Hungarian University of Agriculture and Life Sciences

Szent Istvan Campus

Institute for Wildlife Management and Nature Conservation

Department of Wildlife Biology and Management

Wildlife Management Engineering

WINTERING BEHAVIOUR AND HABITAT USE OF GPS-TRACKED EURASIAN WOODCOCKS IN HUNGARY

MSc Thesis

Author:

Malatji Itumeleng Kwena

Thesis Adviser:

Gergely Tibor Schally

Godollo

2023

Tartalom

1. Introduction

Eurasian woodcocks (*Scolopax rusticola*, Linnaeus, 1758) are medium-sized birds, which can be found in subarctic palearctic. Eurasian woodcocks possess a cryptic camouflage to blend into the environment. Their underparts are reddish-brown and buff-coloured. These birds have eyes that are set far back which allows them to have 360 degrees monocular sight (Cocker & Mabey, 2005). And that is an essential probe for finding food on the ground together with their elongated, delicate bill. Eurasian woodcocks have rounded wings and the legs differ from grey to pinkish colour. Male Eurasian woodcocks execute courtship flights which is known as roding in spring. But the male woodcocks cannot be differentiated from female woodcocks in the field (Robinson, 2005).

Eurasian woodcock are twilight animals meaning they are mostly active at dawn and dusk. And are rarely active during the day but can be active if flushed (Mullarney *et al*., 1999). The flight of the birds is like owls or bats' flight, but woodcocks fly fast and directly especially when migrating or crossing open fields. And in woodlands they fly erratically while twisting and fluttering. Eurasian woodcocks are mostly solitary and are not mandatory migrants, migrate individually. But the birds may gather if climatic of geographical conditions force them (Birdlife International, 2016).

The Eurasian Woodcocks are categorized as Least of Concern species because of their broad range and their large population size (Birdlife International, 2023). The population trend appears to be stable, and their large population size does not approach the thresholds for vulnerable under the criterion of population size (< 10,000 mature individuals with continuing decline which is estimated to be >10% in ten years) (Birdlife International, 2023). The current global population estimation of Eurasian Woodcocks is about 10,000,000–26,000,000 individuals (Birdlife International, 2023) and the European population is estimated to be 6,890,000–8,710,000 lekking males which may be equivalent to 13,800,000–17,400,000 mature individuals (Birdlife International, 2023; Ashpole et al., 2015).

Regardless of the current population estimation of Eurasian woodcock, the quality of the data may be controversial because of the behaviour of the species and it being a cryptic bird (Schally & Csanyi, 2022). The behaviour of Eurasian woodcocks includes diurnal behaviour during the breeding season and nocturnal behaviour during winter (Hopper, 2013). The species roost undercover during the day and fly out to feed during the night in nearby fields.

As a student in the Department of Wildlife biology and Management, I had the opportunity to have a closer look at this behaviour, through the data of the Satellite Tracking project of these birds (Schally *et al*., 2022). Studying the movement data of 8 Woodcocks, the aims and objectives of my thesis were as follows:

- To determine the difference between the day and night home range size and location.
- Do Eurasian woodcocks travel the same distance during the day and night in different regions.
- How many birds would leave the site of tagging in autumn to migrate for wintering season.

2. Literature review

The Eurasian woodcocks (*Scolopax rusticola*, Linnaeus, 1758) are medium-sized birds, which can be found in subarctic palearctic. Eurasian woodcocks possess a cryptic camouflage to blend into their environment. Their underparts are reddish-brown and buff-coloured. These birds have eyes that are set far back which allows them to have 360 degrees monocular sight (Cocker & Mabey, 2005). And that is an essential probe for finding food on the ground together with their elongated, delicate bill. Eurasian woodcocks have rounded wings and the legs differ from grey to pinkish colour. Male Eurasian woodcocks executes a courtship flight which is known as roding in spring (Robinson, 2005). But the male woodcocks cannot be differentiated from female woodcocks in the field.

Many Eurasian woodcocks breed in Europe but about 90% to the world population breed in Russia and Fennoscandia. Their breeding ranges from Fennoscandia, Mediterranean Sea, Canary Islands, and western Europe to Russia (Tucker & Heath, 1995). But the population found in Azores genetically differs from the populations found in the mainland Europe, because they are isolated (Andrade *et al*., 2022). Eurasian woodcocks have a bigger home range with estimated global extent of occurrence of 10 million square kilometres and an estimated population of 15–16 million birds, hence the species' conservation status is least of concern.

Eurasian woodcocks may mostly be found in temperate and subarctic Eurasia. Northern and Asian populations migrate to southern Europe or Indian subcontinent, respectively. But the bird population in the milder European countries and Atlantic islands are residents not migrants (species factsheet: *Scolopax rusticola*, 2016). And majority of the populations breeding in the north-west and southern Europe are mostly sedentary (Tucker & Heath, 1995).

Bird migration is miscellaneous and complex phenomenon, with undiscovered details (Schally *et al*., 2022). Bird migration is often associated with bird ringing. Although bird ringing possesses numerous advantages, it also possesses some disadvantages which limit the usage of data resulting from it (Schally *et al*., 2022). Limiting factors may include spatial or temporal significance in terms of capture, marking, recapture, observation or presence of other species, and human ringing and reporting method (Schally *et al*., 2022). Modern technology such as individual-based satellite trackers are widely utilized across the globe and have indicated various unknown patterns of movement and behaviour of numerous animals (Schally *et al*., 2022). The individual-based satellite tracking devices plays a vital role in the

migration of Eurasian Woodcocks (Schally *et al*., 2022). Because these species are of high international importance due to their cultural heritage and hunting traditions.

The Eurasian Woodcocks are known the breed across Britain but with noticeable absences on high grounds areas of Scotland, Southwest England, and south Wales (Hoodless & Hirons, 2007). Currently, the species is categorized as a bird of conservation concern because of the alarming decline in reproduction numbers (Hoodless & Hirons, 2007). The Eurasian Woodcocks are considered a challenging species to observe or study because of their cryptic plumage, nocturnal behaviour, and crepuscular displays (Hoodless & Hirons, 2007). Hence the current population estimates are controversial, but the estimated decline is not questionable. Majority of Eurasian Woodcock across the world spend their winter in the UK and research indicates that 90% of the total British winter population include continental birds (Hooper, 2013).

Eurasian Woodcocks are known to be diurnal during the reproduction season and nocturnal during winter (Hooper, 2013). These birds tend to roost during the day under shades and fly to fields to feed during the night. This is predator avoidance strategy which is beneficial in terms of feeding efficiency. During the winter season the main food source of Eurasian Woodcocks is earthworms (Hooper, 2013). And these tend to appear in higher densities in areas that are soft grazed fields as compared to woodlands (Hooper, 2013).

The Eurasian woodcock is a vital migratory quarry species across several European countries including Hungary and France (Ferrand *et al*., 2008). The hunting bag have been estimated at 1,200,000 birds annually in France and 3,4 million in Europe. And to warrant renewable use of the woodcock across Europe, an integrated monitoring programme was established for mating and wintering woodcock population in France (Ferrand *et al*., 2008). The aims of the programme are like the identical programme that was initiated in Hungary from the year 2009. The focus of the France program was to estimate demographic trends, collect data on the presumptive cause of the changes, and produce population models that speculate population behaviour (Ferrand *et al*., 2008).

The Eurasian Woodcocks are categorized as Least of Concern species because of their large home range size and their large population size (BirdLife International, 2023). The population trend is stable, and their large population size does not approach the thresholds for vulnerable under the criterion of population size (< 10,000 mature individuals with continuing decline which is estimated to be >10% in ten years) (BirdLife International, 2023). The current global population estimation of Eurasian Woodcocks is about 10,000,000–26,000,000 individuals (BirdLife International, 2023) and the European population estimation is

estimated to be 6890000-8710000 lekking males which may be equivalent to 13,800,000–17,400,000 mature individuals (BirdLife International, 2023; Ashpole *et a*l., 2015).

Figure 1: The original distribution of Eurasian woodcocks across Europe (Birdlife International, 2023).

Regardless of the stable population trends and extremely large home range sizes, the species experiences various threats and drastic decline (BirdLife International, 2023). And currently the main threat to Eurasian woodcocks is the rise of habitat fragmentation of woodlands and the disappearance of grasslands outside non-breeding season (Birdlife International, 2023). Other anthropogenic activities that affect Eurasian woodcock populations are forestry and agricultural changes (Machado *et al*., 2008; Duriez *et al*., 2005) because these habitats are declining in Europe (Duriez *et al*., 2005). And isolation plays a crucial role in island population of birds by increasing their vulnerability, for example a severe population decline of Eurasian woodcock *Scolopax rusticola* in the Azorean archipelago (Machado *et al*., 2008).

The Eurasian woodcock choose habitats with certain characteristics during the breeding season (Machado *et al*., 2008; Ferrand *et al*., 2008). For instance, in Europe, these birds select mosaic habitats like extensive woodlands which are either broad-leaved, mixed, or coniferous (Machado *et al*., 2008). But in winter habitat characteristics are less restrict, the woodcocks occupy woodland or hedges during the day and use farmlands or permanent meadows at night (Machado *et al*., 2008; Hoodless. 1995). This may be because in winter Woodcocks becomes nocturnal and frequently visit nearby fields to feed (Hoodless. 1995).

The permanent meadows play a crucial role in feeding of Eurasian woodcocks in winter because of the high densities of earthworms (Ferrand *et al*., 2008; Duriez *et al*., 2005). But this type of habitat has been drastically decreasing across Europe due to alternative farming techniques (Ferrand *et al*., 2008), for instead, about 25% of meadows in France were lost between 1970 and 1995 (Ferrand *et al*., 2008). Alternatively, woodland habitats are increasing because of tree plantations and forests are not restrictive to Eurasian woodcocks.

2.1. Habitat uses by Eurasian woodcocks.

The selected of habitat that the Eurasian woodcocks prefers during the day differs from the preferred habitat during the night (Duriez *et al*., 2005; Ashpole *et al*., 2015). The habitat requirements of Eurasian woodcocks during the day are identical to mating habitat requirements (Ashpole *et al*., 2015). During the day whereby the species depict diurnal behaviour, the preferred habitats include young forest stands-plantations, coppices, and wet forests (Duriez *et al*., 2005). The type of habitats that the Woodcocks tend to shy away from are old stands of timber because this type of habitats comprises of less shrub strata due to limited light reaching the ground. The layer of shrubs found in plantations and coppices plays an essential role by providing the Eurasian woodcocks with shelter from raptors and terrestrial predators (Duriez *et al*., 2005; Brana *et al*., 2010). In winter Eurasian woodcocks select their habitat in woodlands based on patches that have high food quantity, for example mull humus and the presence of shrub layer (Duriez *et al*., 2005). This was shown through research where mulls humus soils were chosen over moders mors soils. The speculated reason for this was the mulls humus soils are slightly richer in earthworms compared to moders mors soils (Duriez *et al*., 2005). And this kind of soil can be found in most of the preferred habitats by Eurasian woodcocks during the day. Studies on radio-tagged woodcocks have indicated that woodcocks used various foraging strategies based on the availability of earthworms in their diurnal foraging habitat. And may stay for many days, weeks or months foraging only during the day while staying in the woodlands by night (Duriez *et al*., 2005; Brana *et al*., 2010).

The preferred habitats during the night by Eurasian woodcocks are meadows specifically old dry grazed meadows over other fields and seed plots (Duriez *et al*., 2005). And this may be because of the high presence numbers of earthworms and insect larvae in meadows because of soil type.

2.2. Eurasian woodcock in Hungary

Eurasian woodcock (*Scolopax rusticola)* is a small game species that is highly favoured in Hungary and many European countries. As *Scolopax rusticola* is a migratory species, any projects such as hunting or capturing involving it must follow and meet the standards of EU Directive (79/409 EEC) (Schally *et al*., 2012). Hunting the Eurasian woodcock in Hungary in an ancient tradition going from generation to generation and the popular season for hunting these birds is spring. The quality of the data collected on Eurasian woodcock in Hungary and other European countries may be debatable (Schally and Csanyi, 2022). This may because of the behaviour and the camouflage of the birds. Hence it is vital to gather data on the species utilizing reliable methods (Schally and Csanyi, 2022). The law for hunting *Scolopax rusticola* has been modified numerous times in the past and initially the hunting was restricted to posting and only spring season (Schally and Csanyi, 2022). The reasons for this law included that the type of hunting method would have less effects on the bird population. And the spring season has no overlap which means no conflicts with big game hunting (Schally and Csanyi, 2022). But the law contradicts with the regulation of the European Union Directive (79/409 EEC) on the conversation of wild birds. This regulation forbids hunting of birds in spring because this season is for mating and migration. As a result of the contradiction between the national law in Hungary and the European Union regulation on wild birds, a monitoring programme was initialized in spring 2009 (Schally and Csanyi, 2022). Other reason for such implementation in Hungary was to help maintain the spring hunting tradition in Hungary. The aims of the programme were to regularly collect reliable data on the species, evaluate the size of the migrating population occurring in Hungary, collection of data to assist in hunting sustainability of the birds and its effects (Schally and Csanyi, 2022). Additionally, the program supplied an opportunity to understand the population structure and the behaviour of the migrating Eurasian woodcock (Schally and Csanyi, 2022; Farago *et al*.,2012).

3. Methods and Materials

3.1. Study area

The study area is found in Godollo, Babatpuszta (47.62694 N, 19.38323 E); where the birds were caught and tagged. The size of the study area is approximately 86 hectares and is surrounded by deciduous, coniferous, and mixed forests. This area is utilized as a pasture and mowed for forage for both horses and cows. Within the immediate vicinity of the study area, there is a lake system which is comprised of 11 lakes. Big game species (Red deer, Fallow deer, Roe deer, Mouflon and Wild boar), small game species (European brown hare and Pheasant) and carnivore species (Red fox and Eurasian badger) also occur in the area. It is worth mentioning that the M3 highway is also located next to the study area, causing significant noise and light pollution.

Figure 2: The satellite image of the study area, Godollo, Babatpuszta.

3.2. Data collection

For this study, data from GPS tracking project of Eurasian Woodcock for Woodcock Monitoring Program was utilized. This type of method often aids in studies of cryptic and elusive species such as Eurasian Woodcocks because they are challenging to observe directly. I, Gergely Schally (supervisor), and two other colleagues went the field immediately after sunset which was 10–15 minutes' drive, and the birds are known to surface during that time. For capturing the woodcocks, a small net which is attached to a six-meter pole, spotlight, and flashlight were used to catch the birds. It is important to note that the birds were not scared of

the light. The birds were gradually approached, and net was slowly brought down closer the ground while standing six meters away; and then finally the net was quickly dropped over the bird. After the bird was caught it was rapidly approached because the bird may manage to escape from under the net.

This capturing method is the most common and popular method in capturing Eurasian woodcocks in non-breeding season (Powell, 2012). And usually, the birds capturing is overseen during the two-week interval that concur with the new moon. Because the birds are more settled and effortless to catch during this period (Powell, 2012). Upon capturing, the birds were ringed with unique coded metal rings and tagged with pinpoint GPS or Argos 240 tags (Lotek Wireless ltd.). In total, 21 Eurasian Woodcocks (*Scolopax rusticola)* were tagged since 2020, but only data from eight individuals was used for this study. This is because only those eight individuals had periods where two points were recorded per day. All tags were programmed to record one location per day (at 00:00), but for one month (November), these tags recorded an additional point at 12:00. The birds were tagged in Godollo, Hungary in the autumn season between the years 2020–2022.

3.3. Data analysis

The collected data was analysed using various software applications. For graphical representation and data management, Microsoft excel 365(2016) was used. For statistical analysis, PAST (v4.03) software was utilized and for data filtering, home range calculations, distance calculations, and area mapping were performed using QGIS (3.10.9).

The collected data was then separated into locations, day, night periods by filtering the raw data. This was done checking the if each tagged birds have two locations (during the day and during the night). This was done for all the countries the bird(s) travelled to if they have travelled. The distance the birds travelled between their daytime area and night-time area was also calculated. The home ranges were estimated using the Kernel density estimation (KDE) method, with the following parameters: cell size = 5 m, smoothing parameter (h): normal Kernel href calculated value, omitting the outlying href × 2 points; 95% probability contour. Based on our experience, smaller distances between daytime points resulted in smaller h-values for all individuals than night-time points. After, the home ranges of the day and night areas were calculated using polygons in OpenJump HoRAE (v). The distances between the geometrical centres of night-time and daytime home ranges were measured for all the birds using QGIS.

Table 1: The names of the GPS-tagged Eurasian woodcocks, their location, their daytime and night-time home range sizes; and the distance travelled between the home ranges.

Name of bird	Location	Daytime home range (ha)	Night-time home range (ha)	Distance (m)
Bacon	Slovenia	0,6	**1032,8**	**2476,5**
Bacon	Godollo	5,4	3,4	137,5
Brex	Russia	**161,4**	**153,1**	**1169,5**
Drakula	Godollo	12,3	3,3	
Galoca	Godollo	**854,9**	**186,7**	**1813,5**
Galoca	Spain	3,4	2,1	77,4
Gomboc	Godollo	29,8	1,3	531,0
Gomboc	Italy	23,5	1,2	231,2
Halom	Godollo	31,2	0,7	437,9
Russula	Godollo	64,2	44,1	987,3
Russula	Greece	63,9	3,1	731,2
Teflon	Godollo	42,0	8,7	843,4
Average		**107,7**	**120,0**	**827,4**

Table 2: The distances travelled by birds according to literature (Schally, 2020).

Mean distance (standard deviation)	No of individuals	Sources
514 m (s = 471 m)	5	(HIRONS 1982)
A: 1 300 m; B: 750 m; C: 2 254 m	3 (A; B; C)	(WILSON 1982)
A: 1 113 m (s = 520 m); B: 259 m (s = 183 m)	A: 54; B: 23	(DURIEZ *et al.* 2005d)
1 005 m (se = 51 m)	30	(HOODLESS & HIRONS 2007)
>1 500 m	22	(POWELL 2009)
961,5 m (s = 1 041,9 m)	51	(GUZMÁN *et al.* 2017)

Picture 1: a picture of Eurasian woodcock after being caught at study site and it was ringed with a metal ring.

Picture 2: A bird held by me after being ringed and it was about to be released

4. Results

4.1. Comparison of daytime and night-time home ranges

A normality test was conducted for the data collected, and the test indicated normal distribution ($p > 0.05$) of the data set. The daytime and night-time home ranges were not normal distribution ($p<0,05$), so only non-parametric test could be applied. If we consider the outliers, there was no statistical difference between day and night, according to the Mann-Whitney test ($U=65,5$, $p=0,34$), without the outliers, the difference was statistically significant ($U=29,5$; $p=0,045$).

The statistical analysis of daytime home ranges shown that the birds had a slightly lower minimum home range of 0.6 ha as compared to night-time home range which had minimum home range of 0.7 ha. In case of the maximum home range, the night-time home range was higher (1032.8 ha) in contrast to daytime home range (854.9 ha). The high maximum values of home range were because of the two outliers in the dataset. This may be in relation with the species' behaviour. In terms of mean and the median, the daytime home range had a higher mean (107.7 ha) and a median that was extremely low (30.5 ha). Regarding the night-time home range, the pattern was like the daytime home ranges, a higher mean (120.0 ha) and a low median (3.4 ha) which was only third of the home range. Overall, all birds had similar home range sizes which ranged between 3.4 ha–65 ha during the day. But there were two exceptions, the bird Galoca had the highest home range size of 854.9 ha in Godollo, and the bird named Brex had the second largest home range size of 161.4 ha in Russia. And, during the night-time, the birds had alike home range sizes that ranged between 0.7 ha–45 ha. However, there were exceptional cases where the birds had extreme large home range sizes. For instead, the birds Bacon, Brex, and Galoca had the home range size of 1032.8, 153.1, and 186.7 ha respectively.

With the bird Bacon, it had large home range size in Slovenia during the night-time (1032.8 ha), but the home range size during the daytime was small (0.6 ha). The reason(s) may that the night-time home range area was not suitable for the species hence the bird needed to move around to find a suitable feeding environment. Or the bird did not have large home range during the day because of presence of predators or the environment had all the essential resources it required. The same bird in Godollo, it had not so different home range sizes between the daytime and night-time which were 5.4 ha and 3.4 ha, respectively. In contrast with Brex bird in Russia, it had similar home range size in both daytime and night-time. With bird Galoca both its home range size larger but the home range for the daytime

was four time bigger than of the night-time. This may because of the quality of the habitat for the daytime home range is poor, or the climatic conditions were extremely harsh.

4.2. Description of distances between the daytime/night-time home ranges

The various Eurasian woodcocks travelled different distances between the daytime and night-time home range areas. The distance travelled between the home ranges ranged between 77.4 m and 950 m. The bird Galoca travelled the least distance (77.4 m) between the daytime and night-time home range area, as compared to the bird Russula which travelled the longest distance (987.3 m). There were some birds that travelled extremes distances between their home ranges. For example, the bird Bacon in Slovenia moved 2476.5 m between the two home ranges with the most distance travelled in the night-time home range. This may because the size of the night-time home range was larger compared to the daytime home range. And the Galoca bird travelled the second longest distance of 1813.5 m between its home ranges. But unlike Bacon which had extremely small daytime home range as compared to its night-time home range, Galoca in Godollo had large home range sizes. With the daytime home range being slightly larger. The third bird that travelled the longest distance was Brex. It travelled 1169.5 m between the daytime and night-time home ranges. In terms of the size of the two home ranges, they were the same sizes, unlike Bacon and Galoca.

4.3. Maps of the birds' home ranges and the distances between areas

4.3.1. Maps of birds in Hungary, Godollo

The daytime and night-time home ranges of Bacon in Godollo overlapped with each as shown in figure 3. The Kernel Density Estimator (KDE) value was 95% which indicated where the bird spent most of its time. Bacon has spent most of its time in forested areas for both during the day and night as demonstrated by figure 3. This bird rarely or never went to open fields during the as indicated on the map. The distance that Bacon travelled between the two home ranges was short due to localised in the forested areas. Another observation was that Bacon often spent time in the night-time home range during the day.

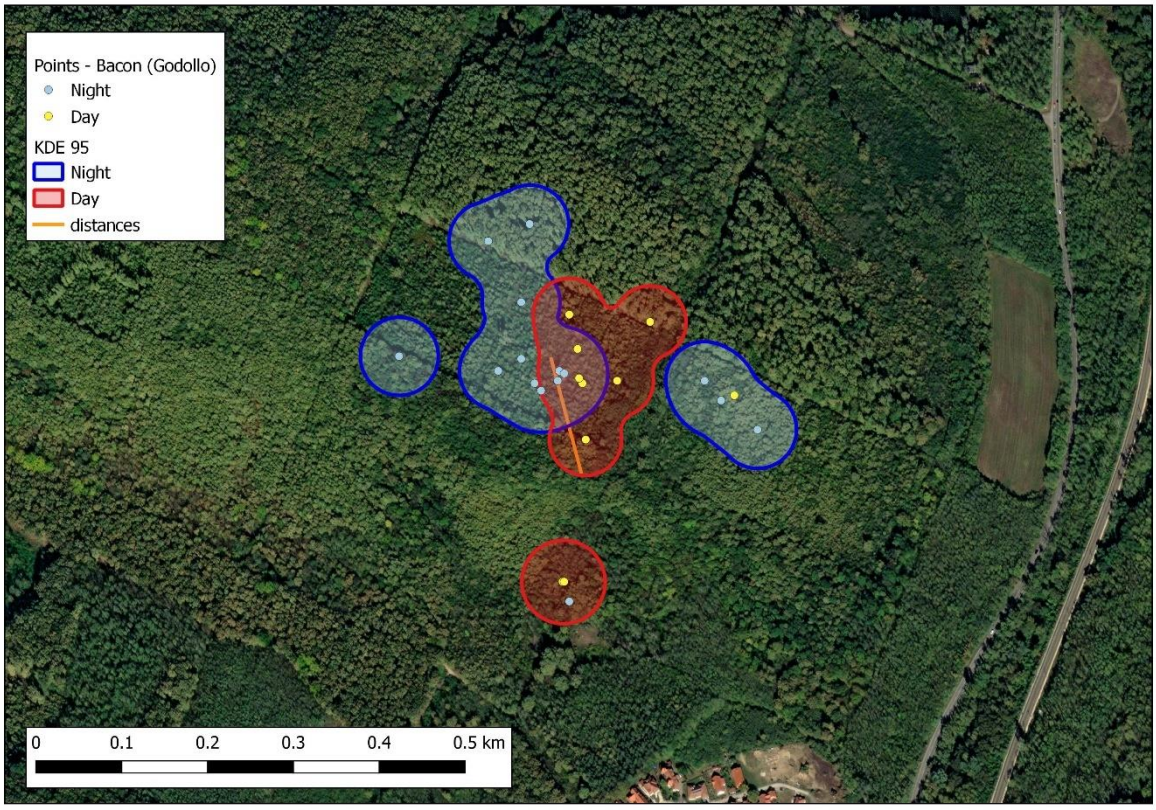

Figure 3: This map depicts the daytime and night-time home ranges of the bird Bacon in Godollo.

The bird Teflon spent in the forest during the day and travelled to open fields at night as the points show on figure 4. The daytime and night-time home ranges overlapped but the overlapping of the ranges was smaller as compared to that of Bacon in figure 3. The distance Teflon travelled between the daytime and night-time home range equals 843,4 meters. Regarding winter migration, Teflon spent all the winter period at the tagging site. And it only

started its spring migration to Russia on March 30th . however, the exact arrival date to the breeding site could not be established, but it was already in Russia on May 4th 2021.

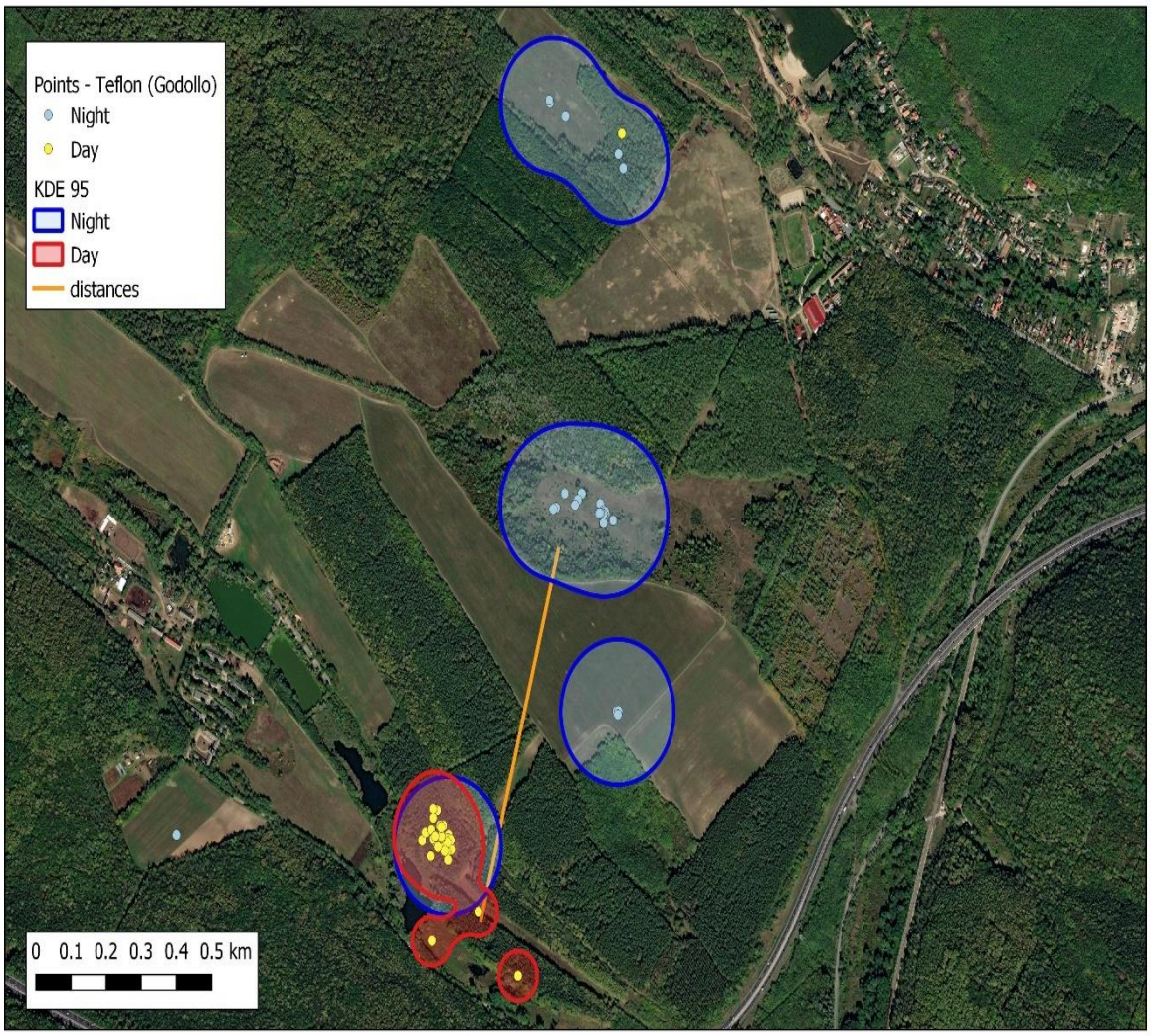

Figure 4: Shows the daytime and night-time points of Teflon in Godollo and the distance travelled between the home ranges.

Figure 5 depicts the daytime and night-time home range of Halom in Godollo. The daytime home range was small and overlapped with the night-time home range. Halom often spent nights at the night-time home range or vice versa as the points show on figure 5. But the bird travelled to open fields during the night and the night-time home was bigger compared to the daytime home range. Unlike Teflon, Halom left for its wintering sites in Slovenia on January 16th which was late winter. The bird stayed in Slovenia until 2nd of March and then within two days, avoiding the tagging site from the West went to breed in Poland.

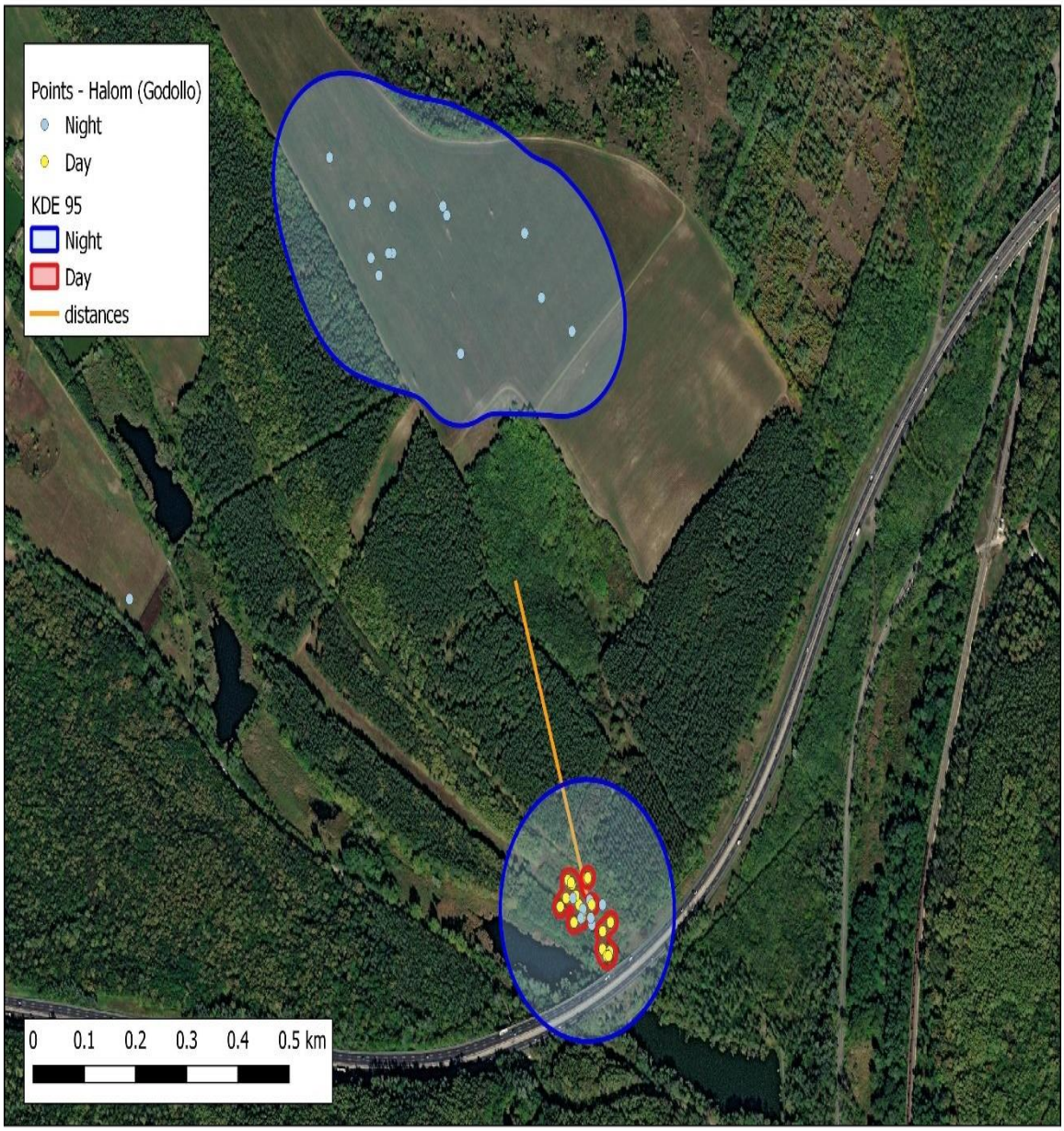

Figure 5: Indicates daytime and night-time point movements of bird Halom in Godollo.

Figure 6 demonstrates that Russula stayed close to where it was initially tagged, and the daytime and night-time home range intersected with each other. The overlapped home ranges were in a forested area which indicated that majority of the time the bird was hiding. But it often travelled to open fields, and it stayed close to the edge of the forest as shown on figure 6 below.

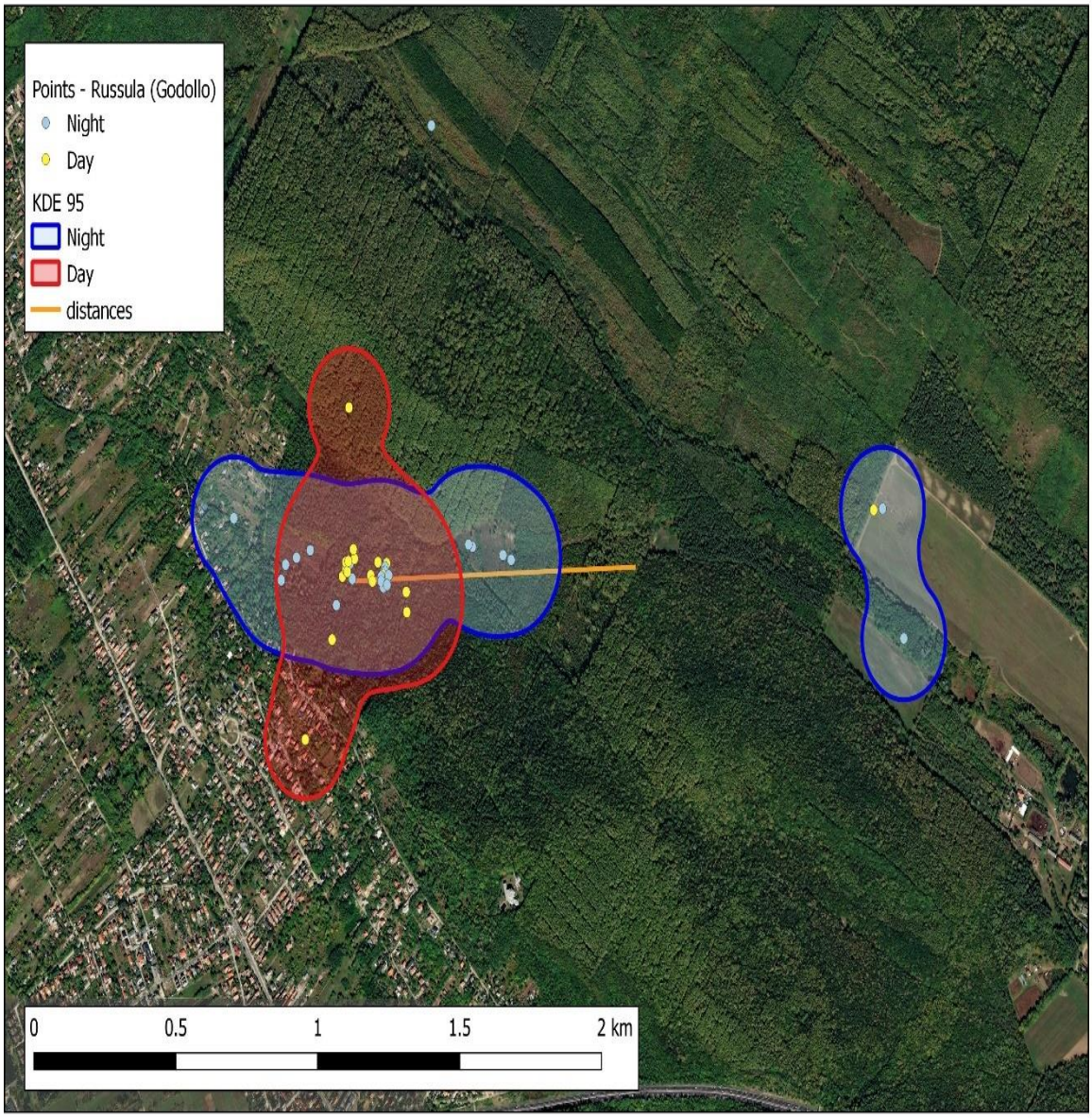

Figure 6: Shows the intersecting daytime and night-time home ranges of Russula in Godollo.

Gomboc Artur, as shown on figure 7 had a smaller daytime home range compared to its night-time home range. Like Bacon, Russula, Teflon, and Halom; the daytime and night-time home ranges crossed each other. But what stood with Gomboc Artur, it did not spend the night at the daytime home range or vice versa. The bird appeared to have travelled to several open fields during the night, hence the night-time home was three times large than the daytime home range. During the day, the bird stayed at the edge of the forest which was close to the open fields.

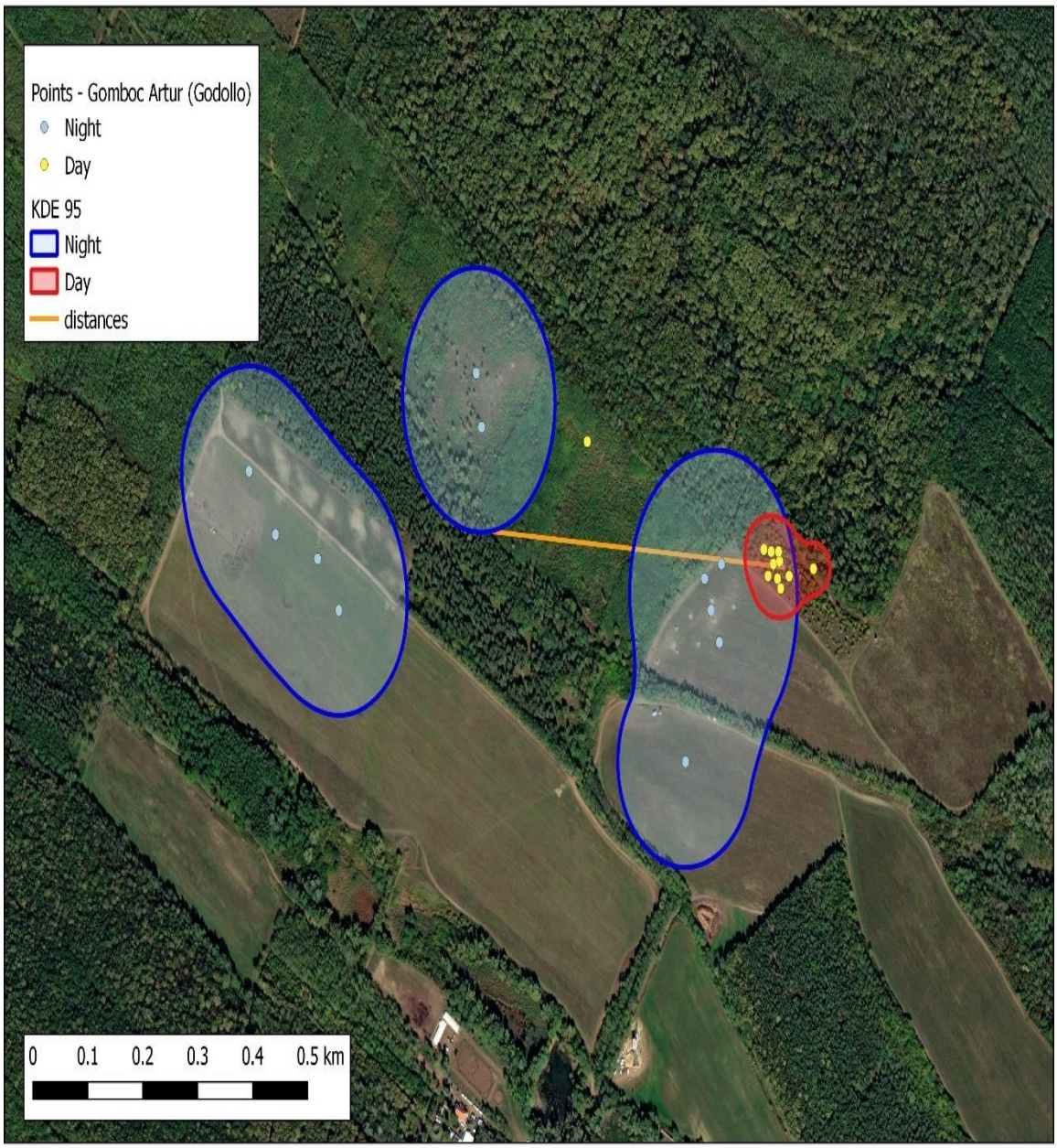

Figure 7: Shows the daytime and night-time point movements of Gomboc Artur in Godollo.

The movements of Galoca were interesting and different from all other birds in Godollo. This was because Galoca spent the nights in a human settlement as seen on figure 8, instead of open fields as it was expected. This was unique behaviour from the species in this study. Like the other birds in Godollo, the two home ranges overlapped and regardless of the bird to have spent the nights in a human settlement, it also spent time in open fields as depicted on the map below.

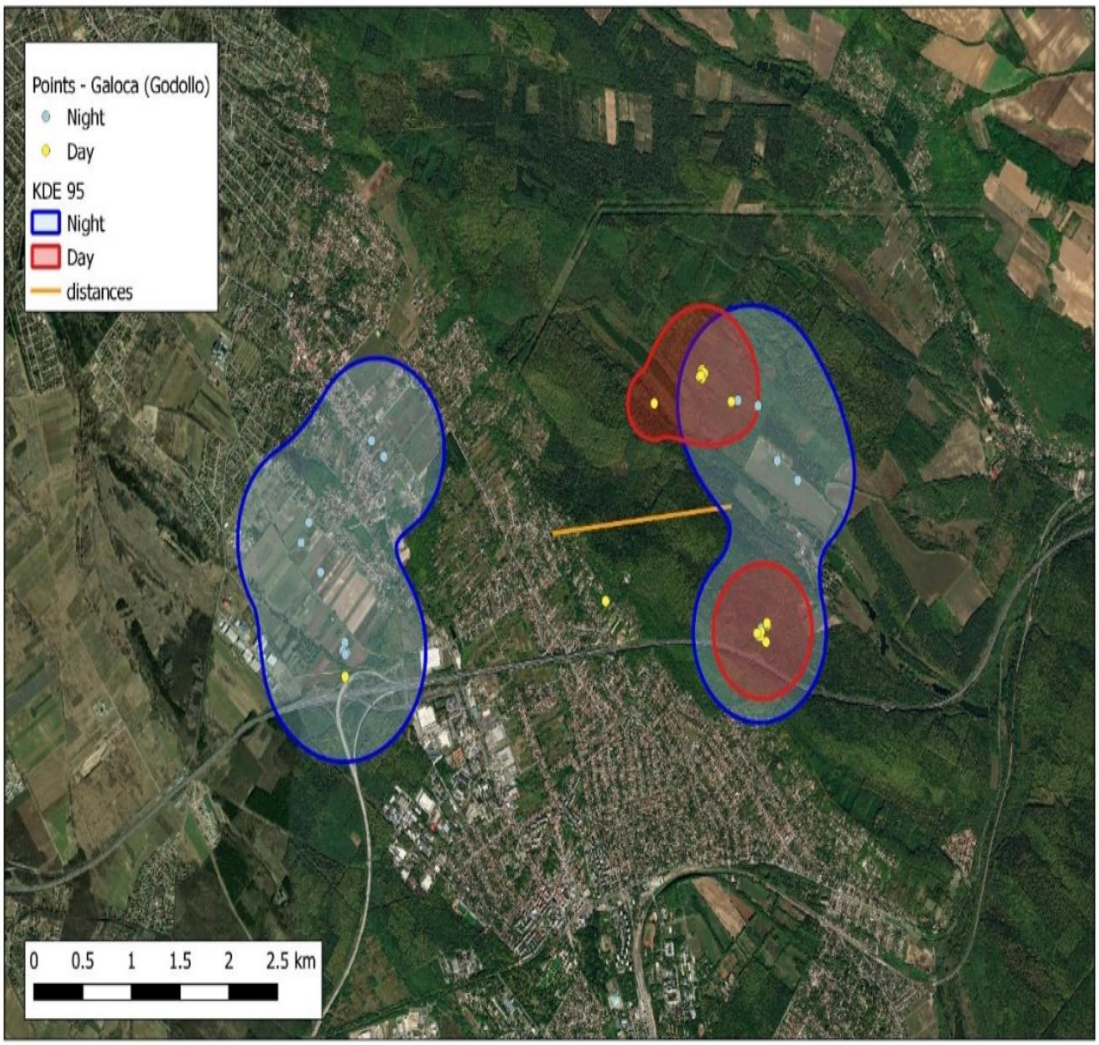

Figure 8: the daytime and night-time home ranges of Galoca in Godollo and the distance it travelled in-between.

The home ranges of Drakuala in figure 9 were like those of Bacon in figure 3, this bird hardly left the forest. Drakula spent both days and nights in the forest as seen on the figure, but it often travelled some distance (491,7 m) between the intersecting home ranges. Drakula left for its wintering site in Italy. On December 26,2020, and reached it within 7 days. On February 26 of the following year, however it returned to the Carpathian Basin exactly at the location it was tagged. It spent another month there before beginning its spring migration on 2 April. It finally arrived in the breeding area in Russia on the 9th of April.

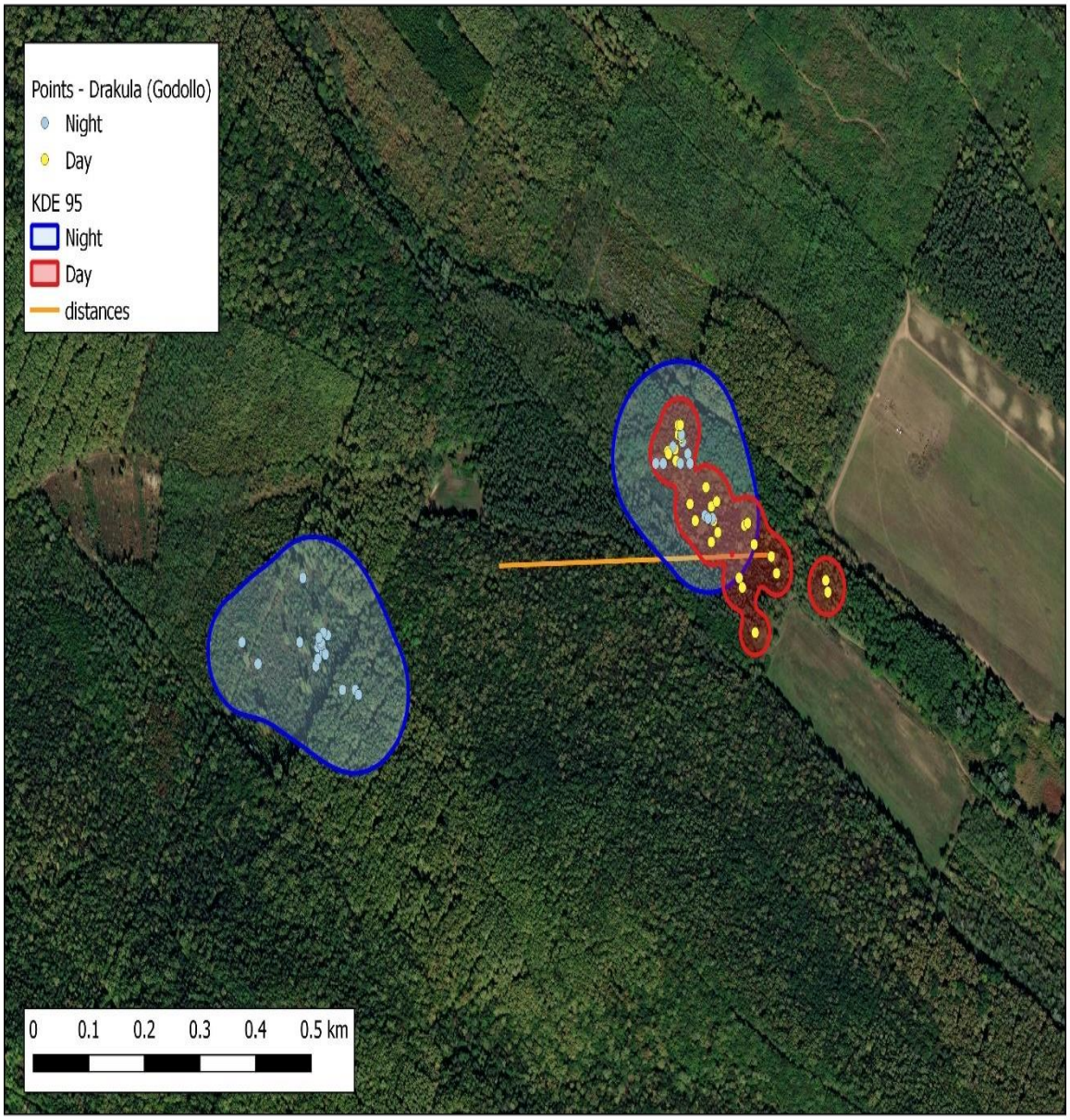

Figure 9: the home range movements of Drakula in Godollo.

4.3.2. Maps of bird that migrated outside Hungary

Bacon left Hungary (Godollo) for winter season and travelled to Slovenia. Its home range in Slovenia were completely different to those in Godollo. As depicted on figure 10 below, the night-time home range was extremely small with the daytime home range being four times larger. Again, Bacon spent nights near the human settlement like Galoca.

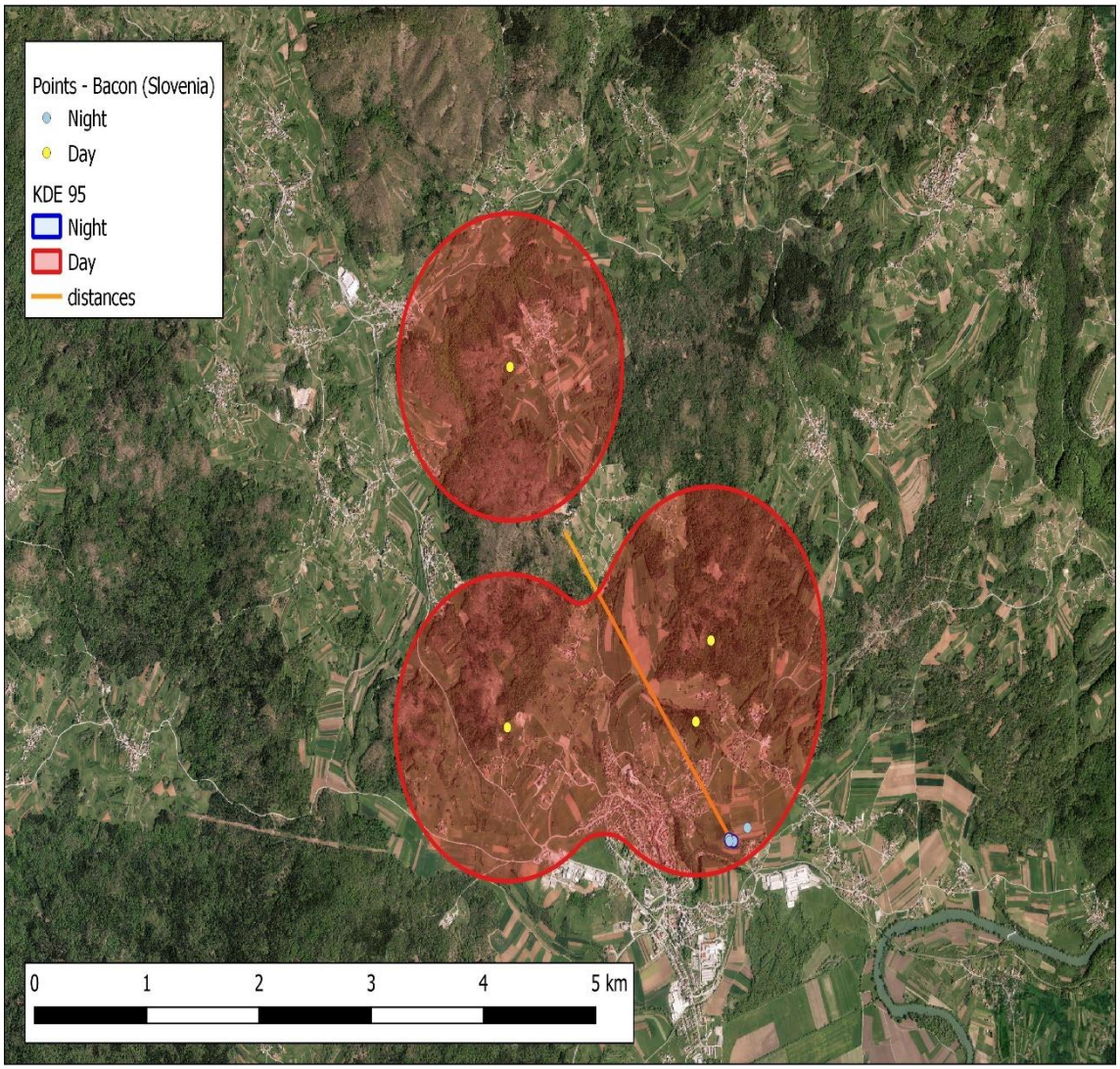

Figure 10: Shows the daytime and night-time home ranges of Bacon in Slovenia.

Russula left the designated location on November 18th ,2021, and stopped in Greece (Thessaloniki) on November9 after travelling 540km. Russula in Greece as indicated in figure 11 below, had almost identical home range movements as Halom in Godollo whereby the daytime home range intersected with the night-time home range. The map (figure 11) shows that Russula spent and travelled to open fields at night and some nights; it spent some nights in the forest. The transmitter for Russula last sent location data until December 19th 2021, however, based on their location it may be assumed that the device fell off or the bird died, and the exact location cannot be established.

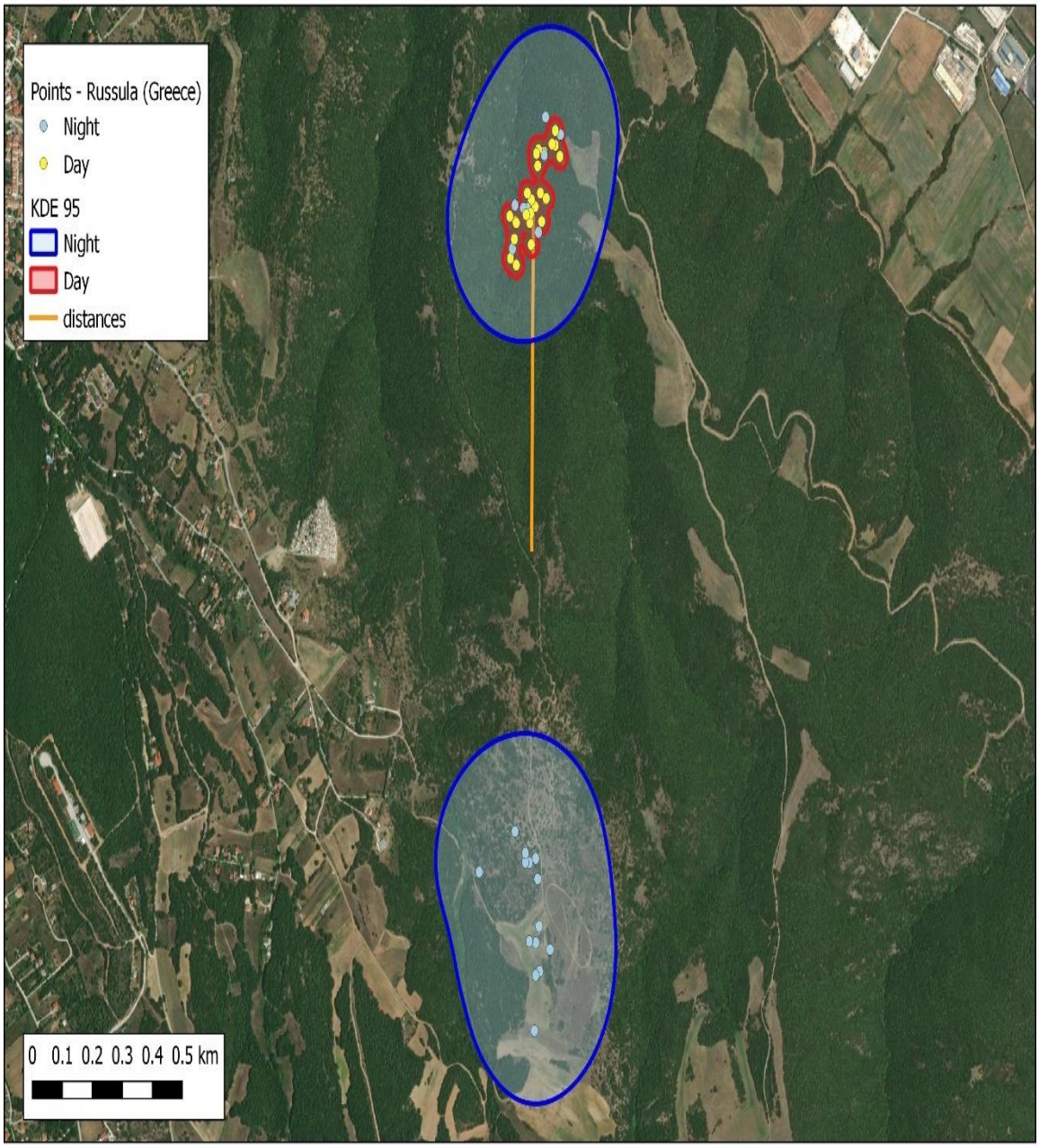

Figure 11: The day and night home ranges of Russula in Greece.

Brex began its spring migration between March 31 and April 4, 2021, and the dates cannot be determined more precisely than that. It arrived at its breeding ground in Russia (Central Siberia) on May 6. In figure 12, it shows that the point movements of Bxe in Russia were nearly identical to those of Drakula and Bacon in Godollo. This because it spent both day and night in the forest. Its autumn migration was longer recorded by the tag.

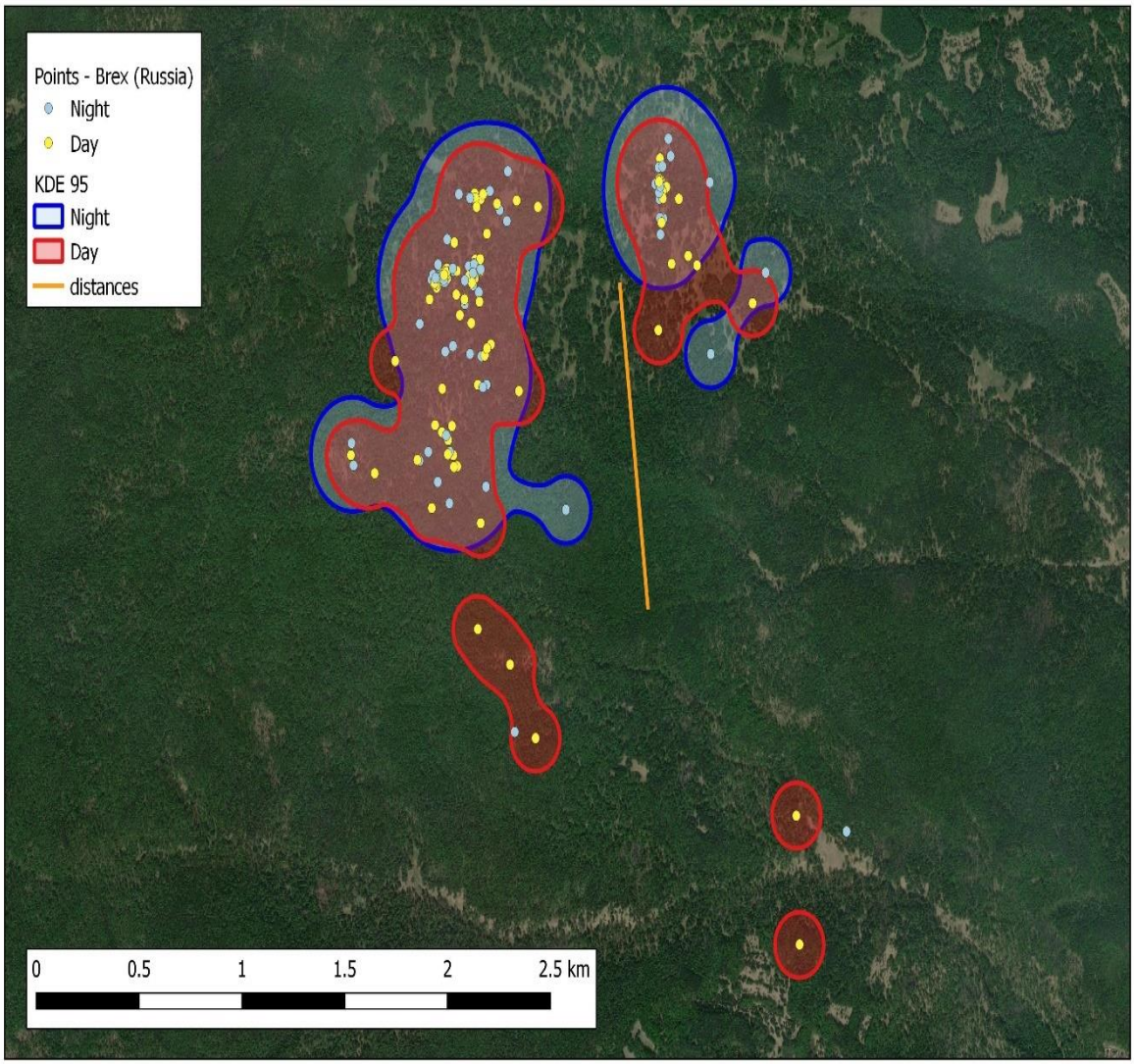

Figure 12: The daytime and night-time home ranges of Brex in Russia.

Galoca migrated to Spain (Menorca Island) between November 18-22, 2021, and reached Spain on November 26. Galoca in Spain had intersecting home ranges, but the bird did not spend the day in the night-time home range or vice versa. Galoca often spent the day in open agricultural fields or close by as depicted in figure 13. In Spain, Galoca stayed in both open fields and forested area which was the opposite of the Godollo movements (figure 8), where it spent the night in human settlement. And bird moved short distance between the daytime and night-time home ranges. The following year, between March 20 and 30, Galoca returned to the Carpathian Basin, exactly at the location of tagging. Spring migration started between April 5-11 and its tag recorded data for the last time on May 2nd, presumably while on the move, in Russia.

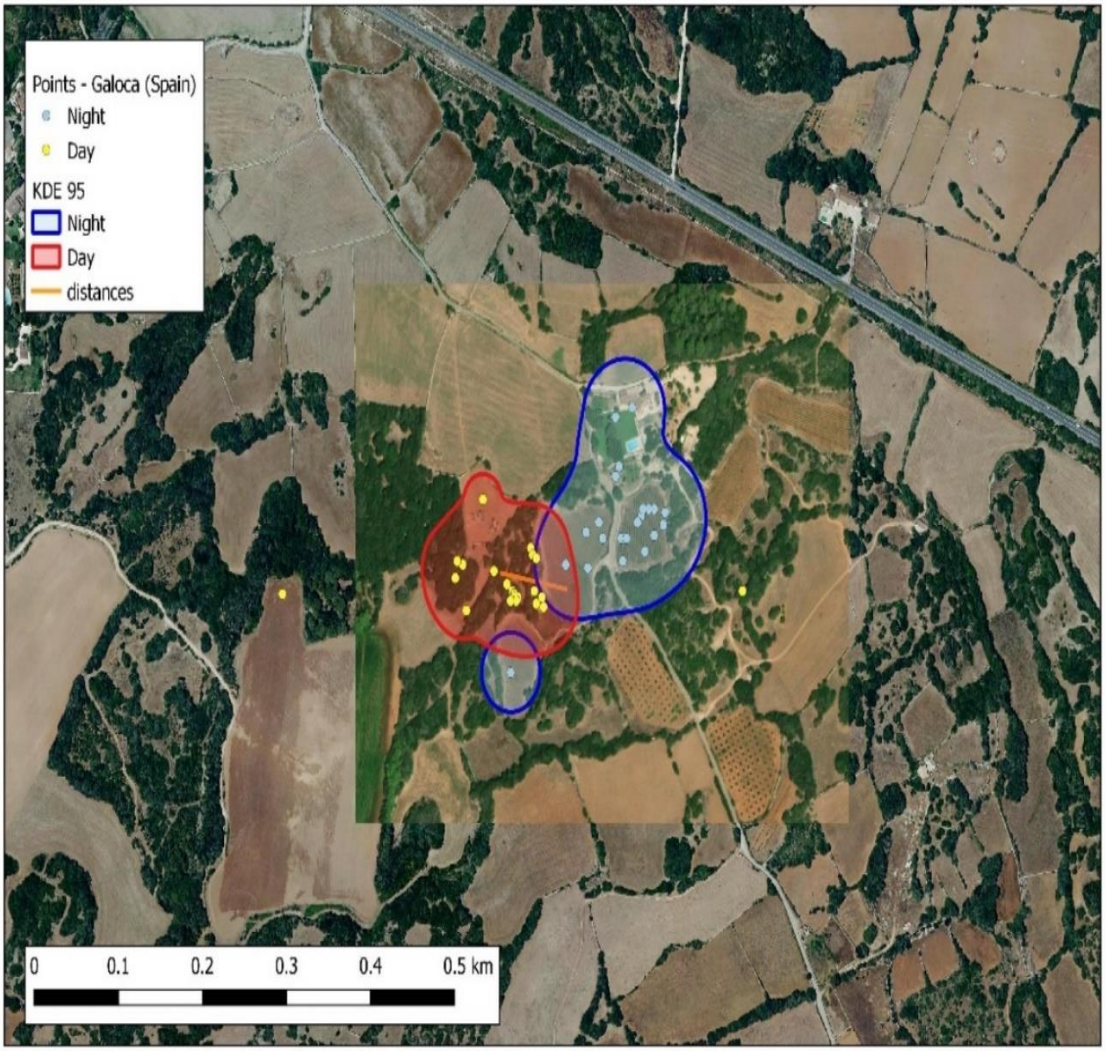

Figure 13: The home range movements of Galoca in Spain.

Gomboc Artur was the first of the birds in autumn to leave the study area on November 1, 2020. It migrated to Italy for the winter. The other birds departed much later than this, due to relatively mild winter weather conditions. What was interesting about this bird was that in Italy it had similar home range movements as in Godollo. The daytime and night-time home range overlapped with the daytime home range closer to the forest edge. And the night-time home range was wider and relatively larger compared to the daytime home range and it was the same in Godollo. After 7th of February of the following year, the localization data came from a small, well-defined area, unlike the previous area use. It is assumed that the device was dropped, or the bird died**.**

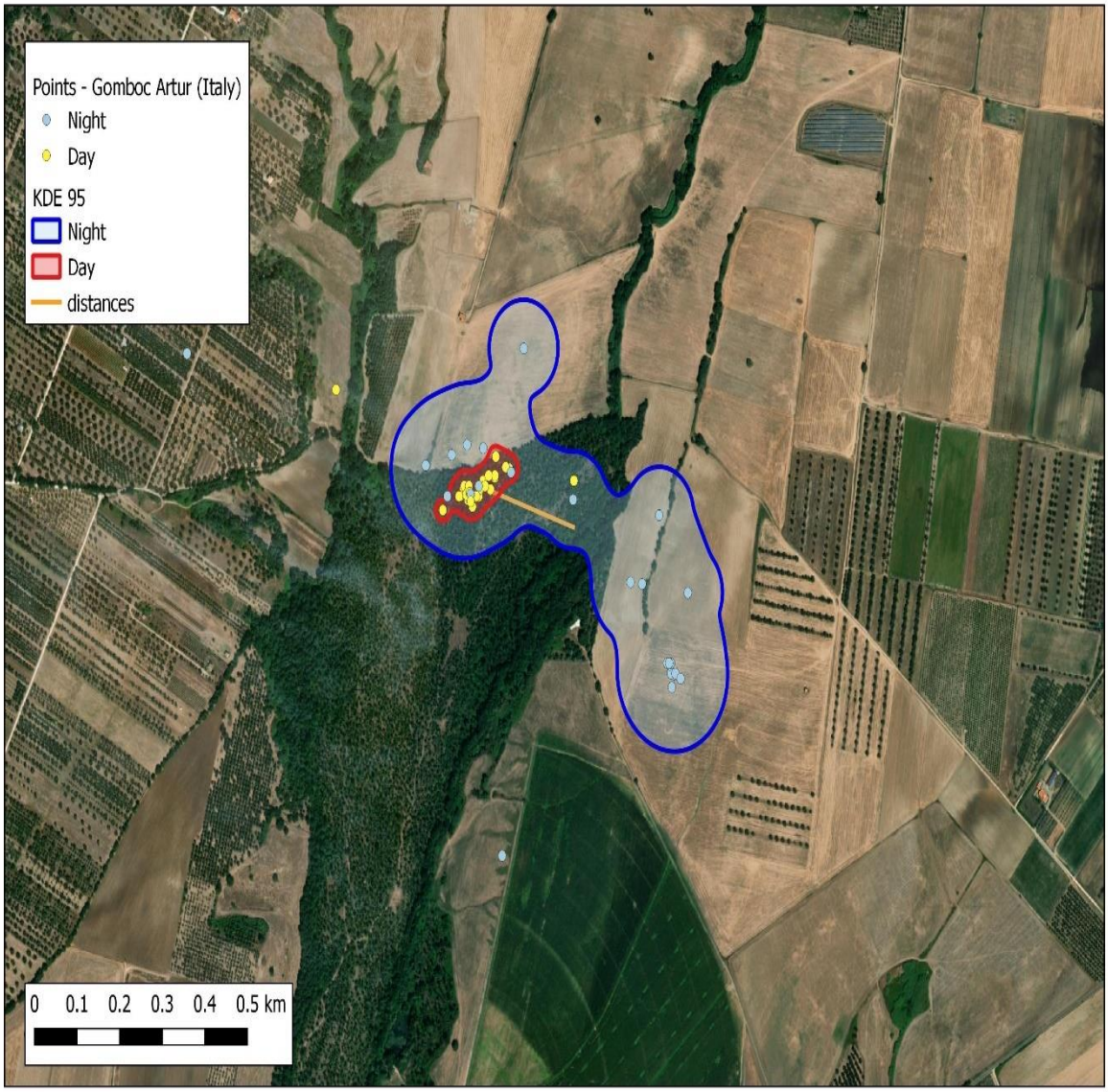

Figure 14: The daytime and night-time home ranges of Gomboc Artur in Italy.

5. Discussion

The hypothesis of this study was that there is no difference in habitat use during the wintering season of Eurasian woodcocks in Hungary. This hypothesis is rejected because the results indicated that there is a significant difference in habitat use of Eurasian woodcocks. The results have shown during the species uses the habitat differently and behaviours uniquely during the wintering season. The species travelled various distance lengths between their daytime and night-time home ranges. And the daytime and night-time home ranges were of assorted sizes, where some were extremely larger compared to others which were smaller.

In terms of the behaviour of Eurasian woodcock in this study, majority of the tagged individuals left the area where they tagged for the winter period. But the individuals did not live altogether at once. And some individuals never left Hungary for winter season, for instead (Teflon). All the individuals that left the tagging site to another country, but they then returned to the tagging site. And in each country the birds had two home range, one for daytime and the other for night-time. The daytime home range appears to have been used to hide from the predators and as shelter, and the night-time home range was mainly used for feeding. And there was no constant change in the for both home range, meaning the birds repeatedly used the same home ranges every single night and day. A similar study was conducted in Central Europe (Hungary), regarding the behaviour the birds depicted identical behaviour (Schally et al., 2021) as this study. But the birds which was conducted in 2021, they shown an increased repetition of changing night-time home range area into daytime home range area daily (Schally et al., 2021).

5.1. Comparison of Daytime and night-time home ranges

The results have indicated that Eurasian woodcock have two home ranges with distinct size, one for feeding and one as shelter. This is consistent with the species' behaviour of feeding during the night and resting at daytime during the wintering season. But in another similar study, their results showed evidence of diurnal foraging during winter which is normally occurs during summer (Duriez et al, 2005). In the case the individuals traded-off the risk of predation for feeding.

Regarding the home ranges of the Eurasian woodcock in this study the sizes of home ranges produced with Kernel Density Estimator (KDE) varied between the daytime and night-time. The daytime home ranges varied from 0.6 hectares to 70 hectares overall. But there were two birds that had daytime home ranges which were larger than 70 hectares and those

birds are Brex in Russia and Galoca on Godollo with 161.4 and 854.9 hectares, respectively. The reason (s) for such wide daytime home ranges may be the search for shelter to avoid the risk of predation. A study was conducted in the United Kingdom (Mander et al., 2022) where they were investigating temporal variation in winter home range sizes of GPS-tagged Eurasian Curlews Numenius arquata. Their results shown that home ranges varied among individuals, for instead the estimated total home range size generated from KDE varied between 60.0 hectares and 802.3 hectares (Mander et al., 2022). However, the home ranges that are considered extreme in this study are not extremely large when compared to other studies, may considered normal.

The night-time home ranges produced with KDE ranged between 0.7 hectares to 45 hectares, like daytime home ranges there were three birds that had larger home ranges compared to the birds. The birds were Bacon in Slovenia, Brex in Russia, and Galoca in Godollo, with home range sizes of 1032.8, 153.1, and 186.7 hectares, respectively. The reasons for such extreme home ranges sizes may be related to the winter habitat requirements such as food availability, absence of predators, weather conditions, and behaviour of exploring during the night of Eurasian woodcocks (Hoodless & Hirons., 2007; Mander et al., 2022). The bird Bacon found it interesting because in Slovenia it had the smallest (0.6 ha) home range size during the day. But during the night it had the largest home range size (1032.8 ha) compared to all the birds in this study. With the birds Brex and Galoca, they both had wide daytime and night-time home range sizes but the daytime home range size for the Galoca four times bigger than the night-time home range. In contrast, the same bird in Spain had small home range size for both daytime and night-time, 3.4 and 2.1 hectares, respectively. The study of Curlews showed evidence varied home ranges especially in winter since home range dynamics are mostly regulated by food availability (Mander et al., 2022).

In comparison of all the home ranges, the birds had bigger daytime home ranges compared to the night-time home ranges except for the extreme cases. The average daytime home range size (107.7 ha) was lower than the night-time home size (120.0 ha). According to Mander et al (2022) the average home range size of wintering Curlews was 555.5 ha which is higher than that of wintering Woodcocks for both daytime and night-time home ranges. But what is consistent with our study is the home ranges sizes were greater during the night than during the day. And their study indicated a relationship between the start of winter season and the size of home ranges, which suggested that home ranges slightly decrease throughout winter.

5.2. Description of distances between the daytime/night-time home ranges

The average distance travelled by the birds between the daytime and night-time home range is equivalent to 827.4 meters. The distances travelled by the birds ranged between 77.4 meters to 990 meters with few exceptions. The bird bacon travelled the longest distance of 2476.5 m amongst all the birds, this correlates with the size of the home during the night-time. Other birds that also moved long distances are Galoca and Brex (1813.5 m and 1169.5 m respectively). In several similar studies, the birds travelled the same distance(s) as the few exceptions in this study, for example same type of species travelled distances of 1300 and 1113 meters between home ranges (Schally, 2020).

5.3. Limitations

The limitations of this are related mostly to tag attachment and the battery lifespan. For health and welfare reasons, minimum harness was used to attach the tags unto the birds. This was done because the tags were being attached at back of the bird. An alternative method could have been used, for instead, attaching the tags on the legs of the birds using leg loops which supports the GPS tag for longer periods (Mander *et al*, 2022). But it is also important to check the effects of such attachments. The principal interest of this study was wintering movement data and because of limited battery lifespan, the GPS tags were programmed to give only two location points per day.

6. Conclusion

Based on our results, we have concluded that Hungary can be an important stopping place for a significant part of the migrating woodcock population. However, due to the mild winters experienced in recent decades, many individuals may try wintering in the Carpathian Basin. They are highly likely to leave the region only if the low environmental temperature and the associated reduced nutritional options reduce their body reserves below a certain threshold (Robin et al. 1999, Boos et al. 2005, Sánchez-García et al. 2018). Regardless of the location of their wintering grounds, the tagged woodcocks stayed in small areas, and we experienced a high repetition in terms of day-night territory change. The repeated movement pattern of the individuals towards the nocturnal feeding areas highlighted how important a small patch of habitat can be in the winter survival of the woodcock.

Duriez et al. (2005) conducted radio telemetry studies in Brittany, France, during which 65 woodcocks were tracked over three consecutive winters. By analysing the movements, three types of individual strategies were revealed. During daylight hours, a third of the birds stayed in a single small seed area in January and February, while some individuals used several core areas in succession and never returned to the previously used seed area, and nearly half of them alternated between several seed areas to which they returned. In their study, two-thirds of the birds used an alternative territory during the night, while one-third remained in the daytime core territory, and the mixed strategy was completely absent. It was shown that bushy-shrub habitats played a significant role in the area use of woodcocks during the day, and meadows at night. Most of the nocturnal areas were open, grassy habitats, however, without exception, it also happened that all woodcocks remained in their safe daytime areas at night.

Based on our results, we assume that woodcocks can adapt their migration to changes in climatic factors even in the short term. In the following years, it remains to be seen whether the easing of the winter will continue and, as a result, the number of individuals of the wintering woodcock population in Hungary will increase.

7. Summary

Eurasian woodcocks (*Scolopax rusticola*, Linnaeus, 1758) are medium-sized birds, which can be found in subarctic palearctic. Eurasian woodcocks possess a cryptic camouflage to blend into the environment. These birds have rich history across European countries including Hungary. And Hungary a monitoring program (Woodcock Monitoring program) was initiated in order to learn and understand more the behaviour od this species. This study documents the habitat use and wintering behaviour of Eurasian Woodcocks which were GPS-tracked in Hungary from the year 2020 to 2022.

The data of this was collected in Godollo, Babatpuszta (47.62694 N, 19.38323 E); where the birds were caught and tagged. The study area was 86 hectares, and the area is surround by various vegetation types which include mixed and coniferous forests. Currently, the area is utilized as a pasture and is mowed for forage for cows and horses. Apart from the various habitat types, this area is surrounded by a lake system consisting of 11 lakes. Different game species can be found in this area and that includes Hungarian big five, Eurasian badger, red fox, and European hares. It is important to note that this study area is near to the M3 highway which causes significant noise and light pollution.

Data from GPS tracking project of Eurasian Woodcocks for Woodcock Monitoring Program was used, and this is a common method for studying this species. Because Eurasian woodcocks are cryptic and elusive species. For capturing and tagging of the birds, this was done immediately after sunset because the birds are known to be active during that time. A net attached to six meters pole was used to capture the birds and 21 Eurasian woodcocks were tagged. But data from eight individuals was used since these individuals were the only ones with periods where two points were recorded per day. The data collected was analysed using Microsoft excel 365, PAST (v4.03) for statistical analysis, and for other calculations QGIS (3.10.9) was used. The collected data was then separated into locations, day, night periods by filtering the raw data. This was done for all the countries the bird(s) travelled to if they have travelled. The distance the birds travelled between their daytime area and night-time area was also calculated. The home ranges were estimated using the Kernel density estimation (KDE) method, with the following parameters: cell size = 5 m, smoothing parameter (h): normal Kernel href calculated value, omitting the outlying href × 2 points; 95% probability contour. Based on our experience, smaller distances between daytime points resulted in smaller h-values for all individuals than night-time points. After, the home ranges of the day and night areas were calculated using polygons in Open Jump HoRAE (v). The distances between the

geometrical centres of night-time and daytime home ranges were measured for all the birds using QGIS. The daytime and night-time home ranges were not normal distribution ($p<0,05$), so only non-parametric test could be applied. If we consider the outliers, there was no statistical difference between day and night, according to the Mann-Whitney test ($U=65,5$, $p=0,34$), without the outliers, the difference was statistically significant ($U=29,5$; $p=0,045$).

The analysis of the results indicated that the Eurasian woodcocks do migrate for winter season to other countries such as Slovenia depending on factors like weather conditions. What also noticeable from the results of this was that they migrate in different time periods depending on an individual. In terms of home range during the day and night, all the night-time home range were wider and larger as compared to daytime home ranges. For this study there were few exceptional birds which had bigger home ranges and travelled the longest distance, for example Bacon in Slovenia it had the largest night-time home range (1032.8 ha) and small daytime home range (0.6 ha). This in comparison with the same bird in Godollo where it had both small daytime and night-time home range sizes.

Generally, all the Eurasian woodcocks in this study had overlapping home ranges and some birds behaved uniquely for instead, Bacon after being tagged it stayed in the forest and hardly visited the open fields. Some birds visited both human settlements and open fields at night and most spent nights at daytime home ranges or vice versa.

For future research on Eurasian woodcocks, would recommend that more individuals should be tagged to fully understand the behaviour of these species.

8. Acknowledgement

I hereby acknowledge with thanks the kind patronage, inspiration, encouragement, constructive criticism, and timely guidance that I have received from my supervisor/ thesis advisor, Mr. Gergely Schally in completing my thesis. I would also like to thank my colleagues for accompanying me to the field. Again, I would like to thank my friends and family for their deep support.

I would like to express my thanks to the Hungarian Hunter's National Association and to the Ministry of Agriculture for the support of the Woodcock tracking research.

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