

Eurasian lynx. How many of them lives in Central Europe?

Klaudia Wlaźlak¹, Przemysław Cwynar¹, and Anna Mucha¹

¹Wroclaw University of Environmental and Life Sciences

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Abstract

Knowledge about the number of Eurasian lynx in Poland is important from the viewpoint of lynx protection and education of society in the field of wild animals. The occurrence of lynx in Poland is limited to the forest environment. These animals rarely leave forested areas as the territories used by humans are a relevant barrier in long-distance migrations. Habitats' fragmentation is probably the most important factor determining the stability of the lynx population. This is evidenced by the comparison of the species situation in areas with different levels of forestation. Based on the collected data, we observed that Eurasian lynx occur mostly in the Podkarpackie Voivodeship, which is a part of Carpathian Mountains, and in the primeval forests of north-eastern part of Poland. In the west part is still scarce. Our study presents estimation of the number of Eurasian lynx in Poland from 2004 to 2018 and the prediction of the trend in the population development in the next 10 years, using Holt's model as statistical analysis which is the most useful for wildlife populations. The data were collected from Central Statistical Office of Poland and supplementary data from the Polish Hunting Association in Poland. This study may be helpful for the better understanding of the species and also to protect it, because since 1995 the Eurasian lynx is an endangered species in Poland. Many institutions have been implementing conservation plans for this species, mainly attempts to reintroduce the species are used into the most suitable areas of Poland.

Introduction

Eurasian lynx belongs to carnivores (*Carnivora*) and is one of three representative from *Felidae* family in Poland (two other species are: domestic cat (*Felis catus*) and wildcat (*Felis silvestris*)) and also the largest among the *Lynx* genus (Garbarczyk et al. 2010). The presence of the lynx in its environment, places it at the top of the food chain. It has very strong, wide paws (Sumiński 1973; Okarma et al. 2004). The trail of tropes is called lacing (Jędrzejewski et al. 2011). The most developed of all five senses are hearing and sight. Distinctive ears are finished with 4 cm tufts (Sumiński 1973; Okarma et al. 2004). Lynx's coat and the number of spots on it, varies in relation to the place where they live and also depends on the season. Coat color ranges from yellowish-gray to brownish-red., It is an individual feature. In some situations, mottling may disappear and the coat becomes uniform. The underbelly, throat and groins are always creamy white (Sumiński 1973; Jędrzejewski et al. 2010). The length of an adult's body is 100-150 cm, and the tail itself is 15-30 cm. The height at the withers the lynx reaches up to 75 cm. The average weight is 20 kg, but there are also specimens weighing from 12 to 35 kg (Szokalski 2014). Males are about 25% heavier than females (Keller 2001).

The Eurasian lynx eats a wide range of prey but tends to focus on roe deer whenever they are available. In their absence other ungulates, including red deer, are typically favoured, and various other small mammals are also often in the diet. Lynx will occasionally hunt gamebirds and, quite rarely, sheep (Sumiński 1973; von Arx et al. 2004). It is strictly carnivorous and will eat 1-2 kg of meat per day (Szokalski 2014).

According to global qualifications, Eurasian lynx belongs to the group of animals that is considered to least concern animals [LC] (IUNC Red List 2019). However, in the scope of Poland, it is rigorously protected, including active protection since 1995. Eurasian lynx is a nocturnal, solitary animal, secretive,

less mobile than a wolf, and keeping its territories away from human habitats. Its territories are also more overlapping. Therefore, estimating the number of individuals in the field is extremely difficult, labour-intensive and burdened with low detection. Nevertheless, monitoring of this and other predators should not be discontinued, as they have become a measure of the biodiversity and naturalness of forest ecosystems, and thus are included in the list of indicator species. This is due to the European Commission, obligated on Member States to take inventory (Simeonova et al. 2017). On their basis, the European networks of protected NATURA 2000 sites, can be designated. All Polish national parks and forest inspectorates are obligated to carry out the fieldwork to document the presence of lynx in Polish forests. Data analysis remains on the Mammal Research Institute of the Polish Academy of Sciences and the Institute of Nature Conservation of the Polish Academy of Sciences. The tracking of predator migration is aimed at checking the continuation of ecological corridors which connect Polish-European forest complexes (Jędrzejewski et al. 2011).

Lynx in Poland are divided into two main populations: the lowland and the Carpathian. Those, which are living in the north-eastern part of Poland characterized by a slightly lighter coat and less intensive mottling. Clear spots are an element of lynx's coat from south-eastern Poland (Okarma 2000). Lynx are active for about 6-7 hours per day. They hunt almost exclusively at night (The Association for Nature WOLF 2008). The territories of males (up to 350 km²) are much larger from the females' territories (up to 150 km²). The lynx can move a distance of 5-10 km, daily (Sumiński 1973; Jędrzejewski et al. 2002). Males do this further and more repeatedly than females (Samelius et al. 2011).

The increasing urbanization of western Europe results in habitat loss and diminished prey base, led to a significant reduction in the occurrence of Eurasian lynx population size there. Escalating deforestation and poaching remain major threats to their future (Jędrzejewski et al. 1999).

The aim of the study was to estimate the number of Eurasian lynx in Poland from 2004 to 2018 (the data was used from Central Statistical Office of Poland) and to predict the trend in the population development through 2027 (using the Holt's model).

Material and methods

Study area and data collection

At this work we analysed the materials which were collected in 2018 and 2019 from the following sources:

- Central Statistical Office of Poland (CSOP). Public statistical information – environmental protection area in the years 2004-2018 (estimated data of the Polish Ministry of Environment and General Directorate for Environmental Protection; Table 1).
- Report on game animals in Poland, Environmental Protection Inspectorate in the years 1975-1991 and the Research Station of Polish Hunting Association (PHA) in Czempin for the period 1985-1997 (Table 2).

Population estimates of the Eurasian lynx in Poland indicate that this species has undergone major fluctuations in numbers over the last 44 years. Collected data from Central Statistical Office of Poland (CSOP), which are public statistical information, have been found in environmental protection thematic area for years 2004-2018, detailing the number of lynx in each voivodeships, together with their quantity in national parks in Poland (Table 1). CSOP provides also the information on the national lynx's quantity (without division into voivodeships) in years 2000-2003.

Statistical analysis

The Holt method (Holt 2004) was used to predict the Eurasian lynx population size. This method is preferred for time series with random fluctuations and employs exponential smoothing methods:

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where: y_t is the Eurasian lynx population size for the t th period, \hat{y}_t is the Eurasian lynx population size for the t th period adjusted for trend, α is the smoothing constant between 0 and 1, c_t is the trend adjustment increment for the t th period and:

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where β is the smoothing constant between 0 and 1.

The forecast of Eurasian lynx population size for the T th period is therefore given by:

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where: y_n is the latest Eurasian lynx population size adjusted for trend, h is the time ahead forecast and c_n is the latest trend adjustment increment. The smoothing constants α and β were determined with Solver in MS Excel while minimizing the sum of squared errors of prediction.

Tables and figures

Based on the collected data, the estimated number of Eurasian lynx and its distribution in Poland (in 16 voivodeships and 23 national parks), are shown in Table 1. The number of Eurasian lynx in Poland in the years 1975-1991 and 1982-1997 we have illustrated in Table 2.

The number of Eurasian lynx in Poland in the years 2004-2018 and, additionally, the Holt method predictions through 2027, we have shown in Fig. 1. Figs 2-9 illustrate the number of Eurasian lynx in each voivodeships in the years 2004-2018, with the Holt method predicting population through 2027.

Results

Every year since 2000, the Central Statistical Office of Poland issues a summary of all wild animals living in the country. From environmental protection thematic area obtained accurate data. In 2000, was recorded 285 lynx, in 2001 – 150, in 2002 – 171 and a year later – 192 lynx. Since 2004, we can notice systematic increase of lynx's number in Poland. However, lynx are absent from 6 of 16 Polish voivodeships (Lubuskie, Łódzkie, Opolskie, Świętokrzyskie, Wielkopolskie and Zachodniopomorskie voivodeships). Furthermore, decreasing trend has been observed in Kujawsko-pomorskie and Mazowieckie voivodeships. The highest number of lynx is noticed in Podkarpackie Voivodeship. The last collected data indicates that in 2017 were 432 lynx in Poland but without divisions into voivodships and in 2018 – 437 lynx (Table 1).

The numerical status of the lynx expressed in numerical ranges has been averaged. Due to migrations and secretive lifestyle of wild animals, the data should be treated as an estimate of the population size of the species.

The data from CSOP were the determinant for the Holt's prediction (exponential smoothing model). It was used to estimate the number of lynx in Poland and, likewise, in individual voivodeships. Nationwide, the results indicate that the lynx's quantity will rise to 538 individuals by 2027 (Fig. 1). The increase of lynx's number will be noticeable in Lubelskie, Małopolskie, Podkarpackie, Pomorskie and Śląskie voivodeships (Figs. 3, 4, 5, 7, 8), according to the Holt model, while a decrease will be seen in Podlaskie and Warmińsko-mazurskie voivodeships (Figs. 6 and 9). A constant number of lynx will be observed in Dolnośląskie Voivodeship (Fig. 2), for the next 10 years.

It should be noted that this model does not taking into account random factors, which may affect actual population estimates, such as diseases, natural disasters, lack of food, destruction of habitats and environment.

Discussion

The Eurasian lynx was qualified to the NT category (near threatened) 24 years ago by the International Union for Conservation of Nature, as part of the Red Book of Endangered Species and its Polish equivalent (IUNC Red List 2019; Głowaciński 2011).

In Europe, the lynx is protected by the following three directives: the Washington Convention on International Trade in Endangered Species of the Wild Fauna and Flora (CITES), which monitors the trade in wild animals and plants; the Convention on the Conservation of European Wildlife and Natural Habitats; the FFH Directive (Flora-Fauna-Habitat Directive 92/43/EEC), which regulates the designation and conservation of habitats and wildlife and must be implemented by all EU Member States in national law.

In Poland, according to the Regulation of the Minister of the Environment of 28 September 2004 on species of wild protected animals, the Eurasian lynx (*Lynx lynx*) is on the list of *species of wild animals under strict protection, specifying species requiring active protection* (Law journal 2004 No. 220, item 2237). According to the above legal act and the Act of 16 April 2004 on nature protection (Law journal 2004 No. 92, item 880, with changes), it is forbidden to kill, maim, or capture lynx. Destruction of their habitats, as well as the storage and selling of hides without proper permission is also prohibited.

Monitoring of individual populations, has been carried out by the Mammal Research Institute PAS, cooperating with the Association for Nature WOLF and with the Institute of Nature Conservation of the PAS, since 2000. These three institutions acquire information on the predator's abundance, mainly from inventory programs conducted in forest inspectorates and national parks. The first research project was undertaken in 2001 and was called *Optimization of the use of Natura 2000 resources for sustainable development in the Carpathians*. A strategy for the protection of lynx in that area was developed, at that time. The Carpathian population was around 100 individuals and was constantly monitored, at that time. The program was aimed at protecting the habitats, migration routes, as well as introducing a diverse forest structure. The acquisition of roe deer and deer was also taken into account in predatory plans for lynx population (Jedrzejewski et al. 2011).

Numbers of lowland lynx have been studied for 10 years by WWF as part of the project, co-financed by the European Union from the European Regional Development Fund within the Operational Program Infrastructure and Environment. During these years the lynx was reintroduced in the Masurian Lake District (a total of 20 individuals). WWF uses two methods of reintroduction: *born to be free* and *wild to wild*, adapting the telemetry and genetic researches (Krzywiński et al. 2012; Jakimiuk et al. 2015).

Studies carried out in 2006 by a group of scientists, analysing if it would be possible to restore lynx to western Poland, showed that the increasing fragmentation of forests and transportation infrastructure is still a great threat to the lynx population due to strongly deforested and densely populated rendering passage across the central part of Poland impossible for them. There is also no connection between the individual parts of forests. Lynx prefer places far from human habitation and roads. The research also showed that the two necessary living conditions of lynx are: close distance to the existing population and more than 40% of forest undergrowth (Niedziałkowska et al. 2006).

Eurasian lynx was widespread in Poland during the Middle Ages. An intense process of reducing the occurrence range took place during the last 300 years, so that by the 20th century the territory in which the lynx could be found had narrowed to the Carpathians and north-eastern part of Poland. The first inventory of this species was carried out in 1928 and found the presence of about 300 individuals. The lynx was counted among game animals then, with limited hunting only in January and February (Okarma 2000). In the interwar period, only in the Białowieża Primeval Forest, lynx's population was estimated at about 100 animals (Sumiński 1973). In 1955, the lynx hunting period was extended to five months (from November to March). Hunting was banned, along with the recognition of the species as protected, in 1995 (Okarma 2000). At that time, the quantity of different animals was acquired only by two methods: tracking them on the snow and year-round observations. Both methods are not reliable or accurate, because they are burdened with a high error. As indicated by Okarma (2000), during the hunting season of 1972/1973, 212 animals

were counted, and a year later, as many as 415. Further data show, that the population of lynx oscillated during the 70s and 80s of the 20th century, between 200 and 600 individuals (Okarma 2000). The data from the first part of Table 2 comes from the report on game animals in Poland and show the state of the spring population (the lynx was a hunting animal in those days). The research was carried out at the request of the Environmental Protection Inspectorate. They were made by the Research Station of the Polish Hunting Association. A decrease in the number of lynx has been observed by 70 individuals, between 1975 and 1991, and the peak number of lynx was in 1980 and 1982, amounting to 640 individuals. A smaller number of lynx was noticed in the second part of Table 2, due to the fact that the data applies only to districts leased by hunting clubs. They constitute about 93% of the existing districts in Poland, and the remaining 7% comprise forest complexes mainly of eastern Poland (also primeval forests), in which Eurasian lynx also appears. However, a huge downward trend in the monitored areas can be noticed. The number of lynx has decreased by 251 individuals over 15 years. The discrepancies that can be seen between Table 2 and 3 reflect the diversity of available sources from which numerical data were obtained. In 1993, the number of lynx fell below 200. Two years later they were under protection.

At the beginning of the 1990s, occurrence of 3-5 specimens of this predator per 100 km² was found in the Białowieża Forest. Only telemetry studies have enabled a more accurate check of lynx numbers. Thanks to them, the sex and age structure of the population, density and demographic parameters, were known (Okarma 2000).

The most popular science sources indicate the number of lynx living in Poland to be about 200-220 individuals, dividing it into several populations (The Association for Nature WOLF 2006; Zalewski 2011):

- Carpathians Mountains and The Carpathian Foothills: 100-120 lynx;
- Białowieża and Knyszyn Primeval Forests: 40 lynx;
- Augustów Primeval Forest and Biebrza Valley: 15-20 lynx;
- Borki's, Romincka and Pisz Forests: 5 lynx;
- Polesia, Roztocze and Solska Forest: 10 lynx;
- Kampinos Forest: 10-15 lynx.

Lynx are present only in around 12% of Polish forests (Szmidt et al. 2007).

Conclusions

Monitoring and inventory of endangered animals allows better protection, as well as the opportunity to learn about their biology and ecology. It provides the development of a species in nature and estimates the population size in the specific parts of country. In order for the species to expand its areas and not reduce population size, it is necessary to introduce the following elements on a large scale: (1) reconstruction and protection of as many ecological corridors as possible, which means free migration with connection of various populations and exchange of genetic material of the species; (2) diversifying the forest's structure; (3) combating poaching; (4) increasing food base.

Limitations to our studies

It should be noted that the calculation made in our study might suffer from some flaws. For example, high activity of wolves in extensive areas may result in an individual being counted more than once depending on the counting method used. Moreover, accurate counts of the number of Eurasian lynx in their preferred uninhabited forested habitats may also increase the chance of miscounts.

Conflicts of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Authors' contributions

KW and PC conducted the fieldwork and collected the data with additional material from collaborators; KW, PC and AM analysed the data; KW led the writing with assistance from PC and AM. All authors read and approved the final manuscript.

Data availability statement

The Eurasian lynx is an endangered species in Poland. Interactions with human activities are problematic and lead to poaching and anthropogenic pressures. Providing accurate information on lynx locations can be detrimental to the conservation status of the species. As a consequence, the original data could not be shared.

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Tables and Figures

Table 1. Estimated number of Eurasian lynx (*L. lynx*) in Polish voivodeships in the years 2004-2018 (Central Statistical Office of Poland)

Table 2. The number of Eurasian lynx in Poland in the years 1982-1997 (PHA Research Station in Czempin) and in the years 1975-1991 (Pielowski et al., 1993)

Fig. 1. The number of Eurasian lynx (*L. lynx*) in Poland in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 2. The number of Eurasian lynx (*L. lynx*) in Dolnośląskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 3. The number of Eurasian lynx (*L. lynx*) in Lubelskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 4. The number of Eurasian lynx (*L. lynx*) in Małopolskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 5. The number of Eurasian lynx (*L. lynx*) in Podkarpackie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 6. The number of Eurasian lynx (*L. lynx*) in Podlaskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 7. The number of Eurasian lynx (*L. lynx*) in Pomorskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 8. The number of Eurasian lynx (*L. lynx*) in Śląskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

Fig. 9. The number of Eurasian lynx (*L. lynx*) in Warmińsko-mazurskie Voivodeship in the years 2004-2018 (Central Statistical Office of Poland) with the Holt method processing to 2027

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