LIFE Lynx

Preventing the extinction of the Dinaric-SE Alpine lynx population through reinforcement and long-term conservation

LIFE16 NAT/SI/000634

Assessing the effects of lynx translocations on the source populations in Slovakia and Romania

ACTION D.1: Monitoring the effects of lynx removal for translocations on the source populations

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March 2024

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The current document represents the **final report** on the effects of Eurasian lynx (*Lynx lynx*) removal for translocation purposes on the source populations in the Slovakian and Romanian Carpathians and it has been developed under **Action D1. Monitoring the effects of lynx removal for translocations on the source populations** of the **LIFE Lynx project** “Preventing the extinction of the Dinaric-SE Alpine lynx population through reinforcement and long-term conservation” (**LIFE16 NAT/SI/000634**).

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Assessing the effects of lynx translocations on the source populations in Slovakia and Romania

Background

The Eurasian lynx once thrived across the forested landscapes of Europe during prehistoric times. However, due to human activities, the species faced extinction across most of its habitat (Breitenmoser & Breitenmoser Würsten, 2008). By the turn of the 18th and 19th centuries, only five autochthonous populations persisted in Europe: Baltic, Balkan, Karelian, Carpathian, and Scandinavian (Breitenmoser et al. 2000; von Arx et al. 2004, 2021). Toward the end of the 19th century and the early 20th century, the lynx population in the Carpathians neared extinction (Kratochvíl, 1968a, b). The negative trend reversed only through protective measures, controlled hunting, and the regeneration of forests and prey populations, especially wild ungulates (Breitenmoser et al. 2000). In the mid-20th century, the population experienced regeneration, expansion, and connectivity all across the Carpathian range (Hell & Slamečka, 1996). While the positive population status in the Slovak Carpathians during the 1950s and 1960s led to the resumption of lynx hunting, it also drew increased interest from zoological gardens in capturing live lynxes for breeding and commercial purposes (Kubala et al. 2020b). Legislative changes and habitat regeneration in Europe, coupled with the geographical proximity to historically extinct lynx in Western and Central Europe, set the stage for historical reintroduction programs for this species (Breitenmoser & Breitenmoser Würsten, 2008).

Reintroduction programs were implemented in eight countries, releasing 170-175 founder animals, with 57% originating from captured free-living lynxes in Slovakia and 40% being individuals born in captivity. The origin of the remaining animals remains unknown (Linnell et al. 2009; von Arx et al. 2009; Wilson, 2018). The activities related to lynx captures and translocations spurred scientific studies and publications on its ecology and biology in Czechoslovakia, laying a foundation for current systematic monitoring in the region. Moreover, it heightened public interest and awareness about this species (Breitenmoser & Breitenmoser

Würsten, 2008). The capture of free-living lynxes in the Slovak Carpathians occurred over nearly four decades as part of population management, alongside legal hunting (Kubala et al., 2020b). In the Romanian Carpathians, the first captures and translocations of free-living lynxes began in 2019 as part of the LIFE Lynx project. In both countries, past lynx conservation and management activities relied mainly on official hunting statistics (tracking abundance and origin of hunted individuals) and expert estimates (Hell & Slamečka, 1996, Popescu et al. 2016). Despite fluctuations in population size and distribution during the 1970s and 1990s, the Carpathian lynx population was deemed stable and viable in the long term (von Arx et al. 2004). However, this assumption lacked confirmation from scientifically supported information and data (Duľa et al. 2021). The absence of robust data and systematic lynx monitoring, led to a gap in monitoring, assessment, and reporting, despite required by the habitat directive (Kubala et al. 2019a). The absence, coupled with changes in prey populations (for example roe deer, *Capreolus capreolus*), resulted in scientifically unfounded and often misleading information about the lynx population at local, national, and international levels. This contributed to misunderstandings and conflicts between lynx and human interests, exacerbated by habitat fragmentation due to transportation infrastructure development (Kubala et al. 2019a, 2020a, 2023).

The lynx population in the Dinaric Mountains (Slovenia and Croatia) went extinct in the early 20th century. In the 1970s, heightened environmental awareness led to a lynx reintroduction program in Switzerland, setting a conservation example for Slovenia and Croatia (Wilson 2018). The reintroduction program in the Dinaric Mountains was one of the most successful in Europe. Lynx reproduced and the population increased and expanded, but there were no other populations in its vicinity and therefore they remained isolated. By the mid-1990s, inbreeding led to a significant decline in the Dinaric population, impacting their health and reproduction (Skrbinšek et al. 2011, Sindičić et al. 2013, Boitani et al. 2015). Prolonged inbreeding threatened the survival and reproductive success of lynx, risking a population collapse and re-extinction (Wilson et al. 2019). To prevent this, reinforcement and reintroduction programs with lynx from the Carpathian source population were re-initiated, aiming to ensure long-term viability in the Dinaric Mountains, South-Eastern Alps, and other reintroduced populations

(Boitani et al. 2015; Bonn Lynx Expert Group 2021). However, capturing and translocating animals necessitate relevant and systematic research on the source Carpathian population, focusing on its abundance, trend, genetic diversity, and health status (von Arx et al. 2009; Wilson, 2018). The assessment of lynx captures and translocations, crucial for evaluating their relevance without compromising viability (IUCN/SSC 2013), is facilitated by population monitoring results. To ensure the acquisition and security of such essential information and data, systematic population monitoring is necessary (Breitenmoser et al. 2006; Breitenmoser & Breitenmoser-Würsten, 2008; Antal et al. 2017).

1. Systematic monitoring of lynx in the Slovak Carpathians

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Introduction

The Slovak Carpathians are widely regarded as home to a significant and vital lynx population, although this assumption lacked scientific validation until recently (Breitenmoser et al. 2000; von Arx et al. 2004; Kaczensky et al. 2013; Kubala et al. 2023). The lynx population reached its minimum at the end of the 19th century and in the early 1930s due to a combination of prey scarcity, intense persecution, and negative public perceptions (Hell & Slamečka 1996). These negative attitudes stemmed from inadequate ecological education and conflicts / competition in game hunting, particularly concerning roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*), as well as livestock depredation (Hell 1992). Despite these challenges and conflicts, the lynx was saved from extinction in Slovakia by partial legal protection initiated by hunters in 1934 and enacted in 1936. This conservation measure, along with the gradual recovery of prey populations, facilitated the lynx population's resurgence and expansion, especially in the late 1950s (Kratochvíl 1968a, b; Hell & Slamečka 1996). The favourable status of the lynx population in Slovakia during 1960´s – 1990´s, as well as its geographic proximity to historically extinct lynx in the Western and Central Europe (Breitenmoser & Breitenmoser Würsten 2008), lead to the implementation of reintroduction programs (Linnell et al. 2009). Many of the translocated lynxes came from Slovakia, where trapping has been utilized as a management tool for the population alongside legal hunting. These efforts would not have been successful without the effective cooperation and understanding of Slovak hunters. However, the lynx was still considered a pest and a significant threat to game species (Hell & Slamečka 1996).

In the 1970s, the lynx population reached another minimum due to overhunting. Its recovery at the turn of the 1980s and 1990s was facilitated by partial protection granted in 1975 and year-round protection declared by the Ministry of the Environment of the Slovak Republic in 1999 (Hell et al. 2004). However, this year-round protection was implemented with little to no public involvement, leading to misunderstandings, particularly among hunters. While, according to the legislation of the Ministry of Agriculture of the Slovak Republic, lynx hunting remained legal until 2001 (Kubala et al. 2020a). Over the past decade, the monitoring, conservation, and management of the species have been based solely on expert opinions (von Arx et al. 2004). Recent research indicates that these figures were not reliable and significantly overestimate the population size (Kubala et al. 2019a; Duľa et al. 2021). Exaggerated data and misleading information about the status and trends of the lynx population have fostered conflicts between lynx and human interests, ultimately leading to illegal killings (Kubala et al. 2021a). Furthermore, illegal killing may have a synergistic effect with the development of traffic infrastructure, which increasingly disrupts connectivity between suitable habitats and exacerbates human-induced mortality (Kubala et al. 2020a). Thus, there is a general need to improve knowledge on the lynx population status and biology, as well as human attitudes in the Slovak Carpathians. This should be based on range-wide cooperation and a standardized monitoring system, a stratified spatial concept, and scientifically robust methods (Kubala et al. 2021a; 2023). Moreover, robust data are crucial for evaluating the effects of lynx removal on the source population and ensuring that the source populations in Slovakia are not threatened. These results will also benefit the design of future reinforcement programs for other endangered lynx populations in Europe, as well as other species facing similar conservation challenges.

Survey areas

The Vepor Mountains (Vepor Mts. from now on) is a geomorphological complex of the Slovak Ore Mountains in central Slovakia with a total area of 870 km^2. This mountain range is situated in the Banská Bystrica region within six districts (Banská Bystrica, Brezno, Detva, Poltár, Rimavská Sobota, and Lučenec; Fig. 1.). Part of the area is located and managed by the Poľana Protected Landscape Area (Poľana PLA, IUCN Category V), characterized by a relatively low human population density (81.5 inhabitants per km^2). The major part of the area is highland, with an uninhabited forested landscape, with lower parts of deforested areas converted into meadows and pastures. The orientation of the mountains is in a north-south direction, enabling the occurrence of mountainous and thermophilic species of plants and animals. The European beech (*Fagus sylvatica*) and the silver fir (*Abies alba*) are the most predominant of all existing tree species. In terms of fauna, there are about 50 species of mammals, 9 species of reptiles, 11 species of amphibians, and 174 species of birds. Among the large mammal species, the region is home to the three main European large carnivores: lynx, brown bear (*Ursus arctos*), and wolf (*Canis lupus*); and three large ungulates: red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*).

The Vtáčnik Mountains (Vtáčnik Mts. from now on) are part of a geomorphological unit of the Slovak Central Mountains with a total area of approximately 377 km^2 and are spread over the Banská Bystrica and Trenčín regions and four districts (Prievidza, Partizánske, Žiar nad Hronom, and Žarnovica; Fig. 1.). The western, northern, and northeastern natural border is the Upper Nitra Basin, the eastern border is the Kremnica Mountains and the Žiar Basin. Furthermore, in the south by the Štiavnica Mountains and Pohronský Inovec, and in the west by the Tribeč Mountains. Part of the area is located in the Ponitrie Protected Landscape Area (PLA, IUCN category V) and is characterized by a relatively higher population density (110.53 inhabitants per km^2). The larger part of the area is represented by upland to mountainous forested landscape, lower parts are deforested and transformed into meadows, pastures, and arable land. The mountain range is located within a moderately warm and cold climate. Forest stands are dominated by deciduous forests with a predominance of beech, oak (*Quercus robur*), and hornbeam (*Carpinus betulus*), as well as mixtures of beech and fir. The most dominant mammals are red deer, roe deer, and wild boar. Brown bears and sporadically grey wolves can be found in the region, alongside lynxes.

The Volovec Mountains (Volovec Mts. from now on) are located in the east of Slovakia, representing the largest mountain range in the Slovak Ore Mountains area (around 1330 km^2), forming its eastern part. This mountain range extend into the Košice and Prešov regions and 5 districts (Gelnica, Košice surroundings, Prešov, Rožňava, and Spišská Nová Ves; Fig. 1.). To the south, the Volovec Mts. border with other subunits of the Slovak Ore Mountains, with the Slovak Karst National Park, and the Rožňava Basin. Its northwest border is formed by the Slovak Paradise National Park. The northern boundary is formed by the Hornád Basin and the Šariš Upland. To the east, there is the Košice Basin and the Čierna hora, and to the west, they border with the Muránska planina National Park. The Volovec Mts. are characterized by a relatively low population density (91 inhabitants per km^2). The larger part of the territory consists of upland to mountainous uninhabited forested landscape, while the lower parts are deforested and transformed into meadows, pastures, and arable land. The predominant vegetation composition here consists mainly of deciduous forests, predominantly beech, in the past also spruce, which, however, gradually disappears due to climate change and is replaced by mixed stands of beech, fir, and maple (*Acer campestre*). Among the game species, red deer, roe deer, and wild boar dominate. Brown bear and grey wolf are also present in the area, along with lynx.

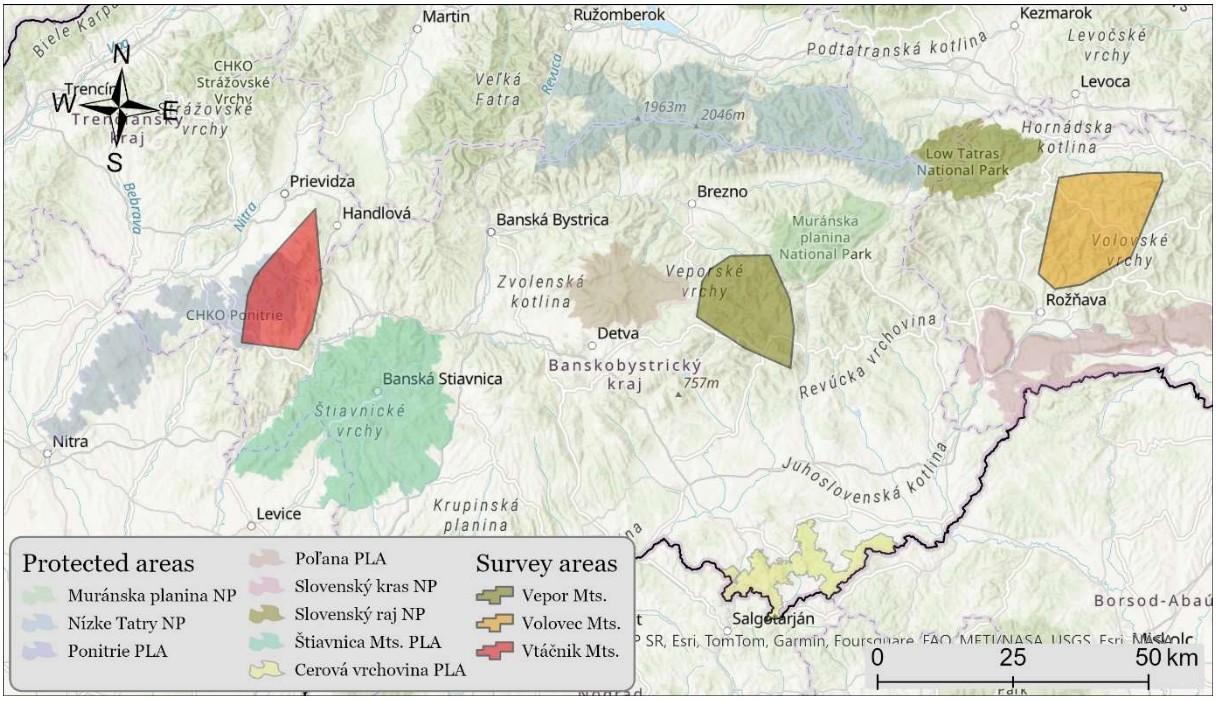


Figure 1. LIFE Lynx survey areas Vepor Mountains (green polygon), Vtáčnik Mountains (red polygon) and Volovec Mountains (orange polygon) in the Slovak Carpathians.).

1.1. Camera trapping

Effective species conservation and management require reliance on relevant and science-based data concerning population size and trends (Primack 1993). Accurate population size data can only be obtained through reliable systematic monitoring, such as the use of camera trapping (Breitenmoser et al. 2006; Breitenmoser & Breitenmoser-Würsten 2008). In recent decades, camera trapping has become a standard method for estimating population size, abundance, and density, especially for elusive feline species (e.g. O´Brien et al. 2011; Rovero & Zimmermann 2016). These species possess distinct natural coat patterns that enable precise differentiation and identification of individual lynx (Karanth & Nichols 1998; Jackson et al. 2006; Breitenmoser et al. 2006; Fig. 2.). Given the territorial nature of lynx, systematic camera trapping can offer insights into their presence, population size, and population trend (Laas 1999; Zimmermann et al. 2013; Palmero et al. 2023). The principle of the method is to make as many pictures of the species as possible within the study area during a pre-defined period of time and then to estimate the number of specimens by means of capture-recapture statistics (e.g. Rovero & Zimmermann 2016; Palmero et al. 2023). Thus, main goal of our systematic camera trapping was to provide a robust estimate of the lynx minimum number, population size and trend (including population abundance and density) within the project survey areas in the Slovak Carpathians (Fig 1.).

Figure 2. An example of identifying the same lynx in two different locations using its unique spotting pattern (photo © Technical University of Zvolen).

Within the LIFE Lynx survey areas in the Western Carpathians (Fig. 1.), we used two different deployments of camera traps according to Breitenmoser et al. (2006): (1) opportunistic use of camera traps throughout the year to identify as many sites and lynx as possible, and (2) deterministic use for capture-recapture to estimate lynx population size. The two deployments are combined, as the pictures of the opportunistic monitoring helped the identification of lynx during the deterministic camera trapping. Deterministic camera trapping in the project areas lasted for 60 days, typically from November to January of the following year. The surveyed area was systematically divided into 2.5 x 2.5 km squares. Each camera station was placed in every second square within suitable habitat, featuring two camera traps facing opposite directions. The survey area sizes were 250 km² in the Vepor Mts., 239 km² in the Vtáčnik Mts., and 339 km² in the Volovec Mts. (Fig. 3.). The lynx population size in the project areas was estimated using the Spatial Capture Recapture (SCR) approach, following established methods (e.g. Kubala et al. 2019a; Duľa et al. 2021). Only lynx older than one year were considered in the analysis, indicating independent individuals. Lynx cubs were excluded, as they do not represent resident animals and tend to disperse after leaving their mother, particularly when resident individuals reach the area's capacity (e.g Pesenti and Zimmermann 2013; Avgan et al. 2014). Habitat proportions in the monitored area, classified as suitable or unsuitable, were determined using CORINE Land Cover 2018 data (Copernicus Program 2018). All forest types (deciduous, coniferous, and mixed), along with shrubs, pastures, and arable land, were identified as suitable habitats, while human settlements were deemed unsuitable (refer to Fig. 3.). A reliable estimation of the lynx population size necessitates a thorough process and robust statistical analysis (e.g. Pesenti and Zimmermann 2013; Palmero et al. 2023). Some resident lynx may not have been recorded during monitoring, potentially leading to an underestimation of results. Hence, their numbers must be statistically estimated and added to the recorded individuals. Conversely, lynx recorded only on the border of the monitored area, with home ranges extending beyond it, could significantly overestimate the population size. To address this, an additional buffer of 14 km in the Vepor Mts., 9 km in the Vtáčnik Mts., and 10 km in the Volovec Mts. was added to the monitored area (forming so called state space), reflecting the spatial requirements of the animals based on the average size of lynx home ranges in the region. The size of the state space ranged from 1 048 to 1 485 km^2 (Fig. 3.).

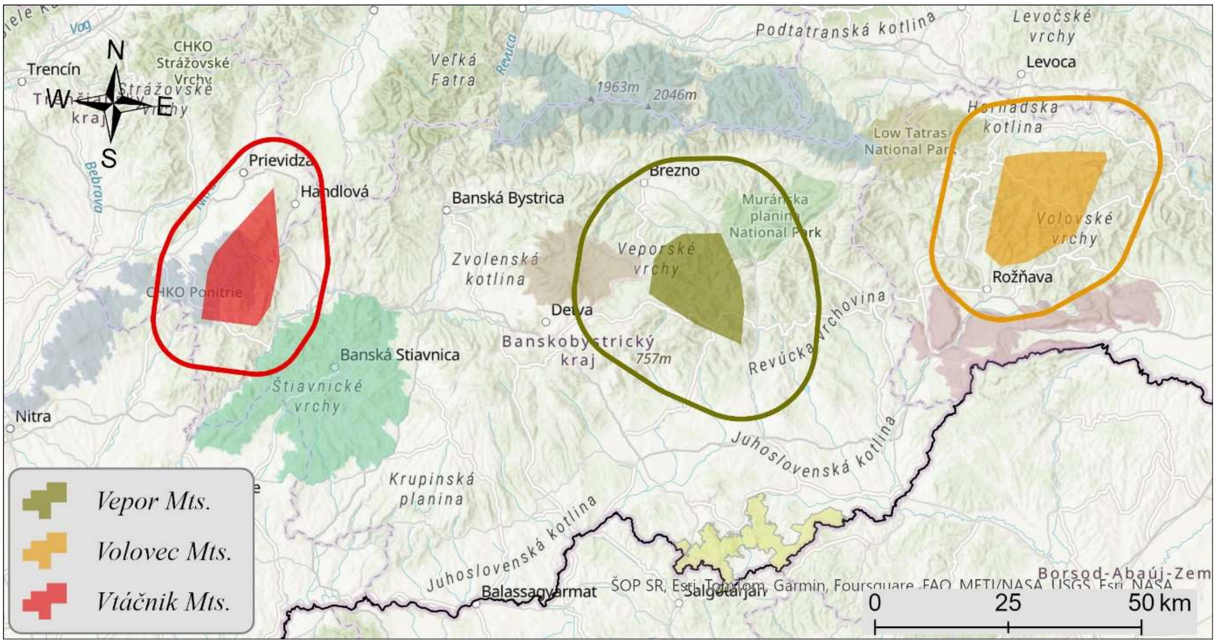


Figure 3. The survey areas in the Slovak Carpathians were expanded by the average size of the lynx's home ranges (a buffer of 9-14 km) to create the state space. The area of unsuitable habitat was subsequently deducted from the state space (i.e., monitored area + buffer).

The lynx population density in the Vepor Mts. was statistically estimated at 1.20 (± 0.49; Kubala et al. 2019b) lynx per 100 km² of suitable habitat, with a population abundance of 17.8 (± 7.3) individuals. In the Vtáčnik Mts., the density of lynx was very similar, estimated at 1.18 (± 0.08; Kubala et al. 2020b) lynx per 100 km² of suitable habitat; however, the population abundance was lower at 8.28 (± 5.61) animals. In the Volovec Mts., the density estimate was the highest, at 1.8 (± 0.39; Kubala et al. 2021b) lynx per 100 km² of suitable habitat, with a population abundance up to 18.8 (± 4.13) individuals. These results, obtained through systematic and robust camera trapping conducted within the LIFE Lynx project (and other previous projects and surveys), allow us to estimate the average lynx population density in Slovakia at 1.15 (± 0.29) individuals per 100 km² of suitable habitat, with an overall population size of 323 adult animals (range: 193 – 327 lynx; Duľa et al. 2021; Kubala et al. 2021a, 2023). This population size and state corresponds to the favourable status according to the Habitats Directive, albeit it does not reach the carrying capacity in some areas / regions due to conflicts with human interests and activities. These surveys and projects were conducted in comparable, appropriately managed, protected, and economically utilized areas (both, core and marginal parts of the lynx population distribution and areas totalling 9,939.75 km^2 of suitable lynx habitat). Therefore, we presume that the results most likely represent an average rather than below-average portrayal of the actual state of this species' population in Slovakia.

Systematic camera trapping, which included both opportunistic and deterministic monitoring, revealed no significant changes in the minimum number of lynxes per survey area (averaging 8 individuals in the Vepor Mts., 7 individuals in the Vtáčnik Mts., and 9 individuals in the Volovec Mts.) or in the overall population size (abundance and density) during the project. However, we observed a relatively high fluctuation of individual lynxes (including resident animals), while the population density in the Western Carpathians exhibited substantial annual variations, ranging from 1.5- to 4.1 fold (Duľa et al. 2023). This variability aligns with previously observed patterns in reintroduced lynx populations across Western Europe (e.g. Zimmermann et al. 2015, 2016; Gimenez et al. 2019). In certain survey areas, such as Muránska Planina National Park (adjacent to the Vepor Mts.), lynx population density increased from 1.47 to 1.82 individuals per 100 km^2 of suitable habitat, despite captures and translocations (Kubala et al. 2023b). It can therefore be asserted that the capture and translocation of lynx for the LIFE Lynx project (as well as the previous LIFE Luchs project) had no negative effect on the viability of the Slovak population at the local, regional, or national level.

1.2. GPS Telemetry survey

Understanding how large carnivores use space is crucial for managing human-dominated landscapes and improving population size estimates. However, the Eurasian lynx shows significant variation in home range sizes across its European range, complicating extrapolation to broader areas of its distribution (Breitenmoser & Breitenmoser-Würsten 2008; Kubala et al. in prep.). Historically, home ranges in the Western Carpathians were estimated by tracking lynx in the snow, with sizes assumed to be around 27 km^2 (e.g., in Slovakia; Hell 1971). However, it wasn't until the use of radio telemetry that the first insight into the variability in the size of lynx home ranges was provided. Surprisingly, adult male home ranges in the Polish Carpathians appeared to be much smaller than those estimated in other studies, while female home ranges fell well within the range of sizes observed elsewhere (Okarma et al. 2007). In order to efficiently monitor the translocation process within the project and its impact on the source population, lynx were also captured and fitted with telemetry collars in the Slovak Carpathians. GPS telemetry enables the study of lynx behavioural patterns, encompassing habitat use, movements, dispersal, predation, feeding and reproduction (e.g. Krofel et al. 2013; Heurich et al. 2014; Mattisson et al. 2022; Ripari et al. 2022). For lynx captures, we used walk-through, double-door box traps made of wood (dimensions: 2×1×1 m), strategically placed at locations identified through systematic monitoring as frequently visited by lynx (Kubala et al. 2019a; Duľa et al. 2021). When activated, the box traps were under constant surveillance through a GSM alarm system and GPRS cameras, which promptly notified the responsible person in the event of trap door closure.

All lynx were tranquilized by a veterinarian, and no mortalities occurred during or after capture. No complications were observed due to collaring. All captured animals were medically examined and equipped with GPS (Global Positioning System) collars. Our primary focus in tracking translocated animals was to survey lynx home range variation, interaction with conspecifics, movement patterns, reproduction and survival. This enabled us to gain a clearer understanding of the territorial distribution of lynx within the source population. We also collect information on prey species, along with the sex and age distribution of prey, to better understand the impact of lynx on ungulates and to guide further ungulate management strategies. Furthermore, discovering fresh kill sites enabled us to use video camera traps to observe lynx, assessing their physical condition and interactions within conspecifics, and / or the presence of scavenger species at these sites and their impact on lynx prey consumption.

On March 13, 2020, a juvenile male lynx named Timo was captured in the Vtáčnik Mts. (Fig. 4.). At the time of his capture, he weighed 12.7 kg. However, he quickly began gaining weight post-capture, as confirmed by camera traps documenting his kills. He was closely monitored while becoming independent from his mother, a process that began shortly after his capture in late March and April 2020. Surprisingly, this subadult did not leave his mother's home range and showed no signs of dispersing from the survey area. Instead, he consistently remained at the periphery of the mountain range (or within suitable habitats), and in at least two instances, he likely interacted with territorial local males.

Figure 4. The juvenile male lynx, Timo, during his capture and collaring in the Vtáčnik Mts. in March 2020.

Unfortunately, on August 11, 2020, Timo´s collar stopped transmitting location data, and the animal could not be located even with a VHF receiver or any other monitoring method. Based on this, it was possible to assume that Timo either left the Vtáčnik Mts. before the end of the vegetation season and the beginning of the mating season (with his collar failing due to technical reasons), or he was killed illegally. Because of the relatively brief monitoring period and limited data, we were only able to calculate Timo's summer home range (March 13 – August 11. 2020) rather than his annual home range. The size of the summer home range, calculated using the 95% Minimum Convex Polygon (MCP; Mohr 1947), was 186 km² (Fig. 5.; Kubala et al., in prep.).

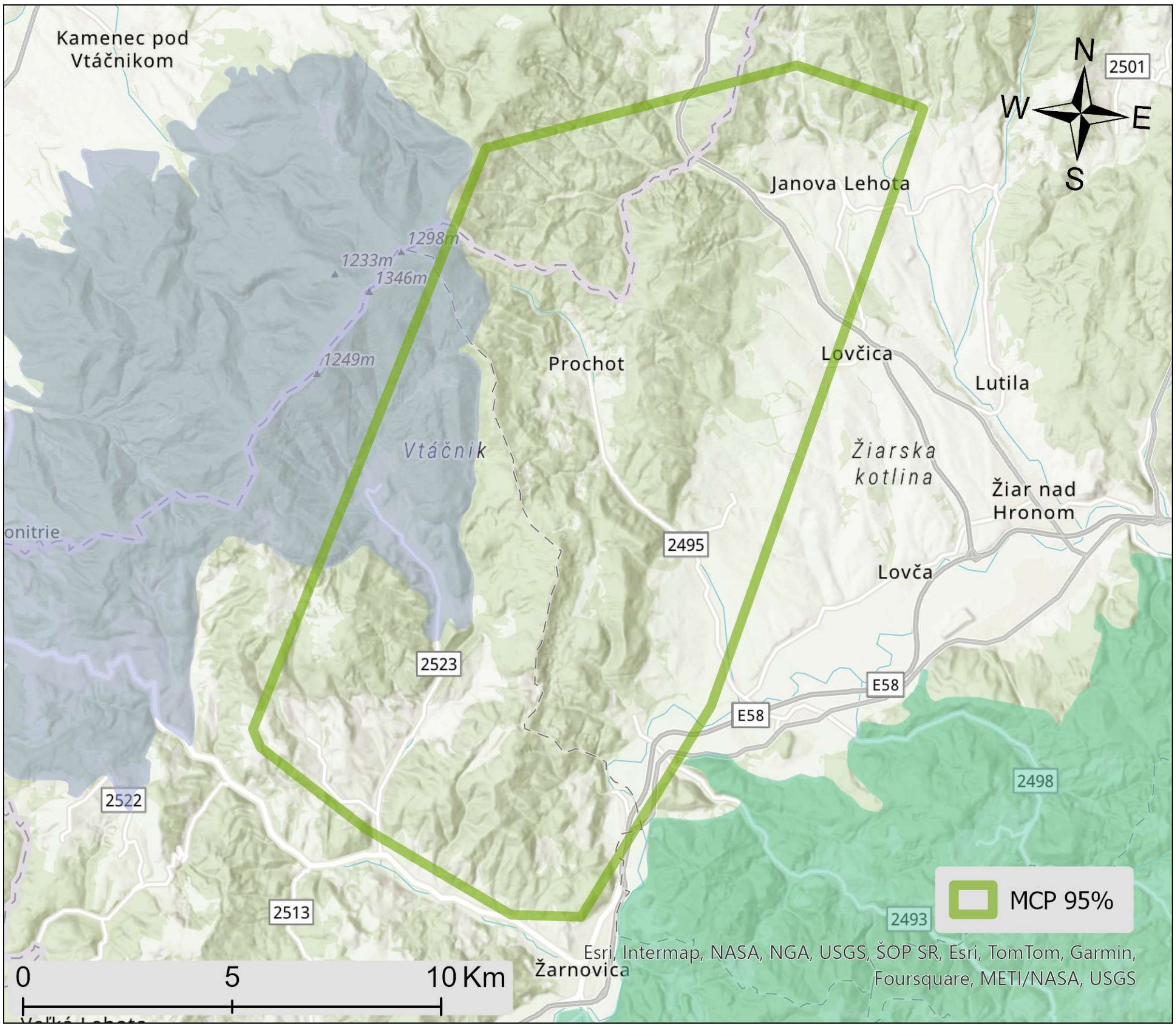


Figure 5. The summer home range of subadult lynx Timo, calculated using the 95% Minimum Convex Polygon (MCP).

Moreover, on February 23, 2022, an adult male lynx was captured in the Vepor Mts. (Fig. 6.). He was named Midas and was estimated to be approximately 2 years old, weighing 18.4 kg at the time of capture. Based on his spatial behaviour, the animal immediately re-engaged in the peak breeding season and hunted successfully.

Figure 6. The adult male lynx, Midas, captured and collared in the Vepor Mts. in March 2020.

However, on March 17, 2022, Midas lost his GPS collar due to unknown technical problems. The size of its temporal home range, calculated using the 95% MCP was surprising even in such a short period of time (less than a month), up to 298 km² (Fig. 7.). Nevertheless, camera trap records confirmed that the lynx remained a resident individual within the survey area and was part of the local population.

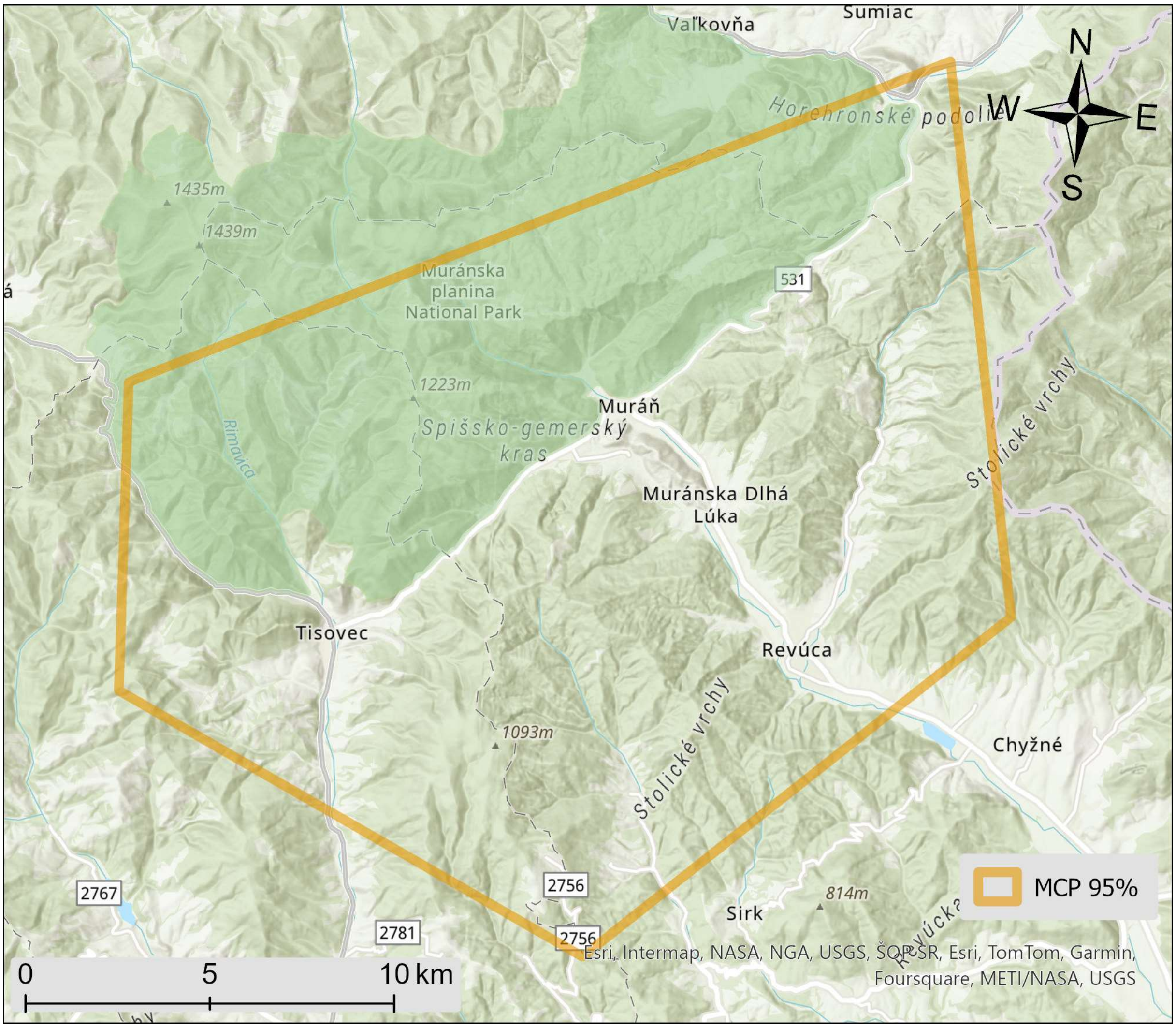


Figure 7. A home range of adult lynx Midas, calculated as the 95% MCP.

The home ranges of lynx in the Slovak Carpathians are consistent with those of Central European populations (e.g., Schmidt et al. 1997; Breitenmoser-Würsten et al. 2001, 2007; Melovski et al. 2020), primarily occupying forested habitats with relatively abundant prey (Breitenmoser & Breitenmoser-Würsten 2008). Additionally, the home range size observed in our study is comparable to those of remnant and translocated lynx in the Dinaric Mts., as well as reintroduced individuals in the SE Alps (Fležar et al. 2024). However, the limited number of animals and the short duration of the survey did not allow us to draw extensive conclusions about the spatial behaviour, requirements, sociality, territoriality and / or prey of lynx. Nevertheless, the collected data constitute an important component of a comprehensive study on the variability of lynx home ranges and the factors influencing home range size in the Western Carpathians (Kubala et al. in prep). Moreover, the collected prey of both individuals will be equally significant for further studies on the impact of lynx on ungulates and will guide future ungulate and game management strategies.).

1.3. Public attitudes towards lynx translocations

Effectively managing large carnivores requires also considering public attitudes a crucial aspect in overcoming divergent views among key interest groups (van Eeden et al. 2019). Attitude studies are essential in biological conservation, informing our understanding of public sentiment and guiding communication strategies and policy decisions (Perry et al. 2022). In the conservation of large carnivores, such studies, targeting various interest groups, are vital for predicting responses to conservation efforts and addressing conflicts over predators (Kaltenborn et al. 1998; Kansky & Knight 2014). Understanding public attitudes is also critical for lynx translocation (reintroduction and reinforcement) programs in western Europe, including LIFE Lynx project, utilizing the Slovak population as a resource. However, despite a remarkable 50-year history of reintroductions of the Eurasian lynx throughout Western Europe (Kubala et al. 2023), attitudes of the Slovak public, who have been providing lynx for translocations and therefore are an essential part of the international lynx conservation efforts, have never been investigated. Activities like trapping, tranquilization, and transport involved in providing animals for reintroduction can be perceived sensitively by some interest groups and the general public. Both, illegal killing by hunters and opposition to trapping live lynx by conservationists pose potential threats to the implementation of translocation programs. Therefore, our aim was also to investigate public attitudes toward lynx in Slovakia to provide a robust foundation for practical national and international management strategies.

We developed an electronic web-based questionnaire, accessible on the websites of the Slovak Hunters' Chamber, the Slovak Hunting Union, and the National Zoological Garden Bojnice, from March 9 to July 23, 2020 (Smolko et al. in prep). To ensure broad participation, we emailed invitations to the State Nature Conservancy of the Slovak Republic, the state enterprise Forests of the Slovak Republic, private forest owners, non-governmental organizations, and educational institutions specializing in nature conservation, environment, forestry, and game management. This targeted recent and future stakeholders within the influential interest groups of hunters and conservationists (Salant & Dillman 1994; Lute et al. 2018; Perry et al. 2022). The questionnaire, based on previous studies (Červený et al. 2002, 2019; Bele et al. 2022), comprised several questions covering key aspects of lynx ecology and management in Slovakia. It also included questions related to international management and the translocation of lynxes (Smolko et al. in prep.). Overall, we collected 1071 completed questionnaires, achieving a 61.5% success rate. The respondents, diverse in socio-economic backgrounds, included 40% hunters, 13% qualified conservationists, and 47% from the general public. Occupation-wise, 37% were students, 11% worked in ecology and environmental conservation, 2% in agriculture, 14% in forestry, and 35% in other fields. Sixty percent were male, 40% female, and 59% lived in the countryside, while 41% lived in cities or towns. Most hunters and conservationists were aware of Western European lynx translocation programs, with about one-third of the general public sharing this knowledge (Fig. 8.). Similarly, the majority of those in forestry and ecology were informed, while only 34–44% of respondents from other fields knew about these programs. A higher percentage of males were knowledgeable compared to females, with no discernible difference between respondents from cities and urban areas.

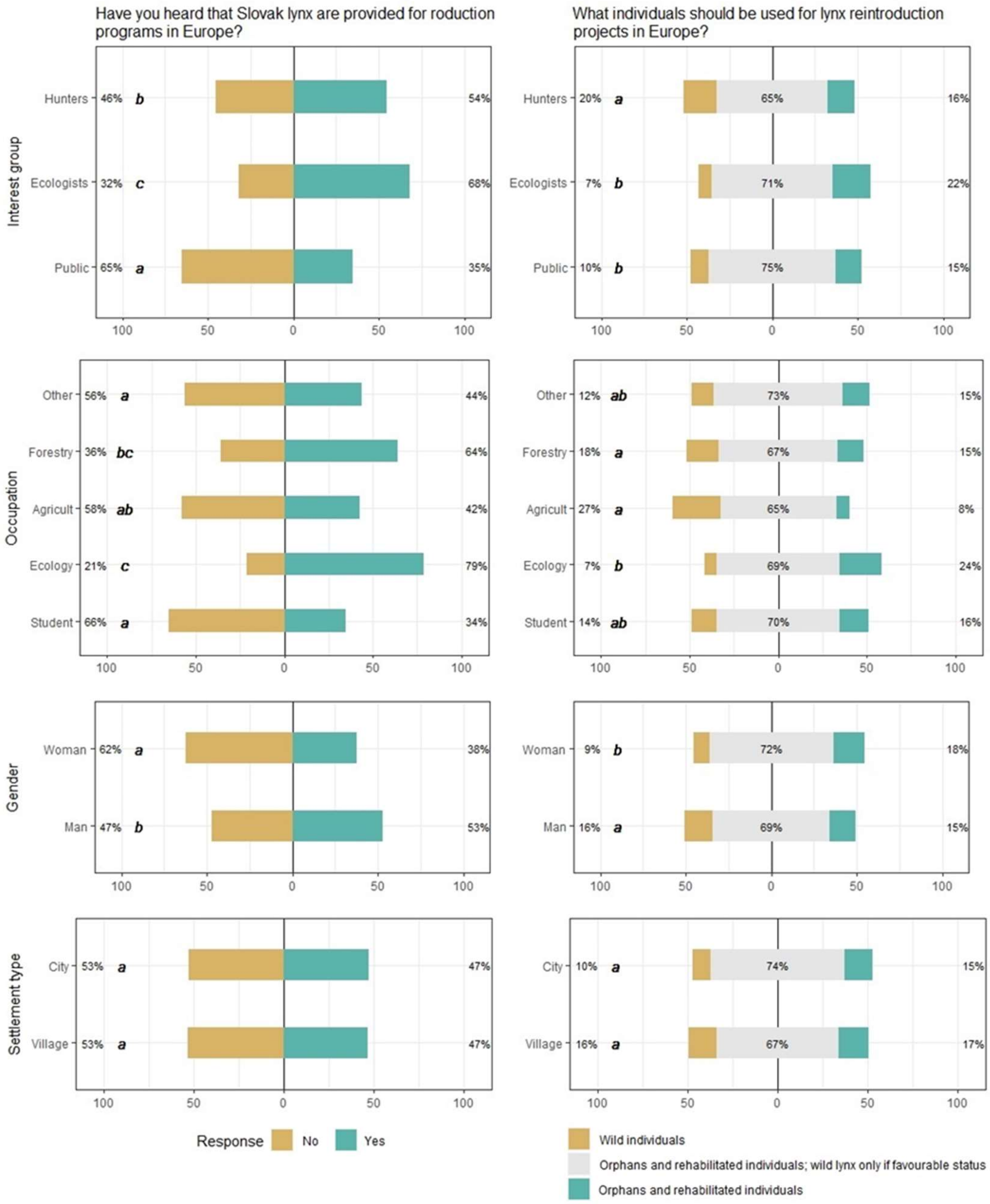


Figure 8. Responses to the questions (*left and right panels*), conditioned by the respondent's interest group, occupation, gender, and settlement type. The different letters beside the bars indicate significant differences in the response distributions across these categories (Smolko et al. in prep).

There was a strong consensus 75–88% among all respondent groups in favour of providing lynx from Slovakia for European reintroduction / reinforcement programs. The majority 65–75%

supported using primarily orphans and rehabilitated lynx for these programs, reserving wild lynx for cases where the local population is in a favourable condition (Fig. 8.). Hence, our survey highlights widespread social support for these important conservation efforts, utilizing the Slovak population as a key source (Smolko et al. in prep.). This consensus within Slovak society plays a vital role in sustaining struggling lynx populations in Western Europe, (Sindičić et al. 2013; Breitenmoser et al. 2022; Mueller et al. 2022). The backing from the public in target countries, including support from hunters (Bele et al. 2022), reinforces the imperative nature of these programs. Nevertheless, the trapping of wild lynx is deemed acceptable only under favourable local population conditions, aligning with the principles of the EU Habitats Directive. Given the variable density and fluctuations in wild lynx populations across Slovakia (Kubala et al. 2019a; Duľa et al. 2021), a sustainable, long-term approach involves a thoughtful combination of wild trapping, the utilization of rehabilitated orphans, and the establishment of ex situ lynx breeding programs like LINKING LYNX (https://www.linking-lynx.org/en/working-groups/sourcing-working-group). Drawing inspiration from the successful example of the Iberian lynx (Delibes-Mateos et al. 2022), this strategy holds the promise of enhanced sustainability for reintroduction and reinforcement efforts throughout Europe.

1.4. Management conclusions

The Slovak lynx represents the core of the lynx population in the Western Carpathians and, consequently, influences the fate and status of lynx populations in all neighbouring countries (Czech Republic, Poland, Ukraine, and Hungary). Furthermore, the majority of reintroduced lynx populations in Europe depend, to some extent, on the status of the population in the Slovak Carpathians. Therefore, Slovakia bears a special responsibility for the international cooperation, management, and conservation of this species in the Carpathians and across Europe (Bonn Lynx Expert Group 2021; Kubala et al. 2021a, 2023a). Our monitoring results are consistent with previous efforts, indicating significant anthropogenic influences on the lynx population in the Western Carpathians (Kubala et al. 2019a; 2020; Duľa et al. 2021). Considering the substantial impact of human-induced mortality, such as vehicle collisions and illegal killings, we recommend implementing effective mitigation measures (Kubala et al. in prep.). Authorities, lynx experts, and interested groups in the Slovak Carpathians should collaborate to mitigate anthropogenic factors jeopardizing lynx survival. Enhancing habitat connectivity is essential, particularly in cross-border areas and regions where key habitats are fragmented by fenced highways. Establishing wildlife crossings within natural corridors can facilitate the safe movement of lynx and other wildlife, thereby decreasing the likelihood of collisions and fostering genetic exchange among fragmented local populations (Kubala et al. 2020a). It is imperative to establish a comprehensive program aimed at mitigating conflicts between lynx and local communities, particularly stakeholders such as hunters, to effectively reduce instances of illegal killing. Simply placing the lynx under legal protection is insufficient without further interaction with stakeholders and mitigation of threats (Kubala et al. 2021a). The collaboration between the project team and various stakeholders—especially foresters, hunters, nature conservationists, livestock breeders, and the local community—within the LIFE Lynx activities and previous projects serves as an excellent example of cooperation and mutual trust. This collaboration has been particularly evident in systematic monitoring and lynx captures / translocations. These initiatives set an important basis for further conservation and management of lynx (and large carnivores) at both national and international levels. This wide-ranging cooperation, coupled with an efficient adaptive approach, can effectively mitigate conflicts and ensure the long-term, large-scale survival of the species within the geographic scope of Slovakia and the Carpathians (Kubala et al. 2021a; 2023). Consequently, it contributes significantly to the conservation of both autochthonous and reintroduced populations in Europe (Bonn Lynx Expert Group 2021).

2. Monitoring of lynx in the Romanian Carpathians

Teodora Sin, Andrei Dinu, Robin Doerr, Bogdan Kraft, Ilenia Marocco, Teresa Oliveira, Mihai Pop, Michael Willett, Andrea Gazzola

Introduction

At the onset of the 20th century, the lynx population in Romania was facing the same path towards extinction as in the rest of Europe. With a documented population of only 100 individuals, in 1933 the species was declared a Natural Monument and gained a level of protection that enabled a gradual and steady recovery (Vasiliu & Decei 1964; Kratochvil 1968a, b). Subsequently, a consistent degree of safeguarding was maintained, and the population was controlled through monitoring and regulated culling, as dictated by several laws and acts issued periodically starting with 1953 (Breitenmoser 1990; Geacu 2007). The lynx population continuously increased from 500 individuals in the 1950s to about 2000 individuals in the early 2000s (Ionescu 2001). Since 2007, lynx in Romania gained strict protection under the provisions of the Habitats Directive (Council Directive 92/43/EEC), where the species is listed under Annex IV. However, regulated harvesting persisted until 2012 (through derogations under Article 16 of the Directive), when (legally) hunting lynx ceased entirely.

The most recent official estimates indicate a population of 2100-2400 individuals (Reporting under Article 17 of the Habitat Directive 2013-2018). Given the vast extent of the lynx area in Romania, accurate national-level population estimates are generally challenging to obtain. The national monitoring system currently in place consists of a non-standardised collection of C1 (although occasional, and spatially restricted) and C2 data, according to the SCALP criteria (Molinari-Jobin et al. 2003; Molinari-Jobin et al. 2012). Administrators of game management units provide track count data (C2), and on occasion camera-trapping data (C1), to the responsible central authorities, where it is further verified and adjusted based on expert opinions to account for double (Salvatori et al. 2002; Cazacu et al. 2014). The process is considered unclear, and the assessments have historically been questioned and assumed to be overestimates (Breitenmoser 1990; Salvatori 2002; Rozylowicz et al. 2010; Cazacu et al.

2014). Nevertheless, this part is still considered the stronghold of the Carpathian population (von Arx 2020), and recent regional-scale studies appear to support its favourable conservation status (Iosif et al. 2022).

As opposed to the population in Slovakia, up until now the Romanian lynx population was never used as a source for the reintroduction projects that occurred as early as the 70s. During the LIFE Lynx project time-frame, a total of 12 lynxes (10 within the project and two within the Ulyca 2 initiative) were translocated from different regions across the Eastern Romanian Carpathians.

When planning for translocations, monitoring of source populations and of the impact that animal removal might have on this populations is often overlooked (Mitchell et al. 2022). Monitoring is needed not only to ensure that the local population is not affected in the long run and to observe changes coming from animal removal in the short term, but to support the decisions regarding the best animals to be translocated as well (e.g. genetic monitoring). In compliance with the IUCN's Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC 2013), in the Life lynx project, the capture areas were monitored before, during and after the translocations occurred from the source population, providing valuable information about the impact of the actions and allowed for ongoing adjustments to the capture and translocation strategy.

During the project time-frame, we implemented camera-trapping, ground survey/snow-tracking and collected non-invasive DNA samples to gather data on lynx presence and movement in the project area and assess i) the minimum number of lynxes in the study areas throughout the project, ii) sex ratio, iii) number of family groups (i.e. female with kittens) in the local source population in the Eastern Romanian Carpathians. In addition, we provide iv) the territory size estimates for two male lynxes fitted with GPS collars and released *in-situ*.

Study areas

Between November 2017 and December 2023, we surveyed and monitored lynx, intermittently, in five study areas (1-Lepșa, 2-Bacău, 3-Vintileasca, 4-Dărmănești, 5-Tarcău) distributed across the Eastern Romanian Carpathians (Fig. 9).

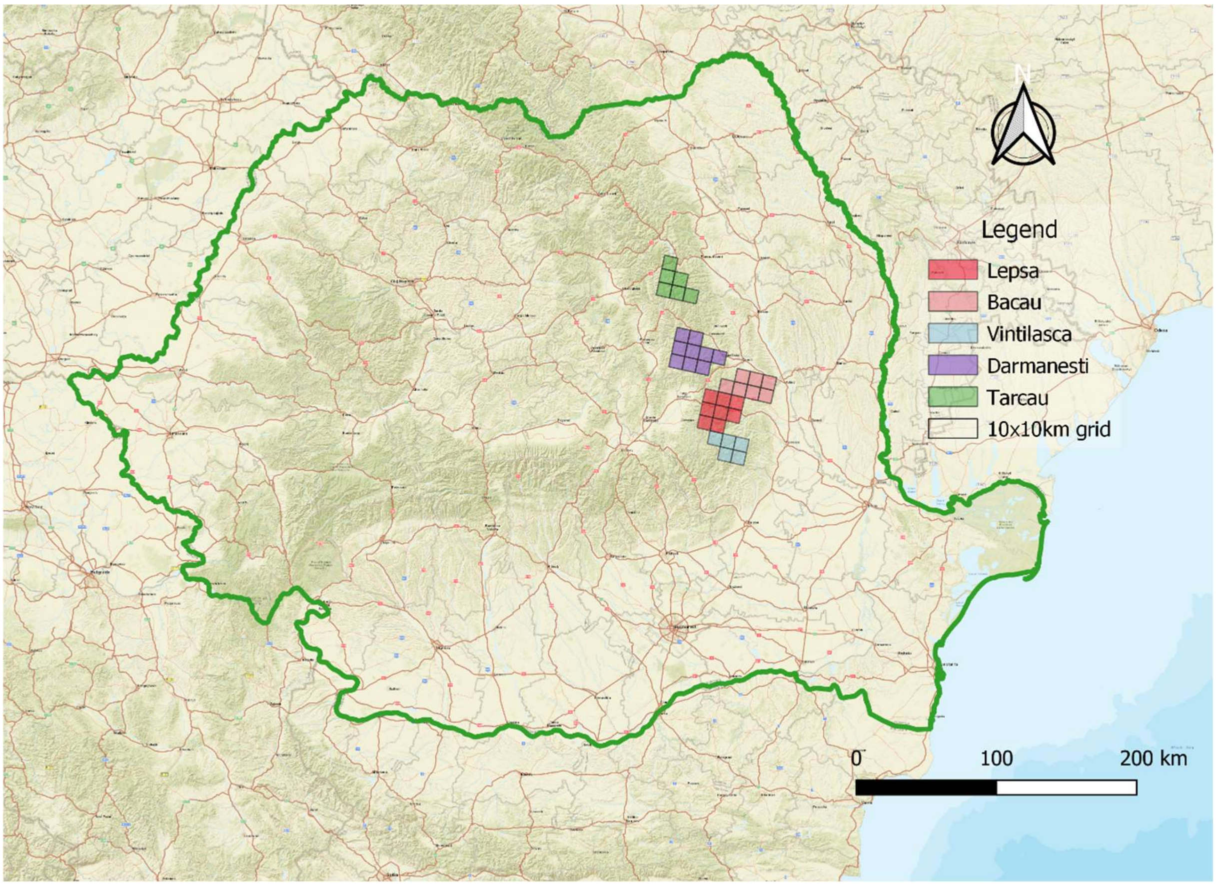


Figure 9. The distribution of the study areas across the Eastern Carpathians, Romania. Although some of the areas are contiguous, they were considered as distinct study areas due to the intermittency of the survey (not all areas were surveyed with the same effort intensity or over the entire period of the project).

The extent of the study areas was defined by the total number of 10x10 km grid cells (EEA reference grid) overlapping the Hunting grounds (wildlife management units) where lynx live-capture occurred. Following Zimmerman et al. (2013), when possible, the area was extended to ensure that a sufficiently large area is covered and the insights and results produced are biologically meaningful and post lynx-removal changes in the population can be accurately detected. The surface of the areas ranged from 100 km^2 (Tarcău) to 900 km^2 (Dărmănești), and the total area covered summed to up to 3000 km^2 (Table 1).

Table 1. General characteristics of the study areas

Study area	Location (center of the area) N	E	Surface (km^2)	Altitude range/average/SD (m)	Forest habitat (%)	Protected area (%)
1-Lepsa	45.951018	26.537186	800	349-1774 / 965 / 306	78	57.3
2-Bacau	46.102312	26.852482	700	112-1237 / 468 / 163	74	2.9
3-Vintileasca	45.608333	26.705556	500	415-1706 / 984 / 268	82	4.1
4-Dărmănești	46.343520	26.254868	900	249-1634 / 918 / 254	80	38.6
5-Tarcău	46.807533	26.046669	100*	647-1459 / 1025 / 142	88	0

*the size of Tarcău study area was increased only during the additional monitoring season (October-December 2023), after the removal of three lynx-individuals in the frame of the project.

Overall, the Eastern Romanian Carpathians form a continuous mountainous tract, with good habitat connectivity and make up for approximately half of the of the lynx range in the country. All of our study areas have highly similar environmental conditions. The largest part of the surface covered (71%) is in the Alpine Biogeographical Region, while the remaining (29%) is in the Continental Biogeogrphical Region (overlapping the majority of Bacău and one third of Lepșa). Altitudes range between 112 and 1774 m, with an overall average of 840 m (SD 326 m) (Table 1).

A cool continental mountain climate with high humidity throughout the year is predominant in all study areas but Bacău, which lies in the wet temperate continental climate zone in the foothills of the eastern Carpathian Mountains (Köppen Climate Classification, Clima României, Administrația Națională de Meteorologie, Bucharest 2008).

Snow cover duration and the depth of the snow layer vary greatly, depending on the altitude and slope exposure. At elevations below 800 m, the snow layer is present between 36 and 76 days, and at altitudes greater than 800 m the number of days with snow varies between 94 and 150 (Micu et al. 2015). The average depth of the snow layer is 30 cm in areas below 800 m and 70 cm in areas over 800 m.

The land cover is dominated by compact forests, occupying almost 80% of the entire project area. Particular to each study area is the variation in the forest composition pattern, with the northern study area having a considerably higher coniferous share (Tarcău 59%) than the rest of the areas (Vintileasca 25%, Lepșa, Dărmănești 23% each, Bacău 1%). Broad-leaved forests are predominant in Bacău (49%), and less common in the other areas (Lepșa 14%, Vintileasca 17%, Dărmănești 11%, and Tarcău 1%). Mixed forests occupy significant parts of all areas, with higher percentages in Lepsa, Vintileasca and Dărmănești (41%, 40%, and 46% respectively), and lower, but still important surfaces in Bacău and Tarcău (24% and 27% respectively). Permanent human settlements are clustered at the bottom of the valleys and represent less than 2% of the total surface area (CORINE Land Cover 2018).

Three of the six species in the European large-carnivore guild coexist in the study area (the European lynx (*Lynx lynx*), the brown bear (*Ursus arctos*), and the grey wolf (*Canis lupus*, while the meso-carnivore guild is represented by the red fox (*Vulpes vulpes*), wildcat (*Felis silvestris*), European badger (*Meles meles*), pine marten (*Martes martes*) and stone marten (*Martes foina*). The complex ecological community is completed by several herbivore species, such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), and chamois (*Rupicapra rupicapra*) (found only in Lepșa and Tarcău).

Approximately 23% of the project area is protected within the Natura 2000 network, unevenly distributed among the study areas (57.3% of the area of Lepșa, 38.6% of Dărmănești, while the remaining 4% is split between Bacău and Vintileasca). Although human density is low in all study locations, human disturbance occurs throughout the year as a result of logging activities, and seasonal disturbance occurs due to grazing, berry and mushroom picking, tourism, and hunting activities.

2.1. Camera-trapping

Camera-trapping is widely used in wildlife population surveys and has proven to be effective in surveying species with easily identifiable, individually unique coat patterns, such as tiger or lynx (Karanth et al. 2006; Zimmermann et al. 2013; Kubala et al. 2019a). Differentiating individuals based on coat patterns allows creating a history of individual detections which can subsequently be integrated in Capture-recapture models to infer population estimates.

In order to use the available resources effectively, the camera-trapping effort varied across study areas and years (Fig. 10). The sampling strategy was adapted accordingly, being either systematic (in primary study areas), or opportunistic (in secondary study areas). The sampling strategy and the ranking of the study areas has been described in the report "Monitoring of the Eurasian lynx in the Eastern Romanian Carpathians" (Sin et al. 2021). Since deterministic monitoring approaches require significant logistic resources, rather than aiming at providing density estimates, we have focused on covering each area as best possible in order to assess the species distribution and to provide the minimum number of individuals and family groups in each study area.

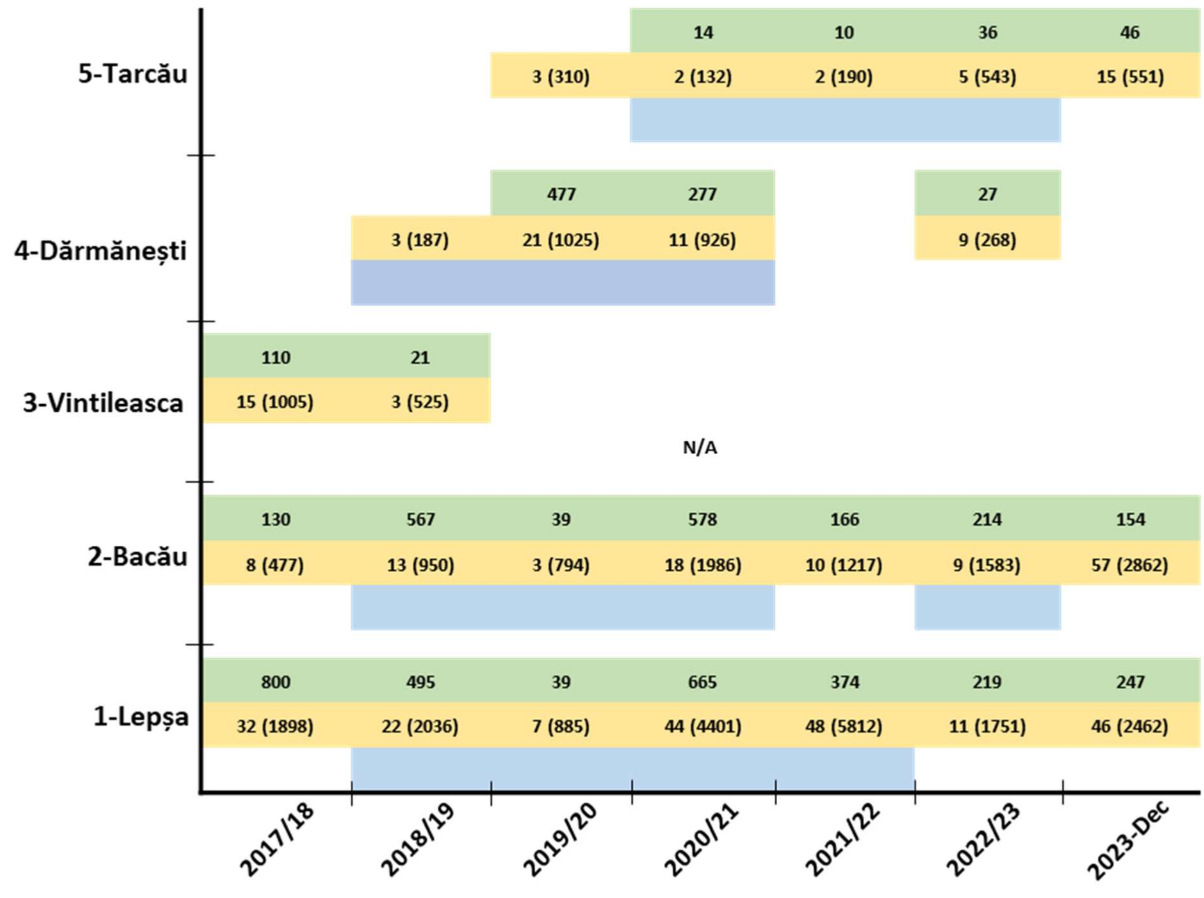


Figure 10. The effort intensity across study areas and years. The coloured lines show the year(s) in which an activity was implemented (green Ground survey; orange camera trapping; for a better understanding, in blue it's shown when trapping occurred in each of the areas). The text on each line shows the overall effort during the respective time frame (No. of km patrolled on foot; No. of CT stations (n. active CT days)).

The results were obtained based on the analysis of data collected exclusively during the winter season (November-April). For the initial systematic survey, a total of 3-4 camera-trapping stations were set in each 10x10 km grid cell (EEA Reference Grid) overlapping the study areas. In the 2020/21 season, data collected through a different project (Project PN-III-P1-1.1-TE-2019-0835, led by the University of Bucharest, and funded by UEFISCDI) in Lepșa study area, was included in the analysis. In this project, over 40 camera-trapping stations were set in the field using a 3x3 grid cell. In addition, during the monitoring season 2023/24, the first deterministic survey approach was implemented in Lepșa and Bacău study areas, through a new conservation project (Lynx Thuringia. Connecting lynx populations across Europe, financed by the Thuringian Ministry of Environment, Energy and Nature Conservation through the ELER Programme). In this project, 49 stations were distributed across a 562 km^2 study area, using a 2.5x2.5 km grid, and once data processing and analyses are concluded will provide the first lynx density estimates in this part of the Carpathians. These additional data sources contributed significantly to increasing the quality of our results.

To maximize sampling efficiency and increase the probability of individual detection, in each of the sampling approaches, we set the camera traps at locations known to be used by lynx, including in the proximity of shelters (generally used by lynx as marking points) or on potential movement corridors (path, forestry road, ridge, valley), following Stergar & Slijepčević (2017). Although two devices per station are often recommended for the individual recognition, based on the unique coat pattern (Breitenmoser et al. 2006; Kubala et al. 2019a; Stergar and Slijepčević 2017), apart from the additional monitoring season in Lepșa-Bacău (2023/24), in all other cases we used a single device at each station, to increase the number of stations and the probability of detecting lynx.

Over the course of the entire study period (2017–2023), a total of 2685 lynx images (correlated events) were recorded in all study areas (Lepșa 1087, Bacău 1029, Vintileasca 11, Dărmănești 32, Tarcău 526). More than half of the images (1617 / 60.2%) were of poor quality (animal too far from the camera, fuzzy image, covered, too much or too little light), making it impossible to observe the coat-pattern of the individuals.

Based on the remaining good-quality images, we identified a total of 27 individuals (seven females, 19 males, one of undetermined sex; including 7 translocated individuals). By pooling data form systematic, opportunisitc and deterministic surveys together we were able to create a history of individual detections (Table 2). We assigned a unique identification code to the animals exclusively when it was possible to recognise them from both flanks.

In Lepsa and in Bacău study areas, where the camera trapping activity had been performed since the beginning of the project and where the bulk of lynx photos was collected, individual identification was particularly successful. Twenty different individuals were identified during the whole study period (from 2017 to 2023) in these study areas. Half of them were detected only one time, but some individuals were repeatedly sampled over the years. Three individuals from Lepşa study area were sampled in Bacau in the last season (winter 2023). Only one individual was identified from the photos collected in Darmanesti, while a positive trend of the number of identified individuals was observed in Tarcau study area in the last 3 seasons of the project, most likely linked to an increase in intensity of effort.

Table 2. Detection history of the individuals identified from the photographic material collected during the entire project period (2017–2023). The individuals who were captured/translocated or released in situ with a satellite collar are shown in brackets (i.e. RO2, RO3, etc). Identification codes with an asterisk (*) refer to individuals that were photographed in more than one study area.

Study area	Cod lynx	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
Lepsa	ROCTLL001M							
	ROCTLL002M*							
	ROCTLL004M *							
	ROCTLL010F *							
	ROCTLL015F							
	ROCTLL018M							
	ROCTLL023M							
	ROCTLL026U							
	ROCTLL027F							
Bacau	ROCTLL003M (RO2)			*traslocated*				
	ROCTLL005M (RO7)							
	ROCTLL006M (RO3)				*translocated*			
	ROCTLL007F							
	ROCTLL008M (RO5)				*translocated*			
	ROCTLL009M							
	ROCTLL011M							
	ROCTLL013M (RO8)							
	ROCTLL014M							
	ROCTLL017M (RO13)							*translocated*
	ROCTLL020F (RO14)							*translocated*
	ROCTLL002M*							
	ROCTLL004M *							
	ROCTLL010F *							
Dărmănești	ROCTLL012F							
Tarcău	ROCTLL016M							
	ROCTLL019M							
	ROCTLL021M							
	ROCTLL022M							
	ROCTLL024F							
	ROCTLL025M							

2.2. Ground survey and Genetic analysis

The ground survey activity was planned to gain important insights (through snow-tracking) on lynx distribution, movements, territory use, and on the number of lynx and family groups in the study areas. Same as camera trapping, ground surveys have been performed in all study areas, intermittently, by following a previously established set of systematic transects designed to allow the operators to cover the largest area possible, and to maximise the probability of intercepting lynx trails. Besides the standard transects, occasionally, additional transects were surveyed with the aim of increasing the chances to collect sufficient biological samples for genetic analysis. Transects were selected following the main and secondary mountain ridges, and the valleys, paths and forestry roads which are generally used by lynx for their movements. Each transect had a length of not less than 7 km and covered the altitude range of the area, from the bottom of the valley up to the mountain ridge, to maximize the probability of crossing a lynx trail (snow-tracking). Once lynx trails were intercepted, they were followed as far as much possible in order to: count number of individuals, record lynx movement and signs (to ascertain the lynx use that area) and to allow the collection of fresh samples for genetic analysis. Ground surveys/snow tracking followed an opportunistic sampling strategy, when the amount of effort was strictly dependent on snow cover conditions. However, in primary study areas, the transects were repeated at least three times per season to reduce the probability of false absences. The ground survey effort per study area and year is reported in Figure 10.

The collection of non-invasive genetic samples followed an opportunistic sampling strategy and occurred mainly during the ground survey/snow-tracking activity. Information on the procedures for collecting samples and preserving the genetic materials are reported in the specific manual "Collecting lynx non-invasive genetic samples. Instruction manual for field personnel and volunteers" (Skrbinšek 2017). The aim of the genetic analyses performed within this specific action of the LIFE Lynx project is to obtain information on: genotype, sex, and relatedness of the individuals, to describe the local population and to support the translocation activity.

During the whole project period, 106 fresh biological samples for genetic analysis were collected across the study areas. These samples were from excrements, urine, hairs and blood collected both during the ground survey and trapping activity. Only 50 samples were of sufficiently good quality for DNA extraction and individual identification. The number of samples collected and analysed exceeded the number of samples planned in the project (30 samples). All analyses were done by The University of Ljubljana.

The sample size and number of markers utilised in the analysis didn't allow for highly accurate relatedness estimates and pedigree reconstructions. Nonetheless, there were some strong links between the species, indicating that many of the animals in Lepşa and Bacau were descended from the same pool of polygamic breeders (Skrbinšek et al. 2022). Nonetheless, a low level of direct sibling and paternal interactions was found. Unfortunately, there aren't many females in the dataset, who would probably provide a much clearer picture through sibling relationships and direct parenthood (Skrbinšek et al. 2022). Still, the genetic data provided additional information about the distribution, number of individuals as well the M/F ratio (Table 3, Fig. 11).

Table 3. Gender of the individuals recognized using different source of information during the seven winter seasons (2017-2023).

Gender	Genetic analysis	Camera trapping	Trapping activity
Male ♂	23	21	12
Female ♀	5	9	2
M/F	4.6	2.3	6

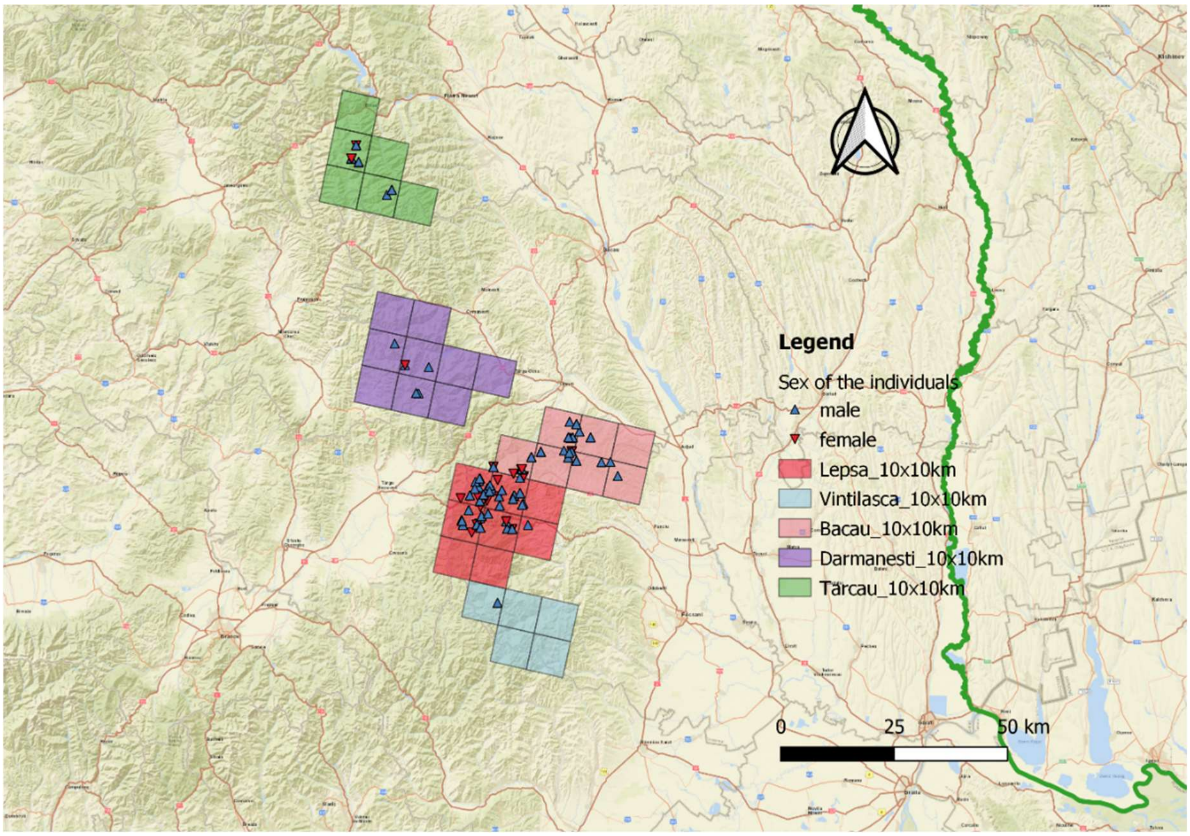


Figure 11. Gender distribution of the individuals using different source of information (genetic, camera trapping, and trapping data) during the seven winter seasons (2017-2023).

2.3. Minimum number of individuals inferred from camera trapping, trapping activity and genetic analysis data

Throughout the project duration, the number of lynxes recorded in the Lepşa study area fluctuated around 5. Only two individuals were trapped and removed from this local population (one in the winter 2018/19 and the other during the following winter 2019/20) (the history of translocations is shown in Fig. 12). Despite the removal of these individuals, in the subsequent seasons the number of individuals monitored remained five with the exception of the last winter (2023/24) when two additional individuals were observed (Fig. 13).

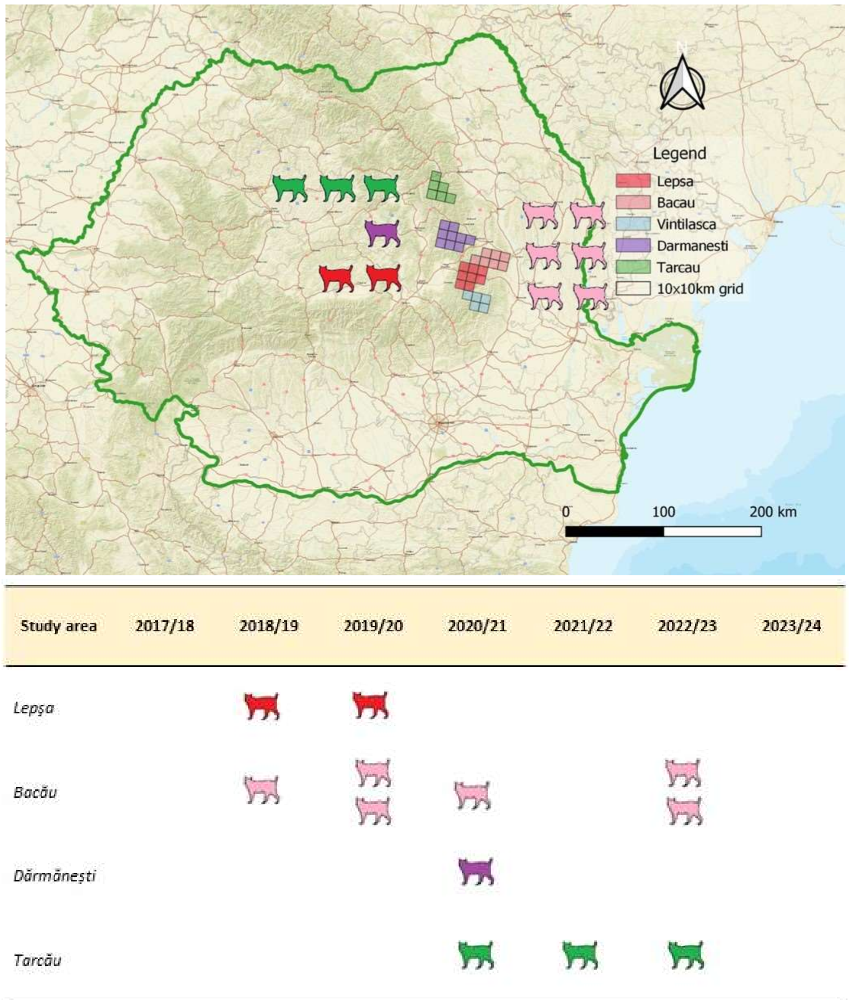


Figure 12. Individuals captured in the study areas during the project timeframe. Two individuals from Bacău, captured in 2022/23, were translocated to Italy, in the frame of the Ulyca 2 project.

Bacau was the study area where the most lynxes were captured (Fig 12). Throughout the project, 50% of the lynxes translocated to Slovenia, Croatia, and Italy came from this area. The number of individuals steadily increased throughout the period of the project, starting from a minimum of two individuals recorded in winter 2017/18, and reaching a maximum of seven individuals observed during the winter 2021/22 and the early winter 2022/23. However, an unexpected decline was observed in the last winter 2023/24 (Fig. 13).

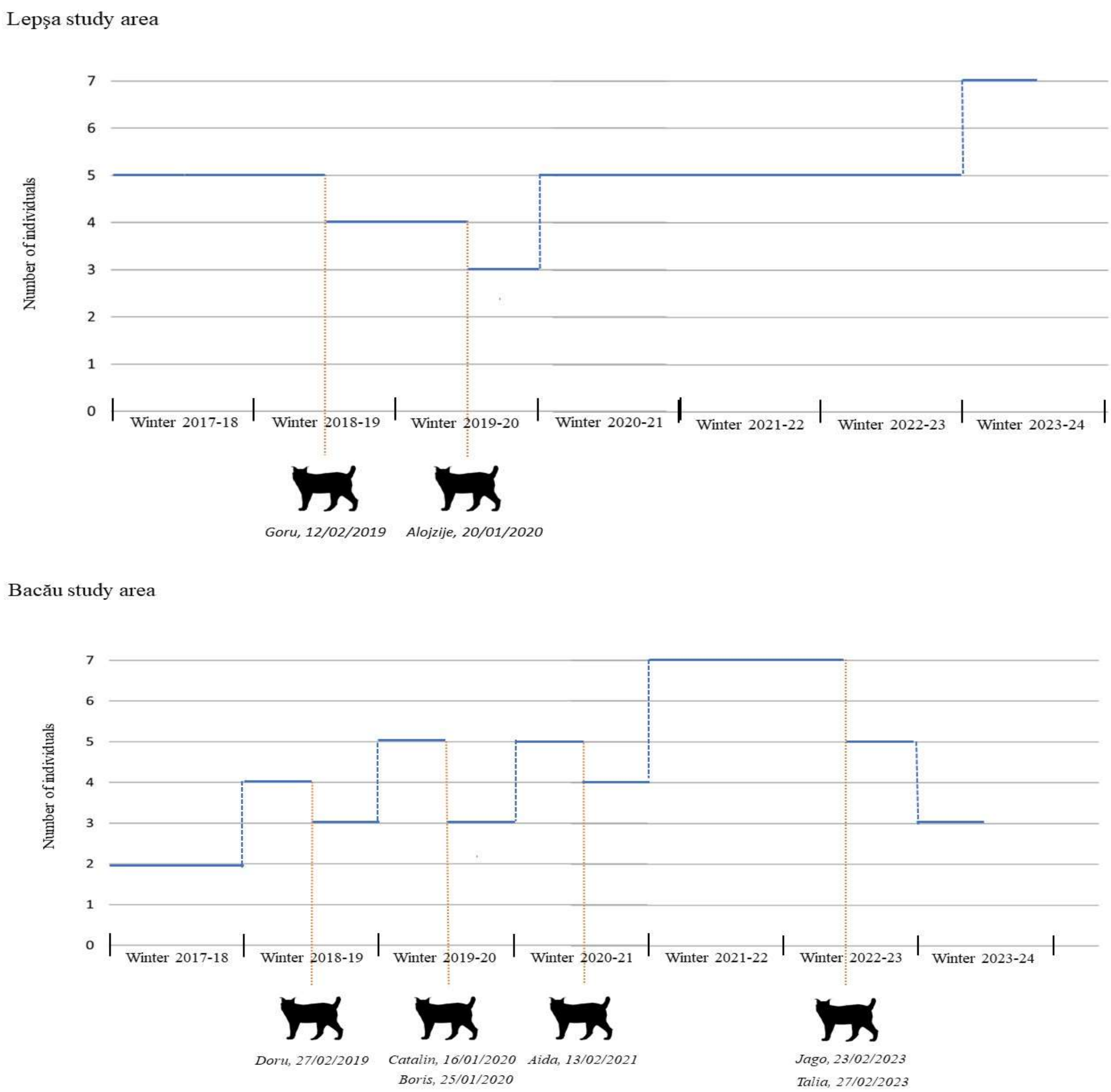


Figure 13. Trend of the minimum number of individuals recognized from direct observations, photos/videos, and genetic analysis in Lepșa and Bacău study areas through the seven winter seasons (October 2017-December 2023). Lynx silhouettes represent the individuals captured and removed from the population.

Although the first camera traps in Dărmănești were installed in winter 2018/19, detailed monitoring was not carried out until the following year, when intensive ground survey and camera trapping activities were conducted. In that year, few animals were detected (three adult lynxes, of which one mother with two kittens). In the last part of this winter, the local hunters found two dead lynxes. The monitoring activity continued also in the following winter (2020/21), as well as the trapping activity. In the same year, we captured an adult male (RO6_Tris) (Fig. 12). Afterwards, it was decided to cease both monitoring and trapping activities since forest cutting activities were scheduled in the parts where the box traps were placed. The last monitoring activity was conducted in the winter 2022/23 where only one individual was detected (Fig. 14).

The monitoring of Tarcău began in the winter of 2019/20 and was limited to the surface of a single hunting district (one grid cell), with an effort maintained throughout the years until the winter of 2022/23. Despite the small surface, the location was found to be ideal for the presence of lynx. In fact, the number of lynxes observed fluctuated between two and four, despite one being captured and relocated each winter season (three overall, Fig. 12). The marked rise in the number of individuals observed in Tarcău study area in the last season is related to the extension of the surveyed surface and a commensurate increase in monitoring effort (Fig. 14).

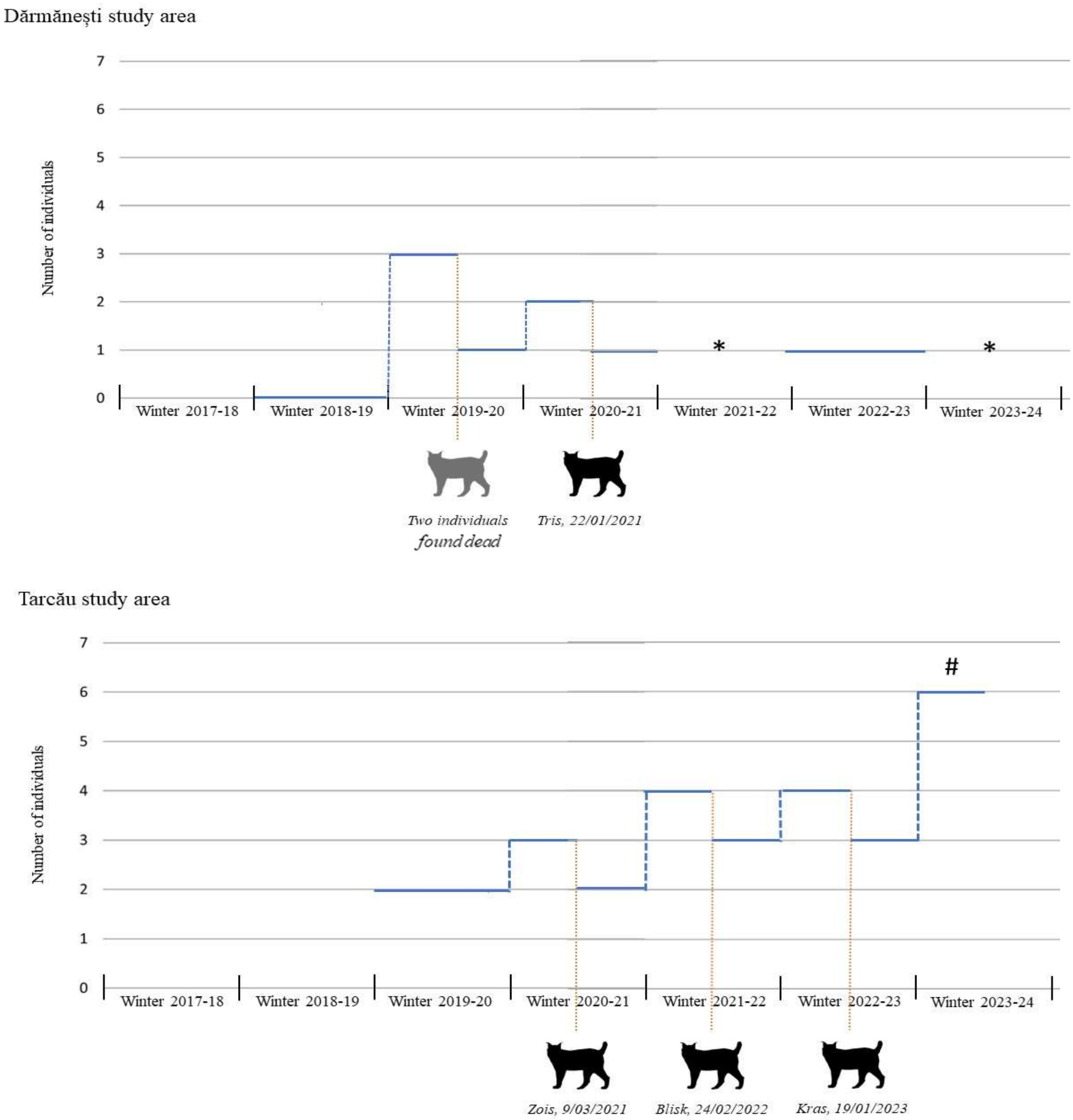


Figure 14. Trend of the minimum number of individuals recognized from direct observations, photos/videos, and genetic analysis in Dărmănești and Tarcău study areas through the seven winter seasons (October 2017-December 2023). Lynx silhouettes represent the individuals captured and removed from the population.

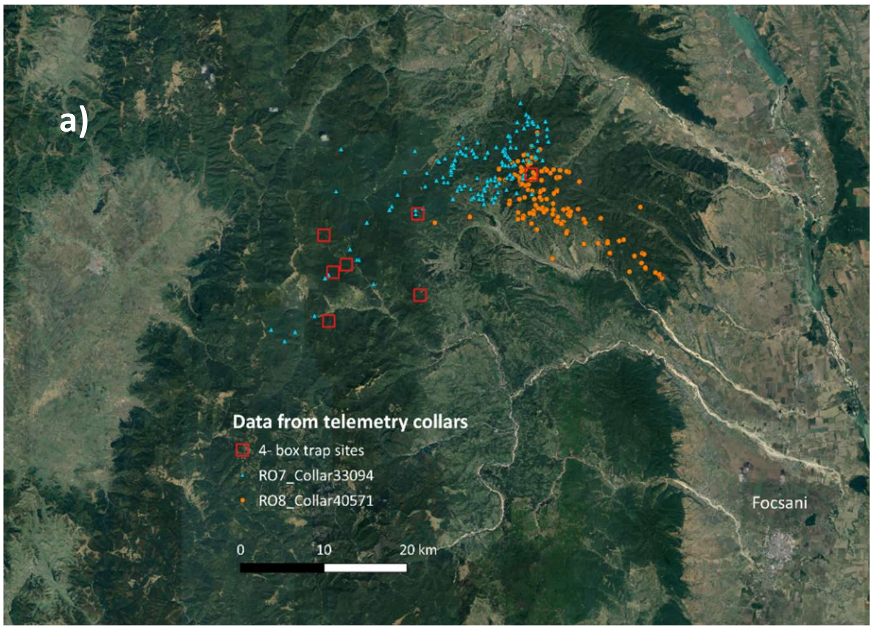
2.4. GPS Telemetry survey

Additional data for lynx monitoring has been gathered from two male lynxes which have been equipped with GPS collars in January 2021 and released *in-situ*. This action was not initially planned and it was possible after the project partners and main beneficiaries, The Slovenian Forest Service, provided ACDB with two refurbished GPS collars.

This dataset provided additional and more detailed information about lynx movement and territory use within and between the study areas Bacău and Lepșa. Furthermore, the GPS locations allowed us to verify eleven kill sites and get an insight into lynx feeding habits in Romania (Fig. 15). The activity was not continued due to delayed receival of the collar data (related to the signal coverage in the area) and the low number of fixes per day (2 locations/day). As of June, 26 2022, one of the collars (on lynx RO07, Collar ID 33094) stopped sending data and after the planned drop-off (in October) several incursions in an attempt to find the collar and retrieve the activity data have been made. The collar was recovered at a later date, but the activity data could not be retrieved. The second collar (on lynx RO08, Collar ID 40571) dropped off on March 15, 2023 and was recovered from the field shortly after.

Figure 15. Remains of the prey found at the kill site (Photos: **a** Andrei Dinu, **b** Ilenia Marocco)

When compared, the data obtained from two different mating seasons (Jan2021-Apr2021 vs Jan2022-Apr2022) showed that both individuals have partially shifted their home-ranges (Fig. 16), which explained their lower presence at the camera traps set in their home-ranges and provided interesting insights into lynx behaviour and could further support management, monitoring or capture decisions.



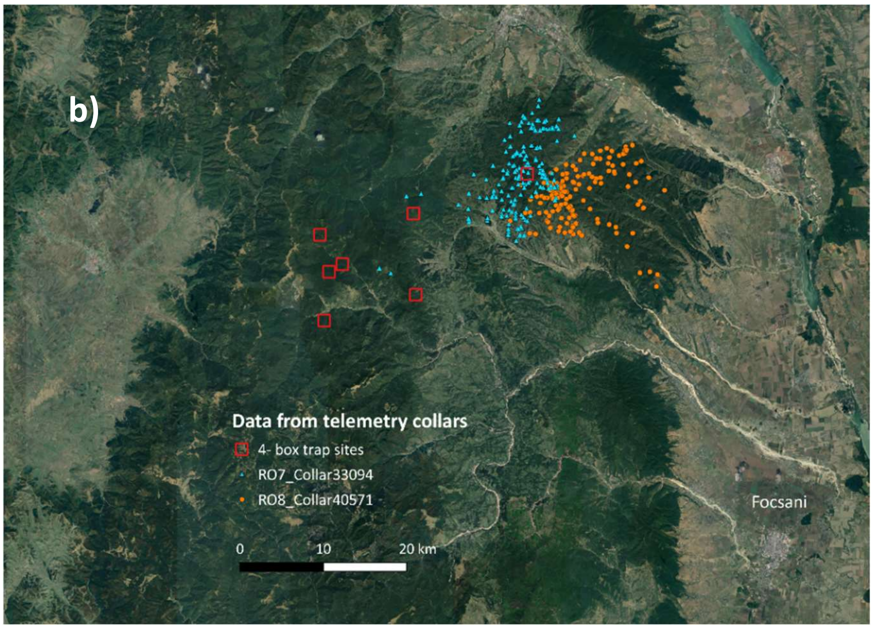
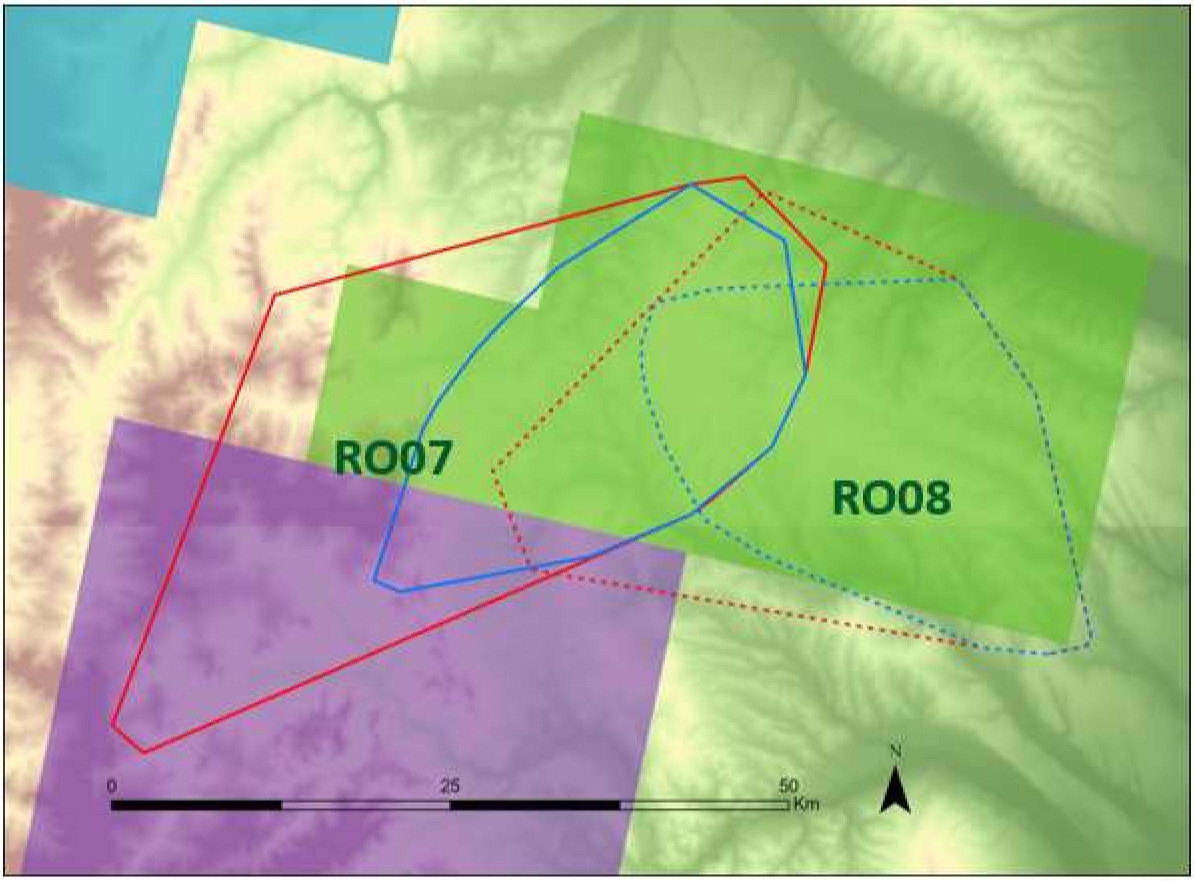


Figure 16. Data from telemetry collars of the two lynxes caught in Bacău study area and released *in situ*. The red squares represent the box traps that were active during the trapping season. The **blue** dots represent the locations of the first lynx caught (RO7 - 24/01/2021), whereas the **orange** dots the location of the second lynx (RO8 - 29/01/2021). In the figure a are reported the locations of the two individuals from January 2021 to April 2021. In figure b are those from January 2022 to April 2022.

Lynx RO07 was monitored for 519 days, while lynx RO08 for 774 days (Fig. 17). To our knowledge, this is the longest lynx movement data set available for lynx in Romania (continuous monitoring of the same individuals).



Parameter	RO07	RO08
No. of days	519	774
No. of fixes	1030	1556
100% MCP (km²)	553	442
Mating season excluded (km²)	263	295

Figure 17. Home range area of two male lynxes released in the Eastern Carpathians in frame of the LIFE Lynx Project. In **red** 100% MCP; in **blue** MCP excluding the mating season, *continuous line* lynx RO07, *dashed line* RO08.

Discussion and conclusions

During the seven years of the project, monitoring and capture activities were carried out over a vast region of the Eastern Romanian Carpathians, ranging from the southernmost sectors, with the study areas of Vintileasca and Lepşa, to the central sectors, Bacau and Dărmănești study areas, up to the most northern sector, the study area of Tarcău, in the county of Neamț. Although not simultaneously during the project period, the survey activities were conducted over an area of approximately 3000 km^2.

The decision to look into such a large area was driven by the fact that, from the start of the project, the only information available about lynx presence was related to the official data gathered by the hunters, but the information lacked the in-depth spatial scale required by the demands of the project (finding good trapping locations). The selection of distant study areas was motivated by the need to maximize the probability that the lynxes captured had a high genetic diversity.

The decision to work on different study areas influenced the survey/monitoring approach, which was mostly opportunistic, with an effort intensity that was not constant among the years (with the exception of the last winter season 2023/24, where in the study areas of Lepşa and Bacău, it was possible to carry out a deterministic camera-trap survey (currently part of the ongoing project "Lynx Thuringia. Connecting lynx populations across Europe"). This was a necessary adaptation to the available resources (a small team, most of the time formed by four technicians and two volunteers, and a limited number of camera traps (50 devices)).

The lynx presence was confirmed in all the study areas investigated, however in Vintileasca study area, after two years of monitoring (winter 2017/18 and 2018/19), we took the decision to exclude it from the suitable study areas for logistical reasons: the area was not easily accessible, which made monitoring, and subsequently lynx capture, ineffective.

Three study areas, Lepşa, Bacau, and Dărmănești, were fully operational during the winter 2019/20, while Tarcău was added as an additional area.

During winter 2020/21, a high survey effort was planned in Lepşa, Bacău, and Dărmănești, while a minimum effort was guaranteed in Tarcău. As far as the capturing activity is concerned, Lepşa and Dărmănești were designated as the primary study areas, while Bacău and Tarcău were designated as the secondary study areas (Sin et al. 2021).

In Dărmănești study area, monitoring and trapping activities were suspended during the winter season (2021/22), while they persisted in the areas of Lepşa, Bacău, and Tarcău until the project's end.

In Lepşa, the number of individuals has remained almost constant with the exception of the last season, when it increased by two individuals. On the contrary, a positive trend was observed in Bacau until the winter 2022/23, followed by an unexpected decline that occurred in the last winter 2023/24. These fluctuations could be attributed to other events rather than a change in the number of animals living in the study area (e.g. impromptu incursions of individual who have their core area in adjacent area; individuals that cross the area because they are in dispersion; or individual that shift their home ranges toward a different area). These conclusions were supported by data from the systematic and deterministic camera-trap monitoring carried out in the last season (2023/24), as well as Iridium GPS-collar data from one of the two individuals caught and released *in-situ* during the winter 2020/2021. Despite its core area lying in the Bacau area, the spatial data pertaining to the individual RO7_collar 33094, indicated that he made occasional visits in the Lepşa area during the winter of 2020/21 (Sin et al. 2021).

Moreover, in the last winter (2023/24), three lynxes from Lepşa study area, were also observed in Bacau study area and one individual from Bacau visited occasionally Lepşa study area.

The small number of individuals identified in the Dărmănești study area could be related to the reduced monitoring effort and the environmental conditions during the surveys in this area (lack of snow made it nearly impossible to do snow-tracking and optimize the positioning of camera-trap stations). On the other hand, the sharp rise in the number of individuals found in the Tarcău study area in the last season is due to an expansion of the surveyed surface and a corresponding increase of the effort.

The information gathered using the different sampling strategies, including the M/F ratio and the number of individuals observed, should be viewed as generic and partial. Nonetheless, the study found that individuals taken from several Romanian study areas and transported to Slovenia, Croatia, and Italy (1-3 lynxes per season, 12 overall) did not appear to have a negative impact on the source population. Moreover, confirmed yearly reproductions (at least one adult female with kittens) in each of the study areas further supports this assumption. Although the minimum number of individuals fluctuated during the study period, the local population did not decrease: each study area showed a steady, if not positive, trend. We assume that the fluctuations were due to the differences in effort intensity between years and study areas.

Acknowledgments

Slovakia: We thank all institutions, fieldworkers and students participating in this project (which are detailed in partial technical reports Kubala et al. 2019b, 2020b, 2021b), particularly the Ministry of the Environment of the Slovak Republic, the State Nature Conservancy of the Slovak Republic, the Forests of the Slovak Republic, the National Zoo Bojnice, various private forest owners and hunting grounds. For field assistance, we would like to especially thank Ľubomír Árvay, Miroslav Kiapeš, Miloš Šály, Peter Novák, and Štefan Zatroch†. Slovak part of this project was funded by the European Commission and the Ministry of the Environment of the Slovak Republic

Romania: We would like to thank our colleagues from ACDB and the Slovenian, Croatian, Slovakian, and Italian partners of the LIFE Lynx project from whom we have learned immensely over the last years. We extend our appreciation to Regia Națională a Pădurilor ROMSILVA who helped in identifying important trapping locations and became an important partner and source of lynxes throughout the project, with all but one lynx being captured on state managed hunting grounds.

We express our gratitude to the volunteers who completed our team and were of invaluable help during the monitoring and trapping seasons: Rossella Casalaspro, Marco Davoli, Manon Culos, Bogdan Vasilescu, Hannah Elizabeth Kirkland, Lan Hočevar, Simona Capelli, Marco Sensi, Francesca Roseo, Marie Pineau, Sarah Bitsch.

The financial support of the EURONATUR Foundation greatly assisted ACDB in meeting the co-financing expenses throughout the project, and for that we are truly grateful.

Participating project beneficiaries:

Co-financed by:

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