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SPATIAL DYNAMIC AND ECOLOGY OF A MALE EURASIAN LYNX, *LYNX LYNX* (CARNIVORA, FELIDAE), IN VOLYN POLISSIA, UKRAINE: FIRST GPS-GSM TELEMETRY FINDINGS

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Spatial Dynamic and Ecology of a Male Eurasian Lynx, *Lynx lynx* (Carnivora, Felidae), in Volyn Polissia, Ukraine: First GPS-GSM Telemetry Findings. Cherepanyn, R. M., Franchuk, M. V., Kubala, J., Andreychuk, Y. M., Yamelynets, T. S., Signer, J., Vykhor, B. I. & Dykyy, I. V. — In landscapes affected by human activity, understanding the spatial dynamics, predation behaviour and habitat preferences of large carnivores is essential for developing effective conservation strategies. The Eurasian lynx, *Lynx lynx* Linnaeus, 1758, plays a vital role in maintaining the ecological balance of temperate and boreal forests in Europe and Asia. However, the ecological patterns and behavior of lynx populations in Ukraine remain poorly studied. This study, based on GPS telemetry data collected from February to August 2023 in the Rivnenskyi Nature Reserve and adjacent territories, is the first to provide a comprehensive assessment of lynx home range, predation ecology and habitat selection in Ukraine. The average annual home range size of the lynx ranged from 181 to 255 km², depending on the home range estimator used (95% MCP, KDE, and AKDE), with significant seasonal variation: larger ranges in summer (172 km², 95% MCP) compared to smaller winter ranges (113.2 km², 95% MCP). The lynx primarily preyed on roe deer (*Capreolus capreolus*) and brown hare (*Lepus europaeus*), occasionally targeting smaller prey and carnivores, including the raccoon dog (*Nyctereutes procyonoides*). Kills and resting sites were located in dense, low-visibility areas such as swampy coniferous and deciduous forests. Moreover, the study demonstrated that lynx actively avoided human settlements and roads, particularly during summer, highlighting the influence of anthropogenic factors. While our findings align with patterns observed in other European lynx populations, they also reveal regional variations driven by local landscape features. Of the lynx telemetry observations, 30.5% occurred within protected areas and 69.5% in forestry enterprises, degraded marshlands and hunting grounds. These results emphasise the importance of spatial ecology in carnivore conservation and highlight the need for continued monitoring to assess the impact of human activity on lynx populations in Ukraine. Furthermore, this study provides valuable insights for developing targeted conservation strategies involving local communities and stakeholders for the species in Ukraine and Eastern Europe. It also emphasises the need for standardised monitoring to facilitate comparative analyses of lynx ecology across different regions, including the Baltic and the Carpathians.

Key words: Eurasian lynx, home range, MCP, KDE, AKDE, Polissia, Ukraine.

Introduction

The spatial dynamics of large carnivores, including their home range size, habitat selection and movement patterns, are primarily driven by the need to secure vital resources (Gittleman & Harvey, 1982; Boitani & Powell, 2012; Gittleman, 2013). These behaviours are shaped by prey availability, competition, human activity and habitat fragmentation. Predation ecology, including diet, hunting strategies and prey selection, is closely linked to spatial behaviour (Sunquist & Sunquist, 1989; 2020). Understanding these dynamics is crucial for the effective conservation of large carnivores, particularly in human-dominated landscapes where they face challenges due to their extensive spatial requirements (Breitenmoser & Breitenmoser-Würsten, 2008; Linnell et al., 2021; Kubala et al., 2024). Accurate home range estimates are essential for assessing population trends, understanding habitat suitability, and informing conservation strategies. Yet, landscapes' inherent variability poses significant challenges to data collection and the reliable extrapolation of findings across different regions (Herfindal et al., 2005; Palmero et al., 2023 a, b). Although the adaptive predation strategies of large carnivores highlight their behavioural plasticity, they also complicate conservation efforts, particularly in areas where prey is scarce or human-wildlife conflict is prevalent (Linnell et al., 2001; Schmidt, 2008; Nagl et al., 2022; Cherepanyn et al., 2023 c, 2024). Another biological function that affects spatial dynamics in large carnivores is resting, which shapes habitat use, territoriality, and intraspecific competition (Kolowski & Woolf, 2002; Signer et al., 2019;

Hočevar et al., 2021). Understanding these relationships enhances our knowledge of carnivore ecology and informs conservation strategies to support their complex habitat needs (Podgórski et al., 2008; Filla et al., 2017).

The Eurasian lynx *(Lynx lynx*) is a generalist carnivore inhabiting boreal and temperate forests throughout Europe and Asia (Breitenmoser et al., 2015; von Arx, 2020, Kaczensky et al., 2024). The size of the lynx's home range varies considerably across Europe (Kubala et al., 2024), influenced by factors including sex, age (Schmidt et al., 1997; Sunde et al., 2000; Melovski et al., 2020), prey availability, environmental productivity (Herfindal et al., 2005; Breitenmoser-Würsten et al., 2007), and conspecific density (Pesenti & Zimmermann, 2013; Aronsson et al., 2016). As an apex predator, it profoundly impacts prey populations, particularly ungulates (Breitenmoser & Breitenmoser-Würsten, 2008; Andrén & Liberg, 2024). Although the diet of lynx in Europe ranges from small rodents to red deer (*Cervus elaphus*), they are specialist predators that primarily target roe deer (*Capreolus capreolus*) when available (Molinari-Jobin et al., 2007; Melovski et al., 2020; Oliveira et al. 2024). Lynx spatial dynamics and resting site selection is influenced by several key survival factors that help them conserve energy, avoid detection, and stay close to resources (Sunde et al., 1998; Filla et al., 2017; Belotti et al., 2012). Integrating spatial ecology with studies on predation and resting behaviours provides a more comprehensive understanding of how lynx interact with their environment and contribute to ecosystem stability. These insights are crucial for informing conservation strategies, mitigating human-wildlife conflicts, and ensuring the long-term viability of lynx populations (Linnell et al., 2021). However, despite extensive research on lynx ecology in Europe, relevant information from Ukraine remains limited or scarce (Cherepanyn et al., 2023 a).

The lynx has been listed in Ukraine's Red Data Book since 1993 (Shcherbak, 1994; Akimov, 2009) and classified as "vulnerable" in 2021 (Order of the Ministry of Environmental Protection and Natural Resources of Ukraine, No. 29). It is protected under Appendix III of the Berne Convention, Appendix II of CITES, and is listed on the International Union for Conservation of Nature (IUCN) Red List (von Arx, 2020). The country's conservation plan for the species was adopted in 2021 according to Order No. 595 (Action Plan, 2021). In Ukraine, the lynx is widespread in two biogeographical zones — the Carpathians and Polissia, belonging to the Carpathian and Baltic populations (Breitenmoser et al., 2015; Kaczensky et al., 2024). In 2019, official data recorded 435 lynx in the Carpathians and 128 in Polissia (Cherepanyn et al., 2023 a), while the Red Data Book estimated 350–400 and 80–90, respectively (Akimov, 2009). Lynx population estimates vary due to differing assessment methods and unsynchronized monitoring and data exchange between institutions (Vykhor et al., 2022). Although the first radio-telemetry study was conducted in 2003 in the Polissia Nature Reserve (Shkvyrya, 2005; Zhyla, 2012), a significant gap remains in empirical research on the ecology and spatial dynamics of lynx in Ukraine, particularly concerning home range size, predation, resting and the ecological factors constraining the species to specific areas based on telemetry data (Kubala et al., 2021; Cherepanyn et al., 2023 b). Therefore, our study aims to: 1) gain insight into the spatial needs of the lynx in Ukraine by estimating individual home-range sizes, 2) provide the first reliable data on lynx predation by monitoring feeding behavior through

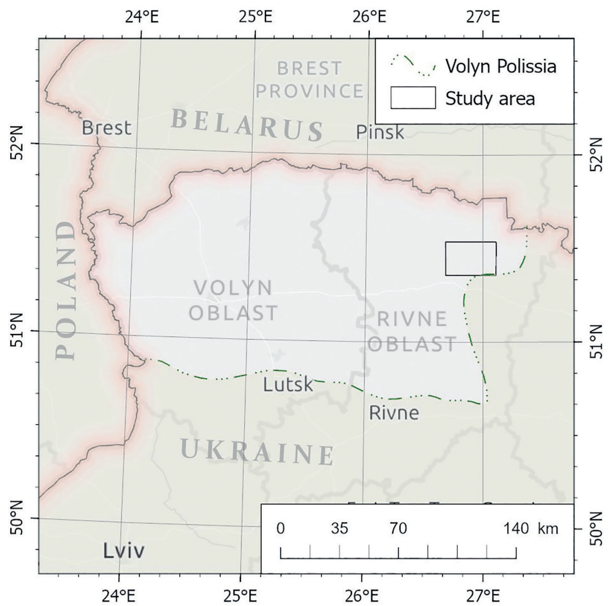

Fig. 1. The study area is situated within the Volyn Polissia region, located in the north-western part of Ukraine

prey species analysis and 3) compare our findings with data from other lynx studies. Finally, we discuss remaining ecological knowledge gaps, offer recommendations for future research, and explore the implications of our results for practical management and conservation efforts of the Eurasian lynx in Ukraine.

Material and Methods

Study area

Our study was conducted within the biogeographical zone of Volyn Polissia (Fig. 1) in the Rivnenskyi Nature Reserve — Somyne Massif, Sarnensky District, Rivne Oblast (IUCN Category Ia, Ramsar sites), in the local importance botanical zakaznyk "Velykoozerianskyi" (zakaznyk, a form of nature protection in Ukraine that designates areas for the sustainable use of natural resources) and the adjacent lands of forestry (Klesiv and Sarny forestry enterprises) and agricultural purpose in the northwest part of Ukraine. The study area, covering a total of 362 km², is characterised by flat terrain, predominantly sandy soils, excess moisture, dense forestation, and the presence of swamps. The climate in the region is marked by notable seasonal temperature variations, with warm summers. The forests of Volyn Polissia primarily consist of oak-hornbeam (*Quercus robur* L. — *Carpinus betulus* L.), pine-oak (*Pinus sylvestris* L. — *Quercus robur* L.), and shrub plant communities, covering approximately 40% of the area. Meadow-swamp plant communities occupy around 10% of the territory (Marynych, 1993, 2007). According to the landscape zoning classification by Marynych et al. (2007), the study area is part of the plain landscapes within the coniferous-broadleaf forest group, divided into the following subgroups: (1) al-

Fig. 2. An adult male lynx captured on February 4, 2023, during a tranquilization, medical examination, and collaring procedure in the Nature Reserve "Rivnenskyi"

luvial-sand plains, flat and undulating, characterised by sod-podzolic soils and lowland swamps predominantly covered by pine (*Pinus sylvestris* L.) forests and subors (90%); (2) outwash plains, flat and undulating, with sod-podzolic and sod soils, lowland swamps, and isolated patches of pine forests, subors, and alder stands (5%); and (3) floodplain landscapes of the plains, consisting of forested areas and meadow-swamp ecosystems (5%). The massif is predominantly covered by forest, aquatic, and swamp vegetation, with isolated areas of psammophytic and meadow vegetation (Akimov, 2009). The fauna comprises 46 mammal species, with rodents being the most numerous group, alongside roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), elk (*Alces alces*), brown hare (*Lepus europaeus*), Eurasian beaver (*Castor fiber*), red fox (*Vulpes vulpes*) raccoon dog (*Nyctereutes procyonoides*) and grey wolf (*Canis lupus*). Moreover, the area is characterised by a relatively low density of human settlements and population.

Lynx captures and collaring

For lynx captures, we utilised walk-through, double-door wooden box traps (measuring 2×1×1 m), strategically positioned in areas identified through prior systematic monitoring as frequently visited by lynx (Vykhor et al., 2022). Lynx capture efforts were conducted during winter and early spring, aligning with the period of increased spatial activity, especially during the mating season. The box traps were continuously monitored through a GSM alarm system (Trapmaster, Germany) and camera traps (Bushwacker Big Eye D3N Camera, China; Willfine WG-4.0CG-GPS Camera, China). These systems promptly alerted the responsible personnel if a trap doors closed. On February 4, 2023, an adult male lynx was successfully captured (Fig. 2). The lynx was tranquillised by a veterinarian using a combination of medetomidine (Domitor®) and ketamine (Ketasol® and Narketan®), with atipamezole (Antisedan®) administered as a reversal agent (LifeLynx, 2018; Signer et al., 2021; Kubala et al., 2024). This study adheres to the ARRIVE guidelines (Percie du Sert et al., 2020) and all procedures were approved by the Ministry of Environmental Protection and Natural Resources of Ukraine (Approval No. 2022/4). The captured lynx underwent a medical examination and was fitted with a GPS-GSM collar, equipped with a drop-off mechanism, providing online access to data stored on the server (Ecotone, Poland). We recorded the animal's sex and weight (22 kg), and estimated its age (4–5 years old) based on tooth wear (Marti & Ryser-Degiorgis, 2018 a, b) and data from systematic camera trapping. After the protocol, the lynx was released at the capture site. The collar was programmed to collect four GPS fixes every 24 hours, with a 6-hour interval between each fix. No mortalities or complications occurred during or after the capture, and none were observed due to collaring.

Spatial analysis

Spatial-temporal geodata of the GPS tracker were processed using a geographic information system ArcGIS Pro 3.2.2 licensed software (ESRI, Redlands, CA, USA, 2016; Andreichuk & Yamelynets, 2015; Chaskovskyy et al., 2021). We calculated annual, seasonal, and monthly home ranges for lynx using 9% 100%, and 50% (core area) Minimum Convex Polygons (MCP; Mohr, 1947), Kernel home ranges (KDE; Worton, 1989), and Autocorrelated Kernel home ranges (AKDE; Fleming et al., 2015) to facilitate comparisons with previous studies. Based on the geographic similarity to the lynx population in the Białowieża Primeval Forest, Poland, and the annual variation in its movement patterns, we followed the definitions of Jędrzejewski et al. (1996) and Schmidt et al. (1997) to delineate two distinct seasons: (1) a period of low movement rates, corresponding to spring and summer (May 1 to September 30, hereafter referred to as "*summer*"), and (2) a period of high movement rates, corresponding to autumn and winter (October 1 to April 30, hereafter referred to as "*winter*"). We further defined the breeding season as February 1 to March 31, and the non-breeding season as April 1 to January 31. To calculate the annual home range, a minimum of 6 months of data was required (Herfindal et al., 2005; White et al., 2015; Kubala et al., 2024). For the seasonal home range, at least 20 locations were necessary (Linnell et al., 2001; White et al., 2015), while monthly home ranges required at least 14 location points. We defined a lynx's home range as established and permanent when it exhibited a consistent polygonal movement pattern, excluding locations that represented excursions of adult lynx. Home ranges were calculated using the *amt* and *ctmm* packages (Calabrese et al., 2016; Signer et al., 2019) within the R statistical environment (R Core Team, 2021).

Predation and anthropogenic impact

We used ArcGIS to analyse GPS data transmitted via the GSM network and to visually identify clusters of GPS locations, referred to as GPS location clusters (GLCs; Merrill et al., 2010). To reliably identify potential lynx kill and resting sites (Podgórski et al., 2008; Schmidt, 2008; Filla et al., 2017), a GLC was defined as a cluster where more than two GPS points were recorded within a 200-metre radius. Previous GPS telemetry studies on Eurasian lynx have shown that after killing an ungulate, lynx frequently return to the kill site or remain within a 300-metre radius for more than one night (Breitenmoser & Breitenmoser-Würsten, 2008; Krofel et al., 2013; Melovski et al., 2020). When a GLC suggested a potential kill site, field investigations were carried out to locate prey remains. Starting from the center of the GLC, we used handheld GPS devices to search the surrounding area, expanding the search radius to 150 metres around each cluster location. In areas with dense vegetation, the search radius was extended as necessary. Environmental characteristics within a 50-metre radius of the kill site were recorded to capture all potentially relevant features. For resting sites, we aimed to identify the precise lynx bed site. If direct access was impeded by impenetrable terrain, we recorded environmental characteristics at the nearest accessible location within a 150-meter radius, assuming it reliably represented the actual bed site due to habitat homogeneity.

The impact of human presence on lynx hunting and resting behaviour was assessed by analysing the proximity to the nearest rural settlements, as well as roads, using the "Near" tool in ArcGIS according to Melovski et al. (2020). The roads in the study area consisted solely of dirt roads and field and forest paths. The results are reported as the closest distances of lynx from rural settlements, as well as from roads. The study area lacked major settlements, urban centers, paved roads or highways. Consequently, these categories were excluded from the analysis as potential sources of disturbance.

Results

Lynx home range size

We collected 487 fixes for the period between February 4, 2023 to August 6, 2023. From these data, we used all fixes for creating the annual home range, 257 fixes for summer home range and 230 fixes for winter home range. Furthermore, we utilised 143 fixes to define the breeding home range and 344 fixes for the non-breeding home range. On average, 70 fixes were used for the monthly home ranges (with the exception of August, when only 14 fixes were available).

The annual home range (MCP 95%) was 181.1 km^2 (Fig. 3; Table 1). In summer, the home range size (MCP 95%) was 172.1 km^2 (Fig. 4), while in winter, it decreased to 113.2 km^2 (Fig. 5; Table 1). The breeding season home range measured 129.2 km^2, whereas the non-breeding home range was larger at 181.6 km^2 (Table 1). All home range sizes were consistently larger when other estimators were applied, with MCP yielding smaller estimates compared to both KDE and AKDE (Tables 1, 2). KDE estimates were generally comparable to AKDE for annual, winter, and breeding home ranges, but were lower than AKDE during the summer and non-breeding seasons. Core areas (MCP 50%) comprised, on average, 26–31% of annual home ranges, 24–30% of summer home ranges, and 23–24% of winter home ranges depending on the home range estimator (Figs 1–3; Table 1). The smallest core areas, representing 15–20% of the home range, were observed during the breeding season, while the largest core areas, ranging from 25–34%, were recorded during the non-breeding season.

Average monthly home range (MCP 95%) was 78.5 ± 15.6 km^2 (mean ± SE) depending on the estimator used (Table 2). The smallest home range was 57.3 km^2 in February

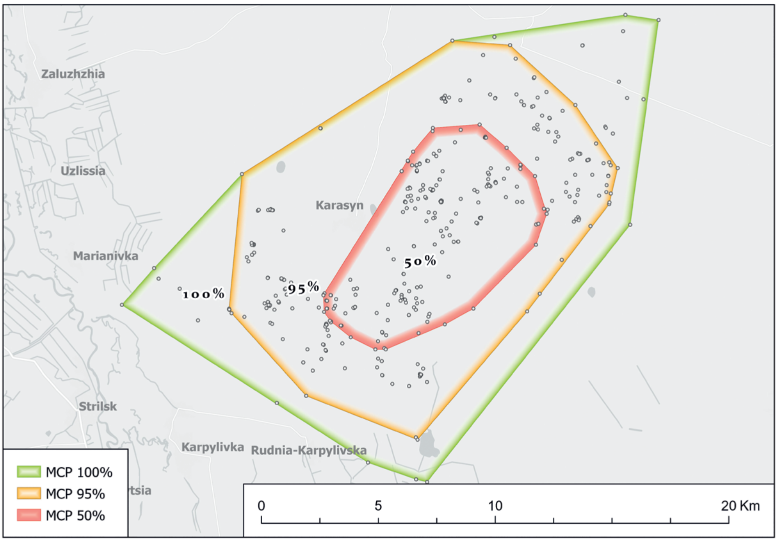

Fig. 3. GPS locations and the annual home range of a lynx in the study area are represented by Minimum Convex Polygons (MCPs) at 100% (green line), 95% (orange line), and 5% (red line) levels. The map also highlights human infrastructure within the study area

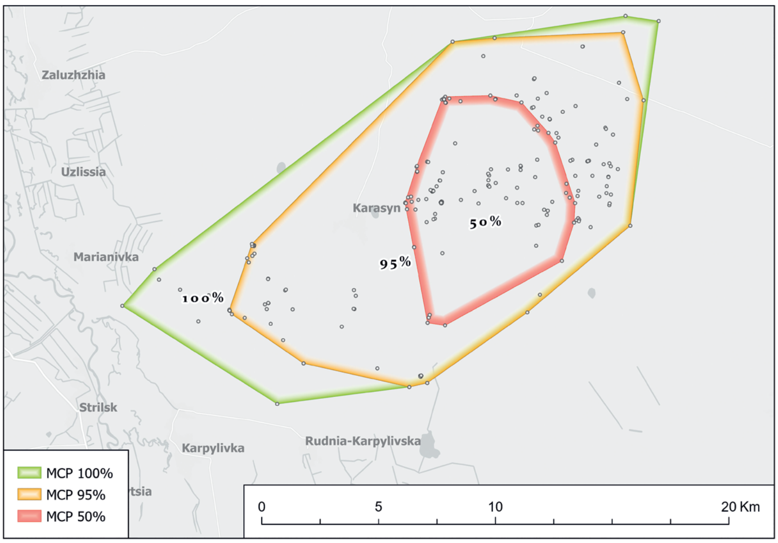

Fig. 4. The summer home range of male lynx in the study area is depicted using GPS fixes and MCPs at the 100% (green line), 95% (orange line), and 50% (red line) levels. The map also highlights human infrastructure within the study area

(with the exception of August, when only 14 fixes were available), while the largest was 128 km^2 in June. The average monthly core area (MCP 50%) was 24.4 ± 8.3 km^2, with the smallest core area of 9.2 km^2 observed in May and the largest at 65.6 km^2 in July (Table 2).

Predation and anthropogenic impact

We identified 13 GPS location clusters (GLC) as potential kill sites, where we located remains from 21 kills (Fig. 6; Table 3), representing six species: roe deer (*Capre-*

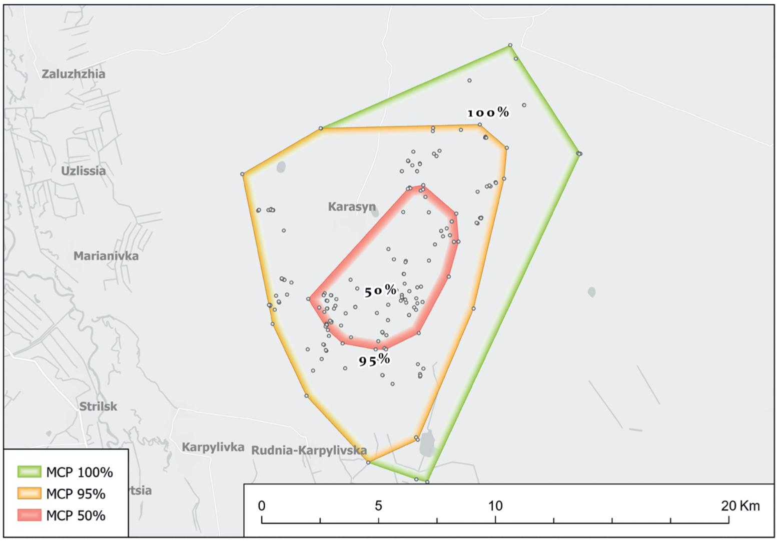

Fig. 5. The winter home range of a lynx in the study area is depicted using GPS locations and Minimum Convex Polygons (MCPs) at 100% (green line), 95% (orange line), and 50% (red line) coverage levels. The map also highlights human infrastructure within the study area

olus capreolus, n = 10), raccoon dog (*Nyctereutes procyonoides,* n = 5), brown hare (*Lepus europaeus,* n = 2), Eurasian beaver (*Castor fiber,* n = 1), wild boar (*Sus scrofa,* n = 1), red fox (*Vulpes vulpes,* n = 1), and hazel grouse (*Tetrastes bonasia*, n = 1). The lynx prey consisted predominantly of roe deer and brown hare. Additionally, there were instances where lynx killed raccoon dogs (n = 5) and a red fox (n = 1) but did not consume them, suggesting selective predation behaviour. Subcontinental moss

Table 1. **Average annual and seasonal (summer and winter) home ranges (km^2 ± SE) of male Eurasian lynx (*Lynx lynx*) in the study area using 95%, 100 and 50% Minimum convex polygon (MCP), Kernel density estimation (KDE) and Autocorrelated Kernel home range (AKDE)**

Home range method	Annual	Summer	Winter	Breeding	Non-breeding
			HR mean 95%, km^2		
MCP	181.1	172.1	113.2	129.2	181.6
KDE	245.7	273.5	177.3	188.7	258.5
AKDE	255	321.6	175	179.2	297
			HR mean 100%, km^2		
MCP	258.3	218.1	160.6	160.5	246.3
KDE	351.5	378.1	250.2	266.5	363
AKDE	339.2	467.5	236.8	265.4	367.7
			HR mean 50%, km^2		
MCP	55.8	51.7	27.1	19.5	61.1
KDE	64.9	66.5	41.1	34.5	68.2
AKDE	66.8	79.1	42.2	35.6	75.6

Scots pine forests, nemoral bog conifer woodlands, broadleaved swamp woodlands on acid peat, and non-riverine woodlands with *Betula*, *Populus tremula*, or *Sorbus aucuparia* dominate the habitats preferred by lynx for hunting. Furthermore, broadleaved swamp woodlands and nemoral bog conifer woodlands serve as the preferred resting sites.

The average distance from kill sites to the nearest settlement was 4.53 ± 0.33 km (mean ± SE), while the average distance to the nearest road was 0.32 ± 0.05 km (Table 3). For roe deer, the average distance from kill sites to settlements was 4.12 ± 0.29 km, compared to 4.9 ± 0.29 km for other prey species. The difference in distances between roe deer and other prey species was not statistically significant. Moreover, the roe deer kill sites were located, on average, 0.43 ± 0.06 km from roads, compared to the 0.23 ± 0.07 km distance observed for other species. However, this difference was also not statistically significant.

We also identified 8 GPS location clusters (GLC) as potential resting sites. The mean distance from resting sites to the closest settlement was 5.35 ± 0.31 km, whereas the average distance to the nearest road was 0.12 ± 0.03 km (Table 4). In summer, the mean distance from resting sites to settlements was 5.74 ± 0.39 km, decreasing to 4.9 ± 0.45 km in winter. Conversely, the average distance from resting sites to roads was 0.08 ± 0.04 km in summer, increasing to 0.18 ± 0.04 km in winter. Nonetheless, these seasonal differences did not reach statistical significance.

Discussion

The home range of a male lynx in the Rivnenskyi Nature Reserve was comparable to those observed in populations inhabiting similar environments, such as the Paazierre Forest in Belarus (Sidorovich, 2022) and the Białowieża Primeval Forest in Poland (Schmidt et al., 1997). This alignment in range size was also evident across mountainous regions of Central Europe, including the Bohemian Forest in Czechia, the Bavarian Forest in Germany, the Swiss Jura and North-

Table 2. **Mean monthly home range size (km^2 ± SE) of male Eurasian lynx (*Lynx lynx*) in the study area using 95%, 100% and 50% Minimum convex polygon (MCP), Kernel density estimation (KDE) and Autocorrelated Kernel home range (AKDE)**

Home range method	February	March	April	May	June	July	August
HR mean 95%, km^2							
MCP	57.3	91.4	64.2	81	127.9	121	6.6
KDE	116.6	175.3	169.3	154.7	353.1	327.5	111.3
AKDE	116	155.7	269.2	174.7	519.7	479.4	502.7
HR mean 100%, km^2							
MCP	85.2	100.3	79.8	97.9	184.3	139.4	14.9
KDE	166.9	248.5	232.1	218.9	497.9	459.8	170.7
AKDE	172.1	228.6	399.4	262.3	766.5	712.5	177.5
HR mean 50%, km^2							
MCP	15	14.1	33.6	9.2	33.3	65.6	0.01
KDE	23.2	40.6	47.8	26.5	90	90.2	21.9
AKDE	26.1	35	67.6	36.6	129.3	122.6	113.7

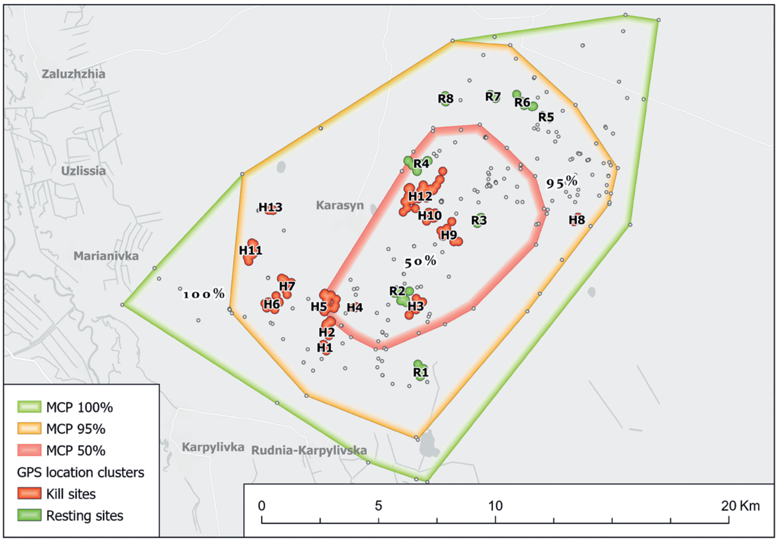

Fig. 6. The study area encompasses annual minimum convex polygons (MCPs) of an adult male lynx, calculated at 100% (green line), 95% (orange line), and 50% (red line) levels. GPS location clusters (GLCs) of potential kill sites (red polygons) and resting sites (green polygons) were documented and verified through comprehensive field investigations. These clusters were then analysed in relation to their proximity to the nearest rural settlements, dirt roads, and field/forest paths

Table 3. **GPS location clusters (GLCs) identified for sites with remains from 21 kills, including the average distances to the nearest settlements and roads**

GLC ID	Year	Month	Settlement distance, km	Road distance, km	Species
H3	2023	2	4.9	0.07	*Vulpes vulpes*
H2	2023	2	5.1	0.42	*Capreolus capreolus*
H5	2023	2	3.9	0.68	*Terastes bonasia*
H5	2023	2	3.9	0.68	*Capreolus capreolus**
H7	2023	2	4	0.2	*Castor fiber*
H6	2023	2	5.4	0.66	*Capreolus capreolus*
H1	2023	3	4.2	0.42	*Capreolus capreolus*
H4	2023	3	4.1	0.18	*Nyctereutes procyonoides*
H9	2023	3	4.3	0.39	*Nyctereutes procyonoides**
H10	2023	3	3.6	0.08	*Capreolus capreolus*
H10	2023	3	3.6	0.08	*Lepus europaeus*
H12	2023	3	3.2	0.4	*Capreolus capreolus*
H2	2023	4	5	0.42	*Sus scrofa*
H2	2023	4	5	0.42	*Capreolus capreolus*
H3	2023	4	4.9	0.07	*Lepus europaeus*
H12	2023	4	3.2	0.4	*Capreolus capreolus*
H13	2023	4	3.5	0.4	*Capreolus capreolus*
H8	2023	6	9.7	0.03	*Nyctereutes procyonoides*
H11	2023	7	4.7	0.2	*Nyctereutes procyonoides*

* Two individuals of *Capreolus capreolus and Nyctereutes procyonoides* species were killed in each GPS location clusters.

western Switzerland (Ryser et al., 2004; Breitenmoser-Würsten et al., 2007), and the Carpathians (Okarma et al., 2000, 2007). Eurasian lynx show significant variation in home range sizes across Europe. The smallest average ranges were recorded in Switzerland's northwestern Alps, while the largest were along northern Norway (Kubala et al., 2024). The MCP method consistently produced smaller home range estimates compared to KDE and AKDE, a pattern also documented in previous studies (e. g., Schmidt et al., 1997; Melovski et al., 2020; Kubala et al., 2024). KDE and AKDE consider both spatial and temporal autocorrelation of locations, which often results in larger home range estimates. In contrast, MCP treats all location points equally, ignoring both their spatial distribution and the sequence in which they were recorded.

Lynx maintained a relatively stable home range size across seasons, consistent with findings from studies conducted in Norway (Walton et al., 2017), Poland (Schmidt et al., 1997; Jędrzejewski et al., 2002), Sweden (Danell et al., 2006), Switzerland (Breitenmoser & Breitenmoser-Würsten, 2008) and Western Carpathians (Kubala et al., 2024). However, summer home ranges were larger than those observed during winter (Tables 1, 2), in contrast to the seasonal estimates from Białowieża and the Western Carpathians (Schmidt et al., 1997; Schmidt, 2008; Kubala et al., 2024). This is indicating that male lynx do not generally adopt a roaming mating tactic (Sandell, 1989). Male lynx likely maintained larger, exclusive home ranges during the summer to minimise the presence of competing males ahead of the mating season. In winter, they used smaller areas with increased interaction, staying closer to receptive females (Breitenmoser et al., 1993; Schmidt et al., 1997; Herfindal et al., 2005). This pattern aligns with Sandell's (1989) prediction that male home range size generally correlates with prey density but may shift in re-

Table 4. **Identified GPS location clusters (GLCs) for resting sites, detailing the average distances to the nearest settlements and roads**

GLC ID	Year	Month	Settlement distance, km	Road distance, km
R2	2023	2	4.2	0.23
R4	2023	3	3.5	0.22
R6	2023	3	6	0.25
R2	2023	3	4.2	0.23
R1	2023	4	6.1	0.17
R3	2023	4	5.5	0.2
R4	2023	5	3.5	0.22
R7	2023	5	6.3	0.04
R8	2023	6	5.8	0.22
R6	2023	6	6	0.003
R7	2023	6	6.3	0.04
R5	2023	7	6.3	0.001
R6	2023	8	6	0.003

sponse to changes in mating strategies. However, the small sample size limits the scope of our research to some extent, and additional data on more lynx, particularly females, are needed to draw more definitive conclusions about the intrinsic and environmental factors influencing home range size.

Regarding predation, lynx in the Rivnenskyi Nature Reserve appear to have a similar ecological role to those in other parts of Central Europe, serving as apex predators of wild ungulates, particularly roe deer (Jędrzejewski et al., 1993; Molinari-Jobin et al., 2007; Andrén & Liberg, 2024). Predation data from 2023 indicate that male lynx in the study area killed 10 roe deer, representing 0.66% of the total hunting bag for the Rivne Region in 2021. As in other populations, its predation is not limited to ungulates and diet is supplemented by other species of smaller prey, including lagomorphs and small carnivores (Breitenmoser & Breitenmoser-Würsten, 2008; Melovski et al., 2020). This dietary pattern closely resembles that of lynx in the Paazierre Forest and the Naliboki Forest, Belarus (Sidorovich, 2022). Our study documented lynx abandoning red fox and common raccoon dog carcasses, with at least five instances involving raccoon dogs along forest roads, contributing to the natural regulation of these trophic competitors within the ecosystem. An intriguing question arises regarding the role of beavers in the lynx's diet, particularly given their high density in suitable habitats within the study area. However, further research is needed to confirm these findings and provide a more comprehensive understanding of lynx predation ecology in this region and its habitats, as well as its implications for ungulate hunting management.

Field examination of both kill and resting GLCs revealed that these areas predominantly consist of wet or heavily saturated biotopes with dense vegetation, including lowland and transitional swamps. These habitats primarily include swampy alder forests and pine forests along large marshes and within degraded drainage systems. In central Europe, lynx preferred open habitats such as meadows with abundant ungulates at night, while during the day, they selected dense, rugged areas away from human activity. Habitat selection was influenced by land cover in summer and by lower altitudes in winter (Filla et al., 2017; Belotti et al., 2018). Lynx preferentially select rugged terrain near rock formations, which provide shelter from temperature extremes, reduce encounters with humans, and enhance scent-marking effectiveness due to prominent locations (Signer et al., 2019; Hočervar et al., 2021). However, the Rivnenskyi Nature Reserve is characterised exclusively by flat terrain, lac'ing rugged landscapes or rocky formations. Consequently, our findings align with those reported in Poland's Białowieża Lowland Forest and Belarus's Paazierre Forest, where lynx preferentially selected kill and resting sites distinguished by complex, hard-to-access terrain, dense vegetation, and low visibility (Jędrzejewski et al., 1993; Schmidt, 2008; Sidorovich, 2022). The male lynx frequently visited hunters' feeding sites, key locations for locating its primary prey, and often concealed its kills by dragging them several dozen metres into areas with dense undergrowth or trees, reducing visibility and minimising the risk of scavengers or predators stealing the carcass (Okarma et al., 1997; Podgórski et al., 2008). Lynx are highly selective in choosing resting sites, with low visibility being a key factor, primarily resulting from dense trees and abundant undergrowth. Similar preferences have been observed in other lynx species, including the Iberian lynx (*Lynx pardinus*; Garrote et al., 2020), Canada lynx (*Lynx canadensis;* Mowat & Slogth, 2003), and bobcat (*Lynx rufus*; Morin et al., 2020), emphasising the importance of habitat cover for their conservation and management.

Spatial dynamics, seasonal home ranges and monthly lynx movements, including distances from kill and resting sites to the nearest settlements and roads, in the Rivnenskyi Nature Reserve may be most likely influenced by the seasonal accessibility of certain areas. Lynx maintained an average distance of 4.5 km from kill sites to settlements and 320 m from roads. Resting sites were, on average, located 5.35 km from settlements and 120 m from roads, with distances decreasing from summer to winter. In comparison, the average distance from kill sites to rural settlements in Mavrovo National Park, Macedonia, was much shorter, approximately 1.77 km (Melovski et al., 2020). In Norway, lynx also maintain shorter distances of 200 m from houses and roads (Sunde et al., 1998), whereas in the Bohemian Forest, they avoid human infrastructure, staying at least 1 km from settlements and 300 m from trails (Belotti et al., 2012; Filla et al., 2017). Similarly, bobcats typically avoid areas within 1 km of anthropogenic zones and 0.8–3 km of roads (Jones et al., 2022). Our findings support previous research showing that lynx exhibit seasonal habitat preferences and avoid areas with high human activity (Ripari et al., 2022; Oeser et al., 2023). To sustain their food supply, lynx must continuously track their primary prey. A significant portion of our male lynx home ranges overlaps with the challenging landscape of lowland swamps in the Lva River floodplain, fragmented by artificial embankments, dams, and roads along drainage canals. Our observations show that lynx frequently use forest roads, embankments, dams, and beaver dens for movement. From June to October, local residents gather wild berries, such as blueberries and cranberries, which increases human presence in forest and wetland areas. Based on this, we hypothesize that seasonal human activity may interfere with the behaviour of both prey and lynx, potentially reshaping their spatial patterns and hunting strategies. To avoid disturbed areas, both predators and prey may seek refuge in more secluded habitats, such as waterlogged alder, birch, and mixed pine forests (Schmidt, 2008; Belotti et al., 2018). Nevertheless, a more in-depth investigation is necessary to fully understand the underlying factors and dynamics of this spatial behaviour.

Overall, only 30.5% of recorded male lynx locations occurred within protected areas, with 15.3% in the Rivnenskyi Nature Reserve and 15.2% in the Velykoozerianskyi Botanical Reserve. The majority, 69.5%, were located in unprotected landscapes, including managed forestry zones, degraded marshlands, and active hunting grounds. Understanding the spatial dynamics and habitat needs of lynx is essential for effective conservation. Research in Scandinavia, for example, has shown that the extent of protected areas alone is often insufficient to sustain the entire lynx population (Linnell et al., 2001; 2021). A significant portion of lynx population occupy multiuse semi-natural areas where economic activities like logging, hunting, and agriculture are common von Arx, 2020;

Kaczensky et al., 2024). These semi-natural areas, while lacking strict protections, are critical for lynx populations but require management strategies that balance conservation with human activities (Breitenmoser & Breitenmoser-Würsten, 2008; Belotti et al., 2018; Linnell et al., 2021). Therefore, maintaining suitable conditions in hunting grounds, ensuring an adequate prey base in forestry and hunting areas, and involving not only conservation organisations but also forestry and hunting institutions in lynx monitoring, conservation and management efforts are essential for sustaining a viable lynx population state in the region.

Conclusions

Using GPS telemetry, we provide the first reliable estimates of home-range size, along with insights into the predation and resting ecology of lynx in the Rivnenskyi Nature Reserve and the adjacent lands in Ukraine. Our findings show that the ecological patterns closely resemble those of other European populations, particularly in the Paazierre Forest, Belarus, the Białowieża Primeval Forest, Poland. Lynx inhabit a home range of several hundred square kilometers, primarily feeding on wild ungulates. However, an important additional factor is their occasional reliance on small prey and carnivores, a behaviour that warrants further investigation. Our study suggests that lynx select resting sites with structural cover for concealment within the flat, swampy, and forested habitats, providing new insights into the ecological role of lynx in Ukraine and Eastern Europe. Nevertheless, the influence of intrinsic and ecological factors on lynx spatial dynamics and ecology requires additional and broader research. This underscores the need for more precise data and the establishment of a standardised monitoring system based on spatial concepts, scientifically robust methods, and range-wide collaborative efforts (Kubala et al., 2021, 2023). Tackling these challenges with an efficient and adaptive approach is crucial for gaining a clearer understanding of lynx ecology and the threats the species faces in this region. This will enable the development of relevant, specific, and targeted strategies and actions necessary for lynx conservation in Ukraine, ensuring the long-term survival and sustainability of both the Baltic and Carpathian populations.

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Credit authorship contribution statement

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