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Long-term dynamics, distribution, and protection of the Eurasian beaver *Castor fiber* in Poland

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Highlights

- Number of beavers increased by an average of 10.99% per year between 1960 and 2023.
- The largest beavers growth rate occurred in 1976–2002 (15.6% per year).
- The beavers growth rate in Poland was the lowest in 2017–2023 (3.8% per year).
- The greatest growth in the beaver population coincided with its active protection.
- The highest population growth was observed in the east and north-west of Poland.

Abstract: The Eurasian beaver (*Castor fiber* L.) has achieved remarkable success in rebuilding its population in Europe, increasing its numbers and range from 1955 to the present. Data on the *C. fiber* abundance in Poland have been collected by the Central Statistical Office since 1960, and since 2000 they have also been available divided into voivodships. We subjected these data to statistical analysis, including chi-square tests, broken-line regression, and correspondence analysis. Biplots, charts of population dynamics, and distribution maps were created. It was also examined whether there is a relation between the density of the *C. fiber* population in Poland and the presence of standing or flowing waters, forest and shrub land, ponds, ditches and the proportion of meadows and pastures in each voivodship. The *C. fiber* population in Poland grew between 1960 and 2023. The geometric mean of the annual data showed an average increase of 10.99% per year. Furthermore, four distinct time intervals were identified within the *C. fiber* population dynamics, each exhibiting a distinct statistical trend: the initial interval, spanning from 1960 to 1975, demonstrated an average increase of approximately 6.9% per year, 15.6% per year in the period 1976–2002, 9.3% in 2003–2016 and 3.8% after. The largest increase occurred in the eastern and north-western Poland, while the smallest number of beavers is found in the central part of the country (in the north-south direction). The *C. fiber* population was negatively affected by standing surface waters and drainage ditches, while flowing surface waters increased its number.

Keywords: beaver expansion in Europe, broken-line regression, Eurasian beaver population recovery, legal protection of *Castor fiber*, population dynamics analysis, wetlands protection

INTRODUCTION

Castor fiber L. belongs to the class of mammals (*Mammalia*), the order of rodents (*Rodentia*) and the family *Castoridae*. It is the largest rodent species found in the territory of European countries (Czech, 2010). The *C. fiber* is a semi-aquatic species which settles on overgrown water banks, often situated in proximity to woodlands. It may also occur in agricultural and urban areas (Halley and Rossel, 2002). Thanks to its incisors, it is distinguished by its ability to cut trees with a diameter of up to 70 cm. The diet of the beaver is based on young, green plant matter, including leaves, shoots and twigs, as well as the bark of deciduous trees, such as aspen and willow as well as ash, oak and birch. In agricultural areas, beavers visit beet, potato and cabbage fields at night, and also plunder vegetable gardens and orchards (Dzięciołowski, 2004). Due to its dam-building behaviour, *C. fiber* is regarded as a keystone species, which provides multiple ecosystem services in wetlands (Ledger *et al.*, 2022).

The original range of *C. fiber* was extensive throughout Eurasia. Nevertheless, as a consequence of excessive hunting and the loss of its natural habitat, the species was already on the brink of extinction by the beginning of the 20th century. The total population was then estimated at only 1,200 individuals (Nolet and Rosell, 1998). After World War II, it appeared sporadically in Europe (Zalewski *et al.*, 2012). In Poland in 1950, only a single *C. fiber* habitat was discovered, situated on the Marycha River, a tributary of the Czarna Hańcza River (Bereszyński and Homan, 2007). Since 1952, *C. fiber* has been legally protected in Poland (Rozporządzenie, 1952). The population of *C. fiber* commenced a recovery through the process of free migration from its reserves situated within the former Union of Soviet Socialist Republics. The distribution of *C. fiber* subsequently expanded from its initial point of occurrence in north-eastern Poland to encompass other regions of the country. In 1975, it was estimated to be between 500 and 800 individuals (Janiszewski and Hanzel, 2021), which, as emphasised by Janiszewski and Hanzel (2021), was inadequate to ensure the species' continued survival. The natural increase in the population growth was accelerated by the reintroduction of *C. fiber*, which was initiated in 1975 as a result of the implementation in Poland of the "Program for the active conservation of the European beaver in Poland" (Żurowski, 1979). Beaver populations were permitted to construct their lodges near water reservoirs (Fajer *et al.*, 2017). This led to an increase in the number and range of *C. fiber*. Since 2001 (Rozporządzenie, 2001) up until the present, the *C. fiber* has been subjected to partial species protection (Ustawa, 2004; Rozporządzenie, 2016). Consequently, the destruction of beaver lodges, dams and the killing of these animals are prohibited. Currently, the species is found throughout the country, with the exception of the mountain belt, although its most numerous refuge is still in the north-eastern part of Poland (Wróbel and Krysztofiak-Kaniewska, 2020).

The approximate number of *C. fiber* in Europe is presently estimated to be 1.27 mln, with an increasing trend (Ledger *et al.*, 2022). For this reason, the current status of the *C. fiber* on the IUCN Red List (Batbold *et al.*, 2021) is classified as "least concern" (LC). International regulations applicable to the *C. fiber* are set forth in agreements and legal acts ratified by Poland. These include the EU Habitats Directive (Annex V for the among others Polish populations, Annex II for all other and the Polish populations and IV for all other populations, the Bern Convention (Appendix III) (Ledger *et al.*, 2022).

The aim of the study was to describe in detail the dynamics of the *C. fiber* population in Poland in the years 1960–2023 and the distribution of its population in Poland in the years 2000–2023. The achievable population growth rate and the distribution of the population between the voivodships were both assessed. In addition, an attempt was made to investigate whether there is a relation between the density of the *C. fiber* population in Poland and certain features of landscape, including the presence of standing and flowing waters, forest and shrub land, ponds, drainage ditches, and the proportion of meadows and pastures in each voivodship. These analyses were conducted using data from the Polish Central Statistical Office (CSO, Pol.: Główny Urząd Statystyczny) (https://bdl.stat.gov.pl/bdl/start).

MATERIALS AND METHODS

MATERIALS

The research was based on statistical data from the Polish CSO (database available at https://bdl.stat.gov.pl/bdl/start, and ALEPH catalog https://statlibr.stat.gov.pl/F for the years 1960–2002). The data set comprised information on the population size of the *C. fiber* in Poland between the years 1960 and 2023. Furthermore, data for the years 2000–2023 were available at the level of voivodship (the highest-level administrative division of Poland, which is analogous to the term "province"), allowing for a more detailed analysis.

STATISTICAL ANALYSIS

Compound annual growth rate

In order to obtain the relative changes in population size, the year-to-year ratio of population size was calculated. There are two ways in which the mean one-year ratio can be calculated. The first is as the geometric mean of the annual ratios. The second is in the event of missing values, by the Equation (1):

$$R = \sqrt[Y_R]{\frac{b}{a}} \tag{1}$$

where: R = mean one-year ratio, Y_R = the years range, that is the last year number – first year number, a = the population size in the first year, b = the population size in the last year.

If all values are available, both methods give the same result. The second method was employed due to the absence of data in 1961, 1962 and the period spanning 1981 to 1984. Upon reduction by 100%, this value represents the compound annual growth rate (*CAGR*) (Farris *et al.*, 2006; Grimm, 2023).

Regression analysis

An exponential model for population changes was assumed ($Y = b{\cdot}a^X$), where X represents the independent variable, which is the year, and Y represents the dependent variable, the population size. This model can be estimated by linear regression after logarithmic transformation of the population size. In order to account for potential changes in the trend, broken-line regression (Wagner *et al.*, 2002; Muggeo, 2016; Nirwana and Wulandari, 2021) was used instead of simple linear regression. This approach assumes that the trend remains constant within the specified time intervals. The number of intervals in the broken-line regression and the determination of whether it was necessary to use broken-line regression were based on the leave-one-out cross-validation method (LOO-CV) (Allen, 1974; Stone, 1974) based on the root mean squared prediction difference statistic (*RMSPD*) (Gauch and Zobel, 1990; Dias and Krzanowski, 2003) also known as the root mean squared prediction error (*RMSPE*) (Rooij de and Weeda, 2020). This technique enables the selection of the model with the best predictive ability among those with differing numbers of intervals of constant trend.

A linear regression analysis was conducted to describe the influence of selected voivodship features on the population density of the *C. fiber*. The considered features were the proportion of a) standing waters, b) flowing waters, c) forest and shrub land, d) ponds, e) ditches on agricultural land, and f) the share of meadows and pastures in the area of voivodships. The Akaike information criterion was employed to identify the important variables. The selected model prediction was used to assess which voivodships may experience population growth.

Chi-square test

The chi-square test was employed to ascertain whether the populations of the voivodships exhibited proportional growth or decline, or whether there were regions where population growth trends differed. The null hypothesis is that the changes are proportional in voivodships. This test requires independence of observations, and because population sizes in two consecutive years are correlated, we chose time intervals of approximately 10 years. The chi-square test was conducted based on the population distribution in the voivodships in the 2000s (the first year for which the distribution of population was available), 2010, and 2023 (the last year for this analysis).

Correspondence analysis

A correspondence analysis (CA) is a method that allows for the generalisation and description of the population distribution over a given time interval. If the population has grown at different rates in different areas or has grown at a faster rate in specific years, this can be described based on the CA biplot. The analysis was based on the population sizes in the years 2000–2023.

A polynomial regression of degree two was used to ascertain the trajectory on the CA plot of the *C. fiber* population allocation. The independent variable was the year, while the dependent variables were the coordinates derived from the correspondence analysis. The curve of predictions was plotted on the CA biplot.

Calculations

The broken-line regression was calculated using the "lm" function in the R programming environment (R Core Team, 2023) and the "segmented" function from the "segmented" package (Muggeo, 2003; Muggeo, 2008; Muggeo 2016) available for the R software. The chi-squared test was conducted using the "chisq.test" function. The correspondence analysis was performed with the "cca" function from the "vegan" package (Oksanen *et al.*, 2022). Finally, the linear regression and its prediction were carried out with the "lm" and "predict" functions.

RESULTS

POLAND IN TOTAL

The *CAGR* for the entire period (1960–2023) for the *C. fiber* population in Poland, was 10.99% ($CAGR_{1960–2023}$). However, the population growth rate was not constant (Fig. 1). Based on the results of the predictive ability of the broken-line regression model, measured using cross-validation, three periods were distinguished in which this trend was constant. The *RMSPD* index values for simple regression (without division into periods, i.e. one period with a common trend) and for broken-line regression with division into 2–5 periods with a constant trend were as follows: 0.0127, 0.0084, 0.0027, 0.0021, and 0.0028. The smallest error value, and therefore the best prediction, was achieved by the model for four intervals with a constant trend. The trend change occurred between 1977 and 1978, between 2002 and 2003 and between 2016 and 2017. This model achieved a determination coefficient R^2 of 99.84%.

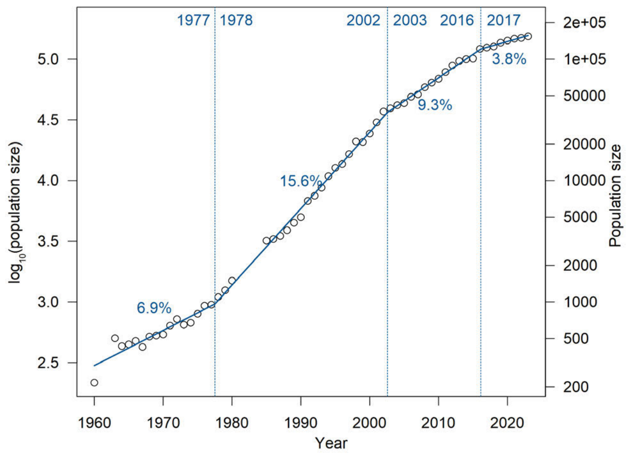

Fig. 1. Broken-line regression analysis describing *Castor fiber* population size (after logarithmic transformation) in the years; the percentage values near the regression line represent compound annual growth rate (*CAGR*) for the time interval; the borders of time intervals was placed under the upper axis; source: own study

In the initial period, the $CAGR_{1960–1977}$ was 6.9%, which represented the lowest result, although it did reflect an increase in the population (Fig. 1). The situation of this species was unfavourable due to the very low initial population, which numbered only 217 recorded individuals in 1960. This almost 7% increase resulted in 950 individuals being recorded in 1977. Since 1978, the population has exhibited the most rapid growth, with $CAGR_{1978–2002}$ of 15.6% per year. The population increased from 1,100 individuals in 1978 to 37,103 individuals in 2002. The growth rate was equal to 9.3% ($CAGR_{2003–2016}$) per year over the period 2003–2016 with a total of 121,624 individuals at the end of this period. Thereafter, the growth rate decreased to 3.8% ($CAGR_{2017–2023}$), resulting in a total of 154,431 individuals in the year 2023.

VOIVODSHIPS

The question was asked whether the population growth was uniform across all voivodships over the period 2000 to 2023, or whether it occurred at a faster rate in some regions. In order to examine the aforementioned problem statistically, the appropriate technique is a chi-squared test of homogeneity of distributions (between years for the *C. fiber* population in the voivodships), which is also known as a chi-squared test of independence. The value of the *P* statistic was calculated for the population size in the voivodships in 2000, 2010 and 2023, which was very close to zero ($<2.2\cdot10^{-16}$). This result led to the rejection of the null hypothesis of the homogeneity of growth in the voivodships.

The year 2000 was one of the final years of the period of rapid growth of the *C. fiber* population (Fig. 1). During that year, the *C. fiber* was observed across the country, with a concentration in the north-eastern region of Poland (Fig. 2a). In 2010, the impact of expansion towards the south (towards the PK

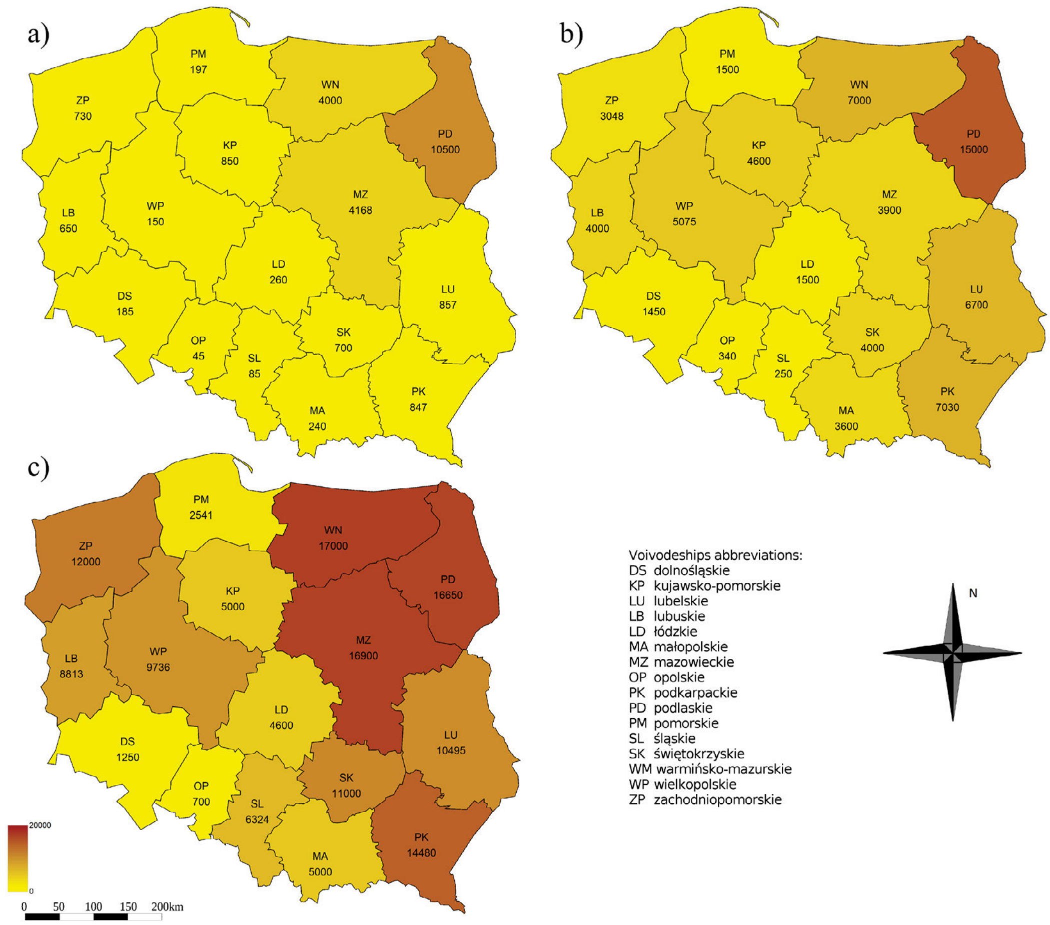

Fig. 2. Population size of the *Castor fiber* in the voivodships in the years: a) 2000; b) 2010; and c) 2023; source: own study

voivodship) and the second direction, west with a slight deviation to the south (towards the LB voivodship) became evident (Fig. 2b). Until 2023, the population exhibited an increase in the SK voivodship and neighbouring voivodships (i.e. SL, MZ, LU and PK). Additionally, a sudden increase was observed in the ZP voivodship (Fig. 2c).

The CA analysis (Fig. 3) was based on the *C. fiber* population in the Polish voivodships between the years 2000 and 2023. The first component explained 50.5% of the variability, and the second 29.1%. The unrepresented variability of the *C. fiber* population was therefore less than 21%. This means that the biplot graph fairly faithfully represented the *C. fiber* population allocation. In addition, to facilitate the trend description, a polynomial regression of degree 2 was used to synthetically describe: a) the first ($CA1_{\text{year}}$), and b) the second component ($CA2_{\text{year}}$) for years. The parameters $CA1_{\text{year}}$ and $CA2_{\text{year}}$ estimated in this way were illustrated by a curve starting from the year 2000 estimator (bottom right corner of the graph) and ending (arrowhead on the CA graph) with the year 2023 estimator.

The MZ and WM voivodships (strongly correlated in terms of dynamics, which is consistent with the mutual proximity of these voivodships) maintained a relatively higher *C. fiber* population fraction in the initial years for the CA analysis (from 2000 to 2004) than in the later years. Similarly, the neighbouring PD voivodship, for which a higher population fraction was observed until 2011.

The group of voivodships DS, WP and KP began to increase its share in maintaining the population from 2006 to 2015

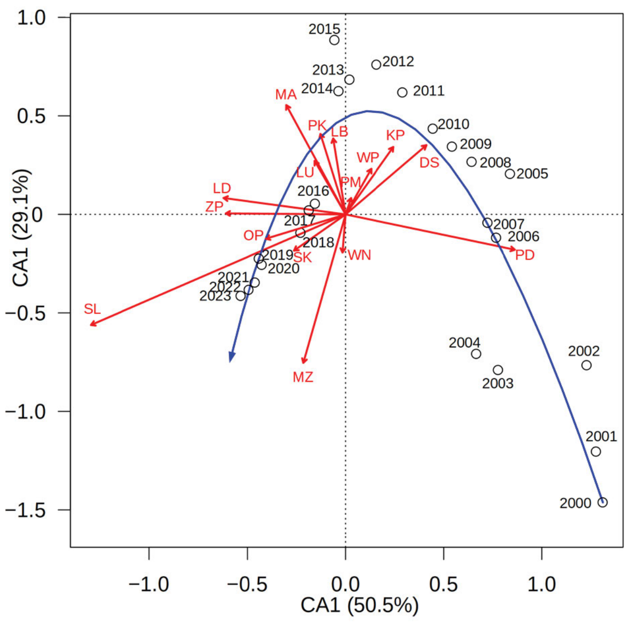

Fig. 3. Biplot for correspondence analysis (CA) describing the population of the *Castor fiber* in the voivodships in Poland in the years 2000–2023; red arrow = voivodships, blue arrow = result of estimating the *CA*1 and *CA*2 coordinates for the years using a polynomial regression of degree 2, starting with the assessment of the coordinates of the year 2000 and ending (arrowhead) with the assessment of the coordinates of the year 2023, voivodships' abbreviations as in Fig. 1; circles = years; source: own study

inclusive (these voivodships form a strip separating ZP and LB from the eastern and southern parts of the country). Since 2011, this role has been taken over by the group of voivodships MA, PK, LU (southeast) and LB (west). Although this group is located in two different places, the dynamics of the *C. fiber* population is very similar for these voivodships. Similarly to the previous group, the last year with a substantially larger relative share was 2015.

In the group of voivodships SL, LD, OP, SK (neighbouring voivodships) and ZP a higher relative share of the population was recorded starting from 2016. Similarly, in the already described group of voivodships MZ and WM higher relative share was recorded starting from 2018. The direction of relative allocation of the *C. fiber* population was related to the increasing importance of the voivodships SL, MZ, LD and ZP.

EXPLANATION OF POPULATION DENSITY

Based on the population size in the year 2023 and vovodships areas the density of *C. fiber* was calculated. In 2023, the mean density of the beaver population in Poland was 0.49 beavers per square kilometre. An attempt was made to explain the population density by voivodships parameters by the linear regression analysis. According Akaike information criterion the share of: flowing waters, standing waters, and drainage ditches on agricultural land influenced the population density of *C. fiber* (Tab. 1). One percent of ditches in the voivodship decreased population by 1.67 individual per one km^2 whereas the one percent of standing waters decreased population by 0.8 individual per one km^2. In the other hand each percent of flowing waters area in the voivodship increased population by 0.5 individual per one km^2. The proportion of forest and shrub areas, ponds on agricultural land, and meadows and pastures on agricultural land were not found to be a justified indicator of *C. fiber* population density.

Based on the regression prediction there were five voivodships with the gap of population size in the year 2023: MA (lack of 6,036 individuals to the predicted value), DS (5,600 individuals), OP (3,097 individuals), LD (2,751 individuals) and PK (1,038 individuals).

DISCUSSION

The analysis of the population size of *C. fiber* is of significant interest, as this species has experienced remarkable success in the expansion of its European population over the period between 1955 and 2021 (Ledger *et al.*, 2022). During this time, the population has grown in both size and range. Currently, the population of *C. fiber* in Poland is undergoing a period of sustained growth, with a recorded population of 154,431 individuals in 2023. This species occurs throughout Poland, but is particularly numerous in the north-eastern region, especially in the PD voivodship (the original refuge area) and neighbouring voivodships (Fig. 2c).

A significant juncture in the expansion of the *C. fiber* population in Poland was 1974, when a resolution was reached to reintroduce this species through the implementation of the "Program for the active conservation of the European beaver in Poland", this program commenced in 1975 (Żurowski, 1979; Żurowski and Kasperczyk, 1988). As outlined by Janiszewski and Hanzal (2021), the reintroduction activities involved the capture of these rodents from the breeding farm at the PAN Research Station in Popielno and from the Suwałki Region. Following this, the animals were introduced to new areas. These activities marked the commencement of the successful process of *C. fiber* migration to other regions of the country, including western Poland, as well as the settlement of watercourses in urban areas. The results of the broken-line regression analysis (Fig. 1) indicated that 1978 marked the beginning of a period of more intensive development. A similar *CAGR* for the period 1960–1977 and 2003–2016, coupled with higher values for the years 1978–2002, may be indicative of an intensified population expansion of the *C. fiber* in new areas during the mid-period. This can be attributed to the reintroduction of species and the resulting expansion of local populations. "The program for the active conservation of the European beaver in Poland" lasted for 25 years and ended in 2000. The broken-line regression analysis indicated a significant change in the average annual population rate of the *C. fiber* population, with an increase from 7–9% per year to 15.6% per year between the years 1976 and 2002. This coincided with the implementation of the "Program for the active conservation of the European beaver in Poland". This is

Table 1. The influence of percentage area covered by different types of land use on the *Castor fiber* population (in units per km^2) using weighted (by voivodships area) linear regression and the variables reduction based on the Akaike criterion

Variability source[a)]	Percentage share[b)]	Complete model (*AIC* = 265.13)		AIC optimal model (*AIC* = 260.87, R^2 = 54.8%)		
		estimate[c)]	*P*	estimate[c)]	*SE*	*P*
Intercept	–	1.158	0.154	1.25***	0.26	<0.001
Forest and shrub land	31.58 (7.02)	0.004	0.744	–	–	–
Flowing surface waters	2.80 (2.33)	0.028	0.494	0.05·	0.03	0.060
Standing surface waters	2.77 (1.86)	−0.065	0.226	−0.08*	0.03	0.031
Ponds on agricultural land	0.28 (0.19)	−0.385	0.368	–	–	–
Ditches on agricultural land	0.41 (0.10)	−1.597	0.053	−1.67*	0.57	0.013
Meadows and pastures on agricultural land	11.98 (2.98)	0.008	0.796	–	–	–

a) The independent variables were the percentage share of different land use across all 16 voivodships.
b) The weighted mean of percentage share and, in parenthesis, the weighted standard deviation.
c) *Castor fiber* population density was expressed in individuals per km^2.
Explanations: R^2 = determination coefficient, significance codes: *** at 0.001, ** at 0.01, * at 0.05, · 0.1.

consistent with the opinion of Janiszewski and Hanzal (2021), who emphasise the importance of the implemented protective measures in preventing the extinction of the *C. fiber* and in facilitating the colonisation of new regions in Poland by beavers. Three years after the conclusion of the program, the *C. fiber* population has exhibited a return to stable growth at a rate comparable to that observed prior to its commencement (Fig. 1) until 2016. The CA analysis revealed general trends in the voivodships. The SL and MZ voivodships exhibited a pronounced acceleration in growth in recent years, while the PD voivodship demonstrated a relatively high initial population size and a rather a tendency to export individuals to neighbouring regions. Conversely, the WN and PM voivodships displayed growth rates that were consistent with the overall trend.

The current situation of the *C. fiber* population is generally regarded as favourable. As Wróbel (2020) notes, the probability of a notable decline is low due to the absence of natural enemies, the capacity to adapt to environmental conditions, and a consistent food source. These findings align with the results of the statistical analyses. The broken-line regression did not indicate a disruption in the increasing trend until the 2023 year. However, between 2017 and 2023, the average annual population growth rate of the European beaver in Poland decreased to 3.8%, representing a reduction of approximately 2.5 times, which was the lowest value observed since 1960. This suggests that continued efforts to protect beavers in Poland are still vital.

Earlier, a certain reduction in the number of beaver population was noted by Rakowska and Stachurska-Swakoń (2021). They found that the data from the CSO published in 2014 were inconsistent with the inventory report conducted in the same year. Specifically, the data from the CSO did not include a decrease in the number of beavers between 2013 and 2014. The authors of the article hypothesised that this may be related to the reduction culling of beavers, which was not included in the CSO publication. However, the cross-validation analysis did not demonstrate a change in the observed trend during this period. This could be attributed to either a minor impact (in comparison to the random error of observations) of culling or to the absence of a long-term impact (rapid recovery of the population size).

As indicated by Wróbel (2020), the population of *C. fiber* in European countries is characterised by continuous growth, amounting to approximately 17% in the period of 6–8 years in the second decade of the 21st century. This equates to an annual growth rate of 2–3%. Consequently, the 3.8% population growth observed in Poland since 2017 closely aligns with the aforementioned data.

Despite the recent reduction in the annual population growth in Poland, the current status of the *C. fiber* population does not indicate an extinction risk at the national or European level (Wróbel, 2020; Janiszewski and Hanzal, 2021; Ledger *et al.*, 2022). This rodent is exhibiting an expansion of its range and is demonstrating the capacity to adapt the environment to its requirements. It can be observed that the population of this species also exhibits a tendency towards spontaneous expansion in urban areas. However, the observed changes in dynamic of this species show that the successful recovery of the *C. fiber* population does not eliminate the necessity for continued conservation efforts on behalf of this species. The environmental transformations that are occurring, including the expansion of urban areas and the construction of new roadways that intersect with the natural communication routes of beaver families, are posing a significant threat to the survival of the European beaver population (Dzięciołowski, 2004; Hędrzak *et al.*, 2011; Batbold *et al.*, 2021). Furthermore, the regulation of water conditions, the reinforcement of river and lake banks, the removal of trees and the pruning of shrubs situated in close proximity to watercourses may restrict the availability of food and the feasibility of secure habitation for these mammals. Moreover, the development of tourism along watercourses may also prove to be a potential threat (Dzięciołowski, 2004; Batbold *et al.*, 2021). The results of the linear regression analysis based on the Akaike criterion (Tab. 1) indicate that the abundance of *C. fiber* Poland was negatively influenced by the presence of the standing surface waters and drainage ditches on agricultural land, while the presence of the flowing surface waters in the landscape, increased its population. Currently, many natural habitats of beavers, such as wetlands and lakes, are being degraded, which may limit further population growth of this species. Therefore, one of the most significant threats to beavers' habitats is the drainage or lowering of the groundwater table caused, among others, by anthropopressure and climate changes (Čížková *et al.*, 2013; Daryadel and Talaei, 2014). In light of these findings, we propose that further research be conducted to elucidate the impact of landscape features on populations of endangered animal species.

In contrast to the benefits of the presence of beaver in the environment, such as the creation of wet and boggy habitats and an increase in water retention and biodiversity, beavers have also been observed to contribute to property damage (Halley and Rosell, 2002; Dzięciołowski, 2004; Hędrzak *et al.*, 2011; Janiszewski and Hanzal, 2021). This is one of the reasons why we observe the destruction of *C. fiber* dams, the burning of lodges, and poaching (Dzięciołowski, 2004; Zając, Romanowski and Kozyra, 2015; Batbold *et al.*, 2021). It is often argued in the literature on this subject, that there is a need for education on the importance of *C. fiber* in nature, as well as the promotion of methods for preventing damage caused by beaver. Such methods include the securing of trees, gardens and flood embankments against beaver. In Poland, farmers are provided with compensation for losses incurred as a result of the activities of *C. fiber* (Hędrzak *et al.*, 2011; Janiszewski and Hermanowska, 2019; Halley *et al.*, 2020; Wróbel and Krysztofiak-Kaniewska, 2020). Additionally, efforts are being made to promote methods for the prevention of environmental damage (Dzięciołowski, 2004; Halley *et al.*, 2020). The findings of the conducted studies are aligned with the objectives set by the communities and researchers engaged in active beaver conservation. The IUCN (Batbold *et al.*, 2021) indicates that further research is required, particularly with regard to population size, its distribution, and the analysis of trends. In the strategies for the protection of *C. fiber* in Poland, it is also emphasised that an important research task is to develop a reliable method for monitoring population size, to study the assessment of the impact of *C. fiber* on the environment and to study the genetics of their populations (Dzięciołowski, 2004; Halley *et al.*, 2020; Janiszewski and Hanzal, 2021).

CONCLUSIONS

1. In Poland, the *Castor fiber* population exhibited a systematic growth between the years 1960 and 2023, with an average annual growth rate of 10.99%.

2. In the population dynamics of *fiber*, four time intervals with the following statistical trends were distinguished: an increase of approximately 6.9% per year in the period 1960–1977, 15.6% per year in the period 1978–2002, 9.3% per year in the years 2003–2016 and 3.8 to the 2023.
3. In the period 1976–2002 population of the *fiber* growth rates doubled in comparison to the neighbours periods, reaching 15.6% per year, which coincided with the implementation of the "Program for the active conservation of the European beaver in Poland".
4. The distribution of the *fiber* population in Poland across voivodships underwent a notable shift between 2000 and 2023.
5. The most substantial increase in population was observed in the eastern and north-western regions of Poland. The lowest recorded number of *fiber* is located in the central belt of the country, in the north-south direction.
6. In the recent period (2016–2023), the largest increase in the number of *fiber* was observed in the following voivodships: MZ, SK and SL.
7. The abundance of *fiber* Poland was negatively influenced by the presence of the standing surface waters and drainage ditches on agricultural land, while the presence of the flowing surface waters in the landscape, increased its population.
8. The applied set of statistical methods proved to be an effective tool for the data considered and may become one of the "protocols of analysis".

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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