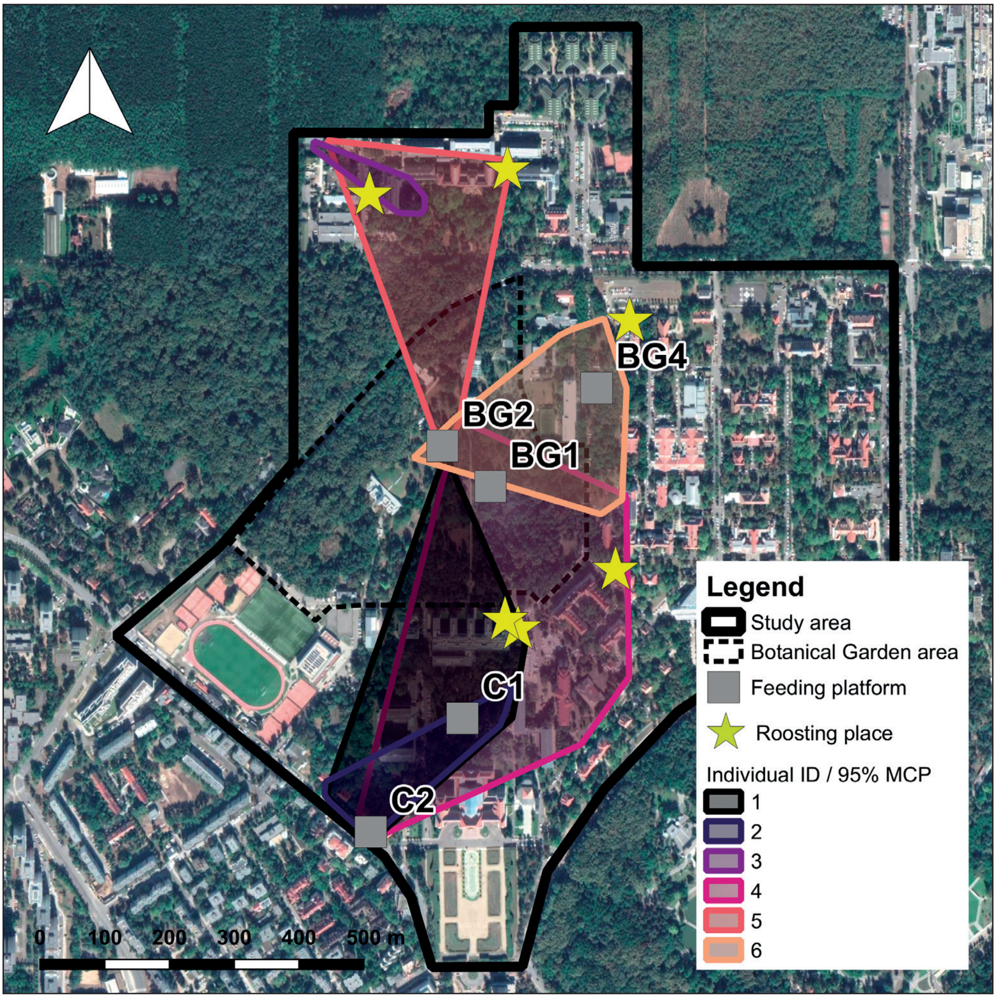

Figure 1. Schematic illustration of the study area covering the Central Campus of the University of Debrecen (black solid line) and the Botanical Garden (black dashed line); and the home ranges and roosting sites of the six radio-tagged Eurasian Tree Sparrows *(Passer montanus)*. The home ranges presented in the figure are based on the 95% minimum convex polygons (MCPs; indicated by the coloured polygons on the figure). The feeders used in the study are also marked (Central Campus: C; Botanical Garden: BG). The arrow on the top map is the direction of North. Background satellite image source: Google Maps

1. ábra A vizsgálati területet bemutató ábra, amely magába foglalja a Debreceni Egyetem Központi kampuszát (fekete folytonos vonal) és Botanikus kertjét (fekete szaggatott vonal), valamint hat rádiójeladóval nyomon követett mezei veréb *(Passer montanus)* mozgásterületét és éjszakázó helyét (sárga csillagok). A mozgásterületek a 95%-os miminum konvex poligon (MCP) alapján lettek megrajzolva. A vizsgálatban használt etetők (C: Központi kampusz, BG: Botanikus kert) elhelyezkedése is látható az ábrán. A terület elhelyezkedését az északi irányhoz képest a sarokban látható nyíl mutatja. Műholdas felvétel forrása: Google Maps

Table 1. Summary data about the radiotelemetry observations in Eurasian Tree Sparrows *(Passer montanus)*. Sex of individuals, trapping site, tracking period, available data quantity and individual home range sizes, expressed as the area of the minimum convex polygons (MCPs) are given

1. táblázat Összefoglaló táblázat a mezei verebek *(Passer montanus)* rádiótelemetrás nyomkövetéséről. A táblázat tartalmazza az egyedek ivara és befogási helye mellett a nyomon követés időszakát, a rögzített helyadatok számát, valamint az egyedek mozgásterületének méretét, a minimum konvex poligon (MCP) módszer alapján becsülve

Bird ID	**Sex**	**Trapping site (feeder)**	**Period tracked**	**No. days tracked**	**No. fixes (total)**	**No. fixes (daytime)**	**No. fixes (roost data)**	**Home range size (100% MCP in ha)**	**Home range size (95% MCP in ha)**	**Home range size (50% MCP in ha)**
1	male	C1	2017/01/25 – 2017/02/19	25	75	52	23	9.496	8.969	2.493
2	male	C1	2017/01/25 – 2017/02/17	23	71	49	22	5.491	2.342	0.146
3	female	BG2	2017/01/30 – 2017/02/21	22	77	55	22	5.150	0.664	0.033
4	female	C1	2017/01/31 – 2017/02/22	22	73	52	21	17.912	16.827	4.363
5	female	BG2	2017/02/03 – 2017/03/02	27	83	63	20	12.211	6.906	0.515
6	male	BG2	2017/02/03 – 2017/02/18	15	55	40	15	6.703	5.658	0.707
Study area total surface										95.20

Bird trapping, measurements and tagging

We captured six Tree Sparrows at two different feeders (details in *Table 1*), with mist nets (Ecotone, Poland), following the protocol described in details by Fülöp *et al.* (2019, 2022). Briefly, at capture, we marked the individuals with a uniquely numbered aluminium ring, issued by the Hungarian Bird Ringing Centre, and with a unique combination of three plastic colour rings to assure individual identification from a distance (see also Fülöp *et al.* 2019, 2022). We measured body mass (± 0.1 g with a Pesola spring balance), tarsus length (± 0.01 mm with a digital calliper), and wing length (± 0.5 mm with a ruler) of individuals, and we photographed their black bib patch (see e.g. Fülöp *et al.* 2021). We also took a blood sample (~50–150 μL) from the brachial vein of each individual to perform molecular sexing (see details in Fülöp *et al.* 2021). The captured birds were subjected to a personality test as well for parallel studies (Fülöp *et al.* 2019, 2021, 2022). Finally, we fitted a radio tag (model PIP3, Biotrack Ltd., UK; weight 0.43 g) on the back of each individual using flexible super glue (Loctite 4860). The weight of the tag represented approx. 2% of the body weight of the tagged individuals (21.58 ± 0.81 g, mean ± SD, N = 6), therefore, we expected negligible (if any) negative effects associated with wearing the tags (Kenward 2000, Barron *et al.* 2010, Bodey *et al.* 2018). After completing all the procedures described above, we released the birds at the site of their capture.

Tree Sparrows were ringed under a licence from the Hungarian Bird Ringing Centre (licence nr. 390 accredited to ZB) and permission for the study was granted by the Hajdú-Bihar County Governmental Office, District Office of Debrecen – Department of Environmental and Nature Protection (permit nr. HB/10-KTF/00487-1/2016).

Radiotelemetry

In order to determine the space use of the radio-tagged individuals, during February and March 2017, we performed regular search sessions (1–3 sessions/day, started at times unspecified beforehand). Search sessions on the same day were separated by a break of at least one hour. During a search session an observer (AF or DL) actively searched for the signal of every tagged individual using a Sika radio tracking receiver and a directional three-element Flex Yagi antenna (both from Biotrack Ltd., UK). When a signal was picked up, the observer determined the position of the tagged individual by following the direction and strength of the radio signals until he/she could accurately locate the tagged bird. After recording, relatively to local landmarks, the position of each tagged individual in the field, we converted these positions into GPS coordinates (WGS1984 projection) by marking them on the Google Maps satellite map (https://maps.google.com/) (see e.g. Farine & Milburn 2013). The spatial heterogeneity of our study area allowed us to record the position of a tagged bird with high accuracy (within an estimated radius of max. 30 m around the recorded position). The tagged individuals were also observed frequently foraging on the feeders, where we could identify them using their unique colour ring combinations, and their exact locations could have been noted. Finally, we also recorded the roosting sites of all birds on multiple days after sunset using a similar methodology as during daytime.

Statistical analyses

All statistical analyses were performed in the R statistical environment version 4.2.1 (R Core Team 2022). To characterise space use of individuals we calculated the home range size of the radio-tagged individuals using the minimum convex polygons (MCPs) method (Mohr 1947). MCP estimates the maximum area an individual uses (i.e. geographical boundaries of its home range). It is a widely used method to estimate home range size and to make comparisons between studies (Seaman *et al.* 1999). We calculated 100% MCPs (i.e. polygons containing all observations, including roosting sites) of individuals using all the radio tracking position data. Besides, since MCP estimates can be influenced by outliers, we also calculated the 95% MCP, and the 50% MCP in order to give a more conservative estimate of the individual's home ranges and the core areas, respectively. Home range analysis was carried out using the R package "adehabitatHR" (Calenge 2006). The map was created using QGIS version 3.18 (QGIS Development Team 2021).

Results

Home range areas of the radio tagged birds varied greatly both in size and in shape *(Table 1, Figure 1)*. Tree Sparrows had a mean home range area of 6.89 ± 5.73 ha (mean ± SD of 95% MCP), with a core area of 1.38 ± 1.71 ha (mean ± SD of 50% MCP). Home range area (95% MCP) was not correlated either with the number of fixes recorded per individual (Spearman's rank correlation test, $r = 0.06$, $N = 6$, $P = 0.913$) or with the number of tracking days (Spearman's rank correlation test, $r = 0.23$, $N = 6$, $P = 0.658$). In general, home ranges of birds from the Campus (bird IDs: 1, 2 and 4) were spatially separated from the home ranges of birds from the Garden (bird IDs: 3, 5 and 6). However, areas of two birds from the Campus overlapped by some extent with the areas of three birds from the Garden on those feeders that were visited by birds from both areas. One individual from the Campus (ID 2) was fully separated spatially from one bird from the Garden (ID 3).

Roosting sites of the tracked individuals were largely consistent at an individual level: all birds used the same locations for roosting during the whole tracking period. Interestingly, even if some of the tracked individuals shared the same feeders during the day, roosting sites were located in different locations *(Figure 1)*. Although the tracked individuals could not be directly observed in the dark, due to the configuration of the habitat, we could determine with a good confidence the locations of the roosting sites. All of the birds were regularly using buildings for roosting, except for a few cases when some of the birds roosted on trees.

Discussion

In this study we explored space use of wintering European Tree Sparrows in a semi-urban area. We found that Tree Sparrows had home ranges of varying sizes and shapes, and the spatial distribution of home ranges was largely influenced by the location of the feeders.

The tracked individuals spent most of their time in the vicinity of the feeders. The roosting sites of the tracked individuals were stable over the period of the tracking and were located predominantly on buildings situated in different parts of the study area.

A previous study investigating home range size of Tree Sparrows found that individuals' home ranges are the largest during winter, when individuals are not constrained to use only the areas around their nest (Sano 1973). The size of the home ranges from our study are comparable in absolute values to previous findings. For instance, Sano (1973) reported 11.5 ha home range for Tree Sparrows in Japan. Also, we have found that individuals apparently limit their daily movements opportunistically around the feeders and hence, tend to spend most of their time around the food source. Consequently, individuals are presumably moving much less around, as compared to when supplemental food is not provided. A similar adaptation was observed in Japanese Tree Sparrows, where individuals stayed mostly in the vicinity of an abundant food source (i.e. rice field) during winter (Sano 1973). Therefore, although our home range estimates are similar to Sano (1973), we are aware that they are influenced to some extent by the presence of bird feeders. This phenomenon is interesting and should be taken into account when the effect of human practices (e.g. bird feeding) on wildlife is investigated. Bird feeding during the winter is a standard procedure aiming to increase the survival of individuals when environmental conditions are harsh. However, our results indicate that artificial bird feeding can influence the behaviour of individuals, shaping for instance their habitat usage.

We found that individuals captured in the Campus and in the Garden, respectively, had home ranges with only a moderate overlap, and the home range of one individual from the Campus had no overlap at all with the home range of individuals from the Garden. This spatial segregation of individuals hints for the existence of multiple social communities, which are separated in space, and perhaps they also form separated social units.

Interestingly, we have found that individuals had different roosting places despite that they shared the same feeders during the day and being members of the same foraging group. As documented in other populations, during the winter Tree Sparrows roost most frequently either alone or pairs (Summers-Smith 1995). On rare occasions, when the temperature drops below freezing, small groups of up to 5 individuals can roost together (Summers-Smith 1995). Our observations on the roosting habits of Tree Sparrows from our population suggests that individuals exhibit a similar behaviour as described by earlier studies, more specifically, that larger foraging groups split at the end of the day and individuals roost alone, or in smaller groups.

All of the tracked individuals were using buildings for roosting. Buildings can have parts and/or cavities that are inaccessible for predators hunting during the night (e.g. cats, owls). Also, some building cavities (e.g. holes in the insulation of the buildings) can assure a warmer microclimate then e.g. tree cavities or artificial nest boxes. Therefore, roosting in/on buildings can confer a higher safety against predators and individuals can also gain thermal benefits from it.

To conclude, our study widens our knowledge about the space use of Tree Sparrows during the winter. We show that individuals have highly variable home ranges, which are partly influenced by the presence of bird feeders. Besides, we show that individuals have a strong preference for certain places where they roost and use the roosting sites consistently during the winter. Although the Tree Sparrow is a species inhabiting primarily rural areas (e.g. farmlands) in Europe, our results indicate that this species can successfully adapt to urbanised areas as well, exploiting the resources and niches provided by these human-modified habitats.

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