



Spatial structure of the male Eurasian lynx (*Lynx lynx*) home range within the Volyn Polissia, Ukraine

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Article info

Received 09.01.2026

Received in revised form 14.02.2026

Accepted 27.02.2026

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Cherepanyn, R. M., Franchuk, M. V., Andreychuk, Y. M., & Dykyy, I. V. (2026). Spatial structure of the male Eurasian lynx (*Lynx lynx*) home range within the Volyn Polissia, Ukraine. *Biosystems Diversity*, 34(1), e2603. doi:10.15421/012603

At the European level, interest in the study and conservation of the Eurasian lynx has increased considerably, particularly with regard to the spatial organization of its populations across different ecosystems and landscapes, including home range size and habitat use. In Ukraine, however, reliable information on the spatial parameters of lynx populations based on modern monitoring approaches remains extremely limited. The objective of this study was to assess the spatial structure of the home range of a male lynx within the Volyn Polissia region using GPS–GSM telemetry data obtained in Ukraine. Spatial analyses were conducted using the Minimum Convex Polygon (MCP) and Kernel Density Estimation (KDE) methods, with additional identification of core and subcore areas. The total home range area of the male lynx during February–August 2023 was estimated at 258.3 km² using MCP (100%) and 119.5 km² using KDE (100%), while the core and subcore areas comprised 24.0 km² and 10.9 km², respectively. During the breeding season, the estimated areas of MCP (100%), KDE (100%), core area, and subcore zones were 158.5 km², 55.4 km², 0.6 km², and 3.2 km², respectively, indicating a pronounced reduction compared with the nonbreeding period. Analysis of core and subcore location points demonstrated the importance of oligotrophic and mesotrophic swampy coniferous and deciduous forests, black alder–dominated wetlands, and swampy pine forests as key habitats for hunting, reproduction, and shelter. The obtained results provide new insights into the spatial ecology of the Eurasian lynx in Volyn Polissia and contribute valuable baseline data for the development of effective management and conservation strategies for lynx populations in Ukraine.

Keywords: GPS–GSM telemetry; MCP method; KDE method; lynx; spatial ecology; habitat; conservation.

Introduction

The Eurasian lynx (*Lynx lynx* Linnaeus, 1758) is the largest representative of the family Felidae in Ukraine and Europe (hereafter referred to as the lynx) (Kaczensky et al., 2024). The species is listed in the *Red Data Book of Ukraine* (Akimov, 2009) and in the IUCN Red List, where, according to the European regional assessment, it is classified as LC (Least Concern) (von Arx, 2020). The lynx is protected under the Bern Convention, which has been ratified by Ukraine (Convention, 1979). At the European level, the species is also protected by the EU Habitats Directive (Council Directive, 1992).

In Ukraine, the lynx occurs in two biogeographical regions: the Carpathians and Polissia. According to official consolidated statistical data as of 2019, the estimated population size of the lynx in Ukraine accounts for 435 individuals in the Carpathians and 128 individuals in Polissia (Cherepanyn et al., 2023a, 2023b).

An important component of lynx conservation is the implementation of national and regional action plans developed under the auspices of the Carpathian Convention, the Council of Europe, and other international frameworks (Linnell et al., 2008; Breitenmoser et al., 2020; Papp et al., 2020; Hackländer et al., 2021). In Ukraine, a national action plan for lynx conservation has also been developed in accordance with European standards (Action Plan, 2021). Among the key objectives of these documents are the establishment of systematic and regular lynx monitoring based on standardized and approved methodologies, as well as the identification and development of model research sites at national and international levels across different biogeographical regions.

Issues related to the biology and ecology of the lynx have been extensively studied in many European countries. For example, considerable attention has been devoted to analyses of population dynamics and range changes of the lynx in Poland (Bieniek & Wolsan, 1992; Bieniek et al., 1998). A substantial body of research has focused on estimating lynx population density using camera traps, which has been shown to yield statistically more robust results compared with expert-based assessments (Weingarth et al., 2012; Weam & Glover-Kapfer, 2017; Kubala et al., 2019). In Ukraine, studies aimed at estimating lynx population density have been conducted primarily in Central Polissia and at selected model sites in the Carpathians (Vyshnevskiy, 2021; Gashchak et al., 2022; Palmero et al., 2023). Separate studies have addressed conflicts between lynx and farmers in the Carpathians (Rigg et al., 2011; Cherepanyn et al., 2023c, 2024). In addition, a biogeographical analysis and assessment of the lynx population status across the entire Ukrainian Polissia have been carried out (Zhy-la, 2021; Zagorodniuk & Rizun, 2022).

Despite these advances, experimental assessments of lynx spatial structure, home range size, and habitat preferences based on telemetry data remain largely absent in Ukraine (Cherepanyn et al., 2025). Telemetry methods are particularly relevant for investigating migration routes and ecological corridors of the species (Zimmermann & Breitenmoser, 2007). In this context, telemetry can provide insights into daily movement distances, as well as seasonal and diel activity patterns. Furthermore, telemetry data are crucial for understanding home range size, characteristics of breeding areas, dietary patterns, and hunting locations. The latter is especially important for studies of interspecific

interactions and the impact of lynx on wild and game fauna across different territories (Shkvyrya, 2008).

Information on the spatial structure of lynx populations is essential for improving the understanding of species ecology and enhancing the effectiveness of lynx management and conservation in both protected and managed landscapes within different landscape complexes (Hočevár et al., 2020). Therefore, the objective of our study was to investigate and assess the spatial structure of the home range of a male lynx in Volyn Polissia, Ukraine, based on GPS–GSM telemetry data.

Materials and methods

Fieldwork involving the temporary removal of a lynx individual from the wild for the installation of a GPS–GSM telemetry collar manufactured by the Ecotone company was conducted within the territory of the Nature Reserve Rivnenskyi (Somyne Wetland Complex,

Karasynske Research and Conservation Department, Samy District, Rivne Oblast, Ukraine, Fig. 1). All activities were carried out in accordance with Permit No. 2022/4 issued by the Ministry of Environmental Protection and Natural Resources of Ukraine, valid from 19 April 2022 to 31 December 2023.

The temporary capture of the lynx was performed using a box trap method (Kubala et al., 2018a) equipped with a Trapmaster alarm system for immediate notification of animal capture. Box traps were installed on 19 October 2022 within the Karasynske Research and Conservation Department of the Nature Reserve Rivnenskyi.

On 4 February 2023, a sexually mature male lynx (4–5 years old) weighing 22 kg was successfully captured, handled, and subsequently released. The animal was subjected to short-term anesthesia for collar deployment in accordance with international veterinary protocols (Kubala et al., 2018b). The telemetry collar was equipped with a drop-off mechanism designed to automatically detach from the animal after 1.0–1.5 years of operation.

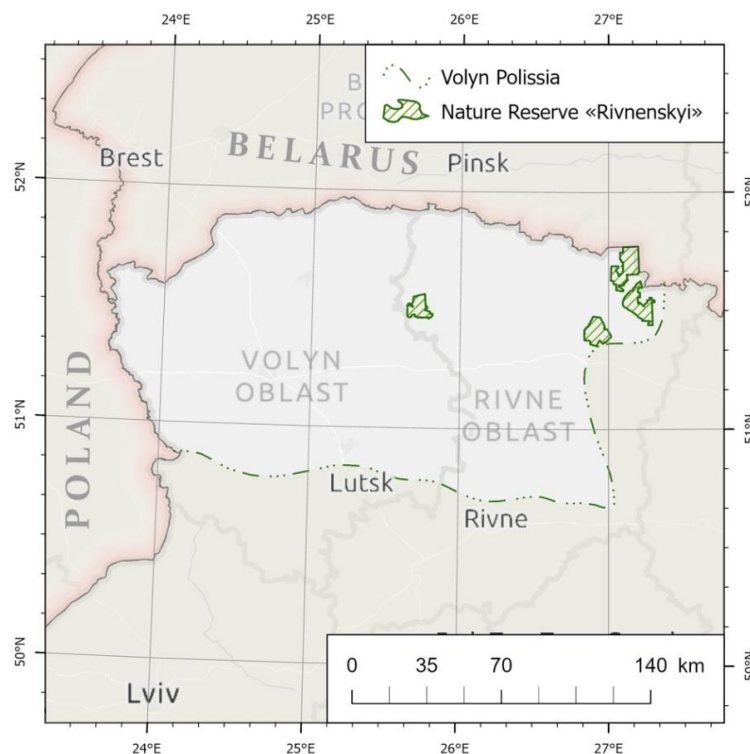


Fig. 1. The territory of the Nature Reserve Rivnenskyi and the Volyn Polissia, where the field telemetry studies of the male lynx were conducted from February to August 2023

Telemetry data were obtained from the collar for the period from 4 February 2023 to 6 August 2023. The device was programmed to record four GPS locations per day at 6-hour intervals. Subsequently, due to a technical malfunction, the device ceased transmitting GPS locations. The collected data were analyzed on a monthly and seasonal basis (spring, summer), during the mating and nonmating periods, as well as across the entire monitoring period. For the assessment of the lynx home range during the mating period, the time interval from 15 February to 15 April was used, corresponding to the approximate period of mating and rutting in lynx (Kvam, 1991; Painer et al., 2014). The period from 16 April to 6 August 2023 was classified as the nonmating period.

Spatiotemporal data obtained from the GPS tracker were processed using licensed software ESRI ArcGIS Pro (Andreichuk & Yamelynets, 2015; Chaskovskyy et al., 2021). The analysis of the spatial structure of the male lynx home range was conducted using the Minimum Convex Polygon (MCP) method and Kernel Density Estimation (KDE), as well as through the identification of core (kernel) and subcore (subkernel) areas of the home range across defined temporal intervals (Home & Garton, 2006; Kapfer, 2014).

The home range of the lynx was defined as the area traversed by the animal during its daily activities, including movement, foraging,

mating, and offspring care. The Minimum Convex Polygon (MCP) was defined as the polygon of minimum area enclosing a given percentage of location points (in this study, 100% of observations), representing the maximum area within which the animal has a probability of occurrence (Matos, 2020; Linnell et al., 2021). Kernel Density Estimation (KDE, 100%) was applied to identify the minimum area within which the animal has a probability of occurrence, using a two-dimensional utilization distribution (UD) function (Worton, 1989; Matos, 2020).

Core areas of the male lynx home range were defined as zones of intensive use, delineated by identifying areas in which the animal spent the greatest amount of time (Vander Wal & Rodgers, 2012; Kapfer, 2014). To further identify localized hunting areas, potential mating sites during the mating period, and other functionally important locations, subcore areas, were also delineated as zones containing five or more occurrence points within a 200 m radius over a defined data collection period. These clusters of GPS points were subsequently examined to determine their functional use by the lynx (e.g., resting, hunting, marking) throughout the study period.

Additionally, the mean movement direction of the individual was calculated for each observation period, along with directional distribution patterns (standard deviation ellipses) of the observation points,

indicating the spatial orientation in which the average movement direction occurred. The mean direction represents the general trend of orientation of a series of linear features and is calculated as the mean angle of the vectors (Mitchell, 2005). Directional distribution was used to assess whether the spatial distribution of the points exhibited a directional tendency and was determined by calculating the standard deviation ellipse (Mitchell, 2005; Wang et al., 2015).

Results

The total number of location fixes obtained from the telemetry study accounted for 487. The locations of the male lynx were recorded at varying distances from roads, ranging from 2.9 to 3,065.8 m.

Table 1

Indicators of the number of location fixes, total track lengths, mean distances to roads, average daily track duration, and mean movement direction of a male Eurasian lynx across different periods in Volyn Polissia, Ukraine, from February to August 2023

Analysis period, 2023	Number of observation points.	Total length of the track, km	The average closest distance to the road, m	The average duration of the track during the day, hours	Overall mean direction
February	68	62.1	721.1	13.3	southwestern
March	75	41.3	706.3	10.9	northeastern
April	87	34.7	744.5	13.2	northeastern
May	94	43.2	833.9	13.0	east
June	80	50.4	833.8	12.4	southern
July	69	31.9	860.1	13.7	northwestern
August	14	5.1	156.4	12.0	northwestern
Spring	256	119.2	761.6	12.4	northeastern
Summer	163	87.4	616.8	12.7	northwestern
Mating season	158	99.5	693.2	12.1	northeastern
Non-mating season	299	146.8	804.3	12.9	northeastern
All period	487	268.7	693.7	12.7	northeastern

The analysis also determined the area of the standard deviation ellipse for the entire monitoring period, which was 81.8 km², and the MCP (100%) area for the same period, which amounted to 258.3 km² (Table 2). The smallest MCP area was recorded in August, which can be explained by the low number of location fixes obtained during this period, whereas the largest MCP area was observed in June

The greatest mean nearest distance to roads was observed in July (860.1 m), whereas the smallest mean nearest distance was recorded in August (156.4 m). The overall mean nearest distance to roads across the entire monitoring period was 693.7 m. In addition, the average daily duration of the collar tracking was analyzed; over the whole study period, it amounted to 12.7 hours (Table 1).

The longest total monthly track of the male lynx, based on telemetry data, was recorded in February, with a length of 62.1 km, whereas the shortest was observed in August, with a length of 5.1 km. The total cumulative track length of the lynx over the entire monitoring period amounted to 268.7 km (Table 1). Analysis of the mean movement direction for the whole study period revealed a clear trend toward the northeast (Table 1).

(184.3 km²; Table 2). The MCP area during the breeding season was 158.5 km², while during the remaining part of the study period (non-breeding season) it reached 246.3 km² (Table 2). Thus, the MCP area during the breeding season was smaller than both the overall MCP area for the entire monitoring period and the MCP area estimated for the nonbreeding season.

Table 2

Indicators of the areas of directional distribution, MCP (100%), KDE (100%), core, and subcore zones of the home range of a male Eurasian lynx across different periods in Volyn Polissia, Ukraine, from February to August 2023

Analysis period, 2023	Area of directional distribution, km ²	Area of MCP (100%), km ²	Area of KDE (100%), km ²	Area of core zones of the home range, km ²	Area of subcore zones of the home range, km ²
February	27.2	85.2	23.3	1.8	1.5
March	45.2	100.3	25.7	–	1.0
April	61.8	79.8	34.3	–	1.7
May	44.7	97.9	21.1	4.0	1.0
June	101.9	184.3	22.2	–	0.8
July	81.3	139.4	9.1	–	0.7
August	1.1	14.9	2.7	0.7	0.3
Spring	57.8	169.6	67.3	11.0	5.4
Summer	97.2	215.0	59.6	–	2.5
Mating season	58.7	158.5	55.4	0.6	3.2
Non-mating season	93.7	246.3	94.1	6.2	4.7
All period	81.8	258.3	119.5	24.0	10.9

The areas of KDE (100%), core, and subcore zones were also calculated on a monthly basis, seasonally (spring and summer), for the breeding and nonbreeding periods, and for the entire monitoring period (Table 2). For the whole study period, the areas of KDE (100%), core, and subcore zones amounted to 119.5, 24.0, and 10.9 km², respectively. Lower values of KDE (100%), core, and subcore areas were observed during the breeding period compared with the rest of the season (nonbreeding period, Table 2). As shown by the results, the automated algorithm implemented in ESRI ArcGIS Pro 3.2.2 did not calculate core area estimates for some observation periods, which can be explained by an insufficient number of telemetry data points during those periods (Table 2).

As a result of the telemetry data analysis, the zones of the home range of the male lynx were mapped for the entire monitoring period using different spatial models – MCP (100%) and KDE (100%).

In addition, polygons of the directional distribution of location fixes and the mean movement direction of the individual were determined (Fig. 2). A total of four home-range location points were identified using the KDE (100%) model, along with six core and 27 subcore location points within the overall MCP (100%) observation area.

Field verification of the identified location points revealed that all six core and subcore loci of the lynx home range were associated with wet or heavily waterlogged biotopes characterized by high structural complexity within a mosaic of lowland and transitional wetlands. These habitats were primarily represented by swampy black alder stands and pine forests located at the margins of extensive bogs and degraded drainage systems. Based on the observed patterns of use, the identified location points were classified into breeding sites (used during the mating period in association with females), shelter sites, marking sites, and hunting sites (Fig. 3).

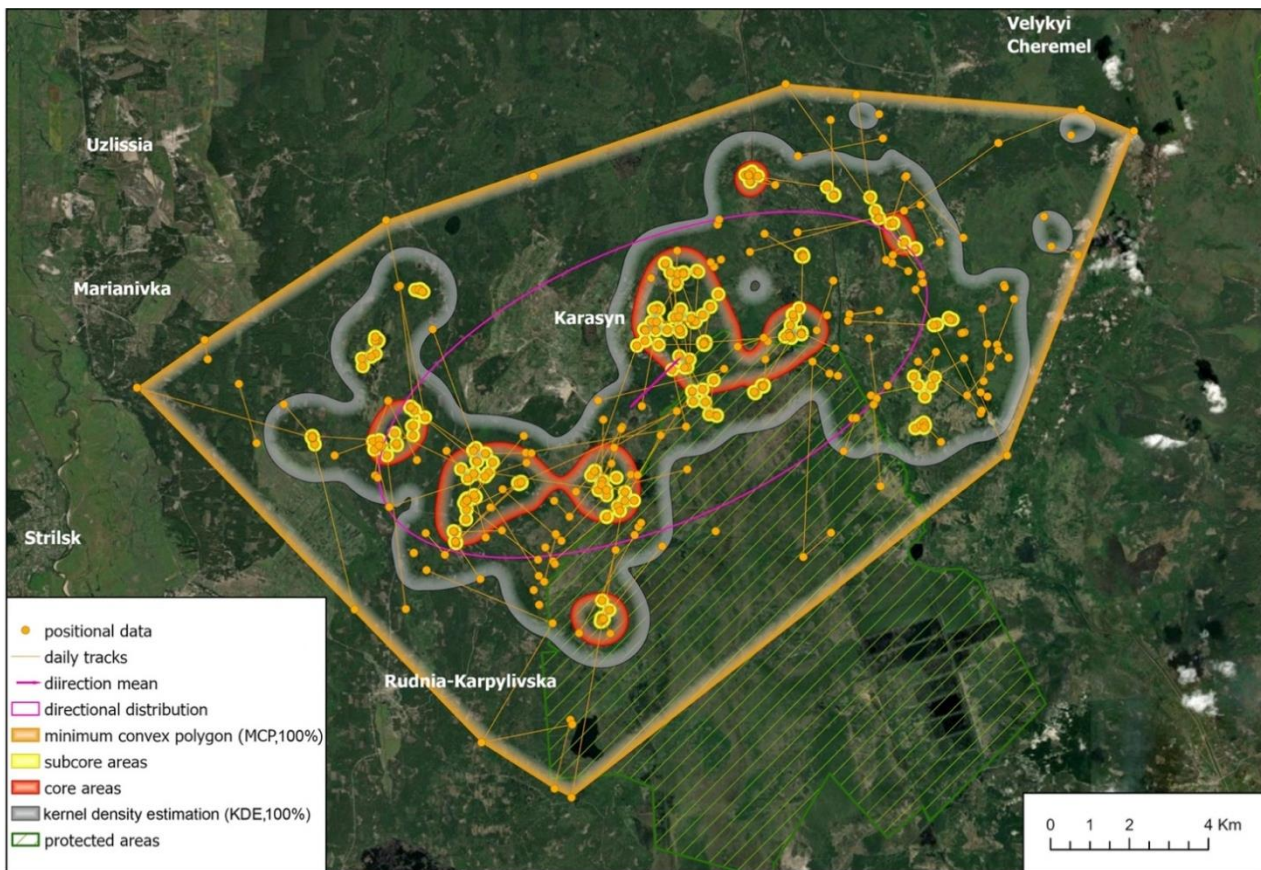


Fig. 2. Map of the spatial structure of the home range of the male lynx during the period from 04 February to 06 August 2023, based on the telemetry data obtained in Rivne Oblast within the Volyn Polissia, Ukraine

Discussion

Studies on the size of home ranges of the Eurasian lynx conducted in other countries demonstrate pronounced intraspecific variation. In particular, MCP (100%) estimates differ by up to tenfold among various European regions (Herfindal et al., 2005). In addition to the availability of suitable habitats and favorable ecological conditions for population persistence, one of the key drivers of variation in home range size is prey density. A negative relationship between prey density and home range size has been documented for lynx individuals of both sexes (Herfindal et al., 2005).

Preliminary telemetry data obtained from a male lynx in the Volyn Polissia region of Ukraine support the dependence of the size of lynx home range on areas with high concentrations of key prey species. In particular, the spatial configuration of the home range appears to be strongly influenced by the presence of core aggregation sites of the European roe deer (*Capreolus capreolus*) and habitats created by the activity of the Eurasian beaver (*Castor fiber*), including dams and lodges.

Comparison of home range sizes obtained in this study with those reported from other biogeographic zones within the species' range indicates notable differences. In the Polish Bieszczady Mountains (Carpathian massif), MCP (100%) home ranges were estimated at 164 and 199 km² for two males and 124 and 190 km² for two females (Okarma et al., 2007). By contrast, the MCP (100%) home range estimated for the male lynx in the present study reached 258 km² for the entire monitoring period. This discrepancy may be explained by differences in ecological and landscape conditions, as well as by prey availability and spatial distribution. The lynx population in Ukrainian Polissia inhabits predominantly lowland landscapes characterized by extensive wetlands and high habitat fragmentation.

Similar results have been reported from the Belarusian Lakeland, where the MCP (100%) home range size of male lynx ranged between 270 and 290 km², under the conditions of low densities of roe deer (*Capreolus capreolus*), hares (*Lepus europaeus*), and black gro-

use (*Tetrao tetrix*), but relatively high abundance of wild boar (*Sus scrofa*) and beavers (*Castor fiber*). Home range size in this region was shown to depend on individual age and prey availability. In the Belarusian Lakeland and the Naliboki Forests, dispersing subadult males and adult males during periods of reduced prey availability may occupy home ranges exceeding 200 km² and perform long-distance movements. Conversely, during years of high prey abundance, male home ranges may shrink to only 62–93 km².

Associations with specific habitat types and distances from anthropogenic features may reflect behavioral and ecological adaptations to different environments. For example, studies on the bobcat (*Lynx rufus*) in North America have shown a preference for ecotonal habitats such as forest edges, as well as for areas located 1–3 km from major roads, more than 800 m from secondary roads, and less than 1 km from anthropogenic areas. This pattern suggests a trade-off between access to prey-rich hunting grounds and the risk of road mortality (Jones et al., 2022). Meanwhile, the male lynx monitored in Volyn Polissia most frequently used habitats located 600–800 m from secondary forest roads.

Understanding the size of lynx home range is critical for effective population management. Studies conducted in Scandinavia indicate that protected areas alone can support only a limited proportion of lynx populations, while the majority of individuals inhabit multifunctional seminatural landscapes with varying degrees of human land use, which require appropriate management measures to ensure long-term species conservation (Linnell et al., 2001). In the present study, only 30.5% of lynx observations were recorded within protected areas, including 15.3% within the Rivnenskyi Nature Reserve and 15.2% within the Velykoozerianskyi Botanical Reserve. The remaining 69.5% of observations occurred within managed forest lands and hunting grounds. Consequently, maintaining suitable conditions in hunting areas, ensuring adequate prey availability in forestry and hunting landscapes, and involving not only conservation authorities but also forestry and hunting institutions in lynx monitoring are essential for the successful conservation and persistence of viable lynx populations.



Fig. 3. Core and subcore areas of the home range of the male lynx during the period from 04 February to 06 August 2023, based on the telemetry data obtained in Rivne Oblast within the Volyn Polissia, Ukraine: *a* – breeding sites; *b* – shelter sites; *c* – marking sites; *d* – hunting sites

Conclusions

As a result of the study, the characteristics of the home range of a male Eurasian lynx, including core and subcore areas, were determined within the Volyn Polissia (Ukraine) based on GPS–GSM telemetry data (487 location fixes) using MCP (100%) and KDE (100%) spatial models across defined temporal intervals. In addition, the mean movement direction of the individual and the directional distribution zone of observation points were identified for selected periods.

The results showed that during February–August 2023, the areas of MCP (100%), KDE (100%), core, and subcore zones of the male lynx amounted to 258.3, 119.5, 24.0, and 10.9 km², respectively. The area of the standard deviation ellipse was 81.8 km², and the trend of the mean movement direction was oriented toward the northeast. The total track length reached 268.7 km, while the mean nearest distance to roads over the entire study period was 693.7 m.

Key habitat types used by the lynx within both protected and managed landscapes were identified. These habitats are primarily associated with wetland complexes adjacent to forest biotopes (predominantly waterlogged or swampy forests) with a well-developed hydrological network of water bodies regulated by beaver dams. Such areas play a crucial role in hunting, sheltering, and reproduction of the species.

The obtained information is essential for the further development of management plans aimed at sustainable land-use practices and effective conservation of lynx populations.

This work was coordinated by WWF-Ukraine within the Coexistence for Conservation project (funded by WWF-Poland); and the EuroLargeCarnivores project, funded by the LIFE Programme (LIFE16 GIE/DE/000661). We are grateful to the administration of the Nature Reserve “Rivnenskyi” for facilitating fieldwork activities, as well as to colleagues who contributed to the implementation of the telemetry study. Special thanks are extended to veterinarian Mykola Kychan and assistant Dmytro Vovchenko for medical supervision and anesthesia of the lynx; to Oleksandr Dobrynskyi for technical support, fabrica-

tion of telemetry equipment, and assistance during animal capture; to Taras Kryvulskyi; to Adam Kovalets, Head of the Karasynske Unit of the Nature Reserve Rivnenskyi; and to rangers Petro Martyniuk, Serhii Shevych, Mykhailo Tymoshytskyi, and Oleksandr Kovalets for their support during field operations.

The authors declare no conflict of interest.

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