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POPULATION EXPANSION OF THE EUROPEAN BADGER (*MELES MELES*) IN SW POLAND DURING THE YEARS 1981-2020

SUMMARY

Based on hunting bags records from the years 1981–2020, distribution, numbers and population dynamics of the badger was analysed in in SW Poland (29 358 km^2, including 8411 km^2 forests). Before 1999, the badger was harvested in SW Poland only occasionally. From 1999 till 2020, there was a steady increase from c. 200 in 1999 to c. 1100 in 2019. This increase in harvesting was a result of a parallel increase in numbers of badgers between 1996 (1000 individuals) to 2013 (c. 6500 individuals). Crude population density of the badger in SW Poland in 2001-2020 was everywhere below 1 ind./1000 ha of the total area. The ecological density, however, ranged from 0.2 to 6.1 ind./100 ha of total wooded area.

Keywords: wildlife ecology, population dynamics, introductions.

INTRODUCTION

The European badger *Meles meles* is a representative of the family Mustelidae, widespread and common all over Europe up to Vola River. According to Lariviere & Jennings (2009) it is replaced further to the east by another congeneric species, the Asian badger *Meles leucurus*, which range extends to the Pacific Ocean from Vladivostok in the north to Hong Kong in the south. Japan islands are occupied by another species, the Japanese badger *Meles anakuma*. The Asian and Japanese badgers have been, however, considered conspecific by most authorities (e.g. Nowak 2005).

The European badger (hereafter referred to as the badger) is highly adaptative, generalist forage capable of exploiting a wide range of habitats. It prefers forests close to open fields, but it also occupies riparian habitats, waste lands and farmlands. In recent decades it even began to occupy rural and urban environments in many countries, including Poland (Roca et al. 2014). In forests the badger plays a role of an ecosystem engineer and as such it is useful. Unfortunately its closer than ever contact with human often results in damages caused to properties and cultivated plants, and increased road causalities. It is

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therefore often a subject of persecution. Even so, for a long time it is also a priced game animal hunted in most (69%) European countries (Kurek et al. 2022). However, in UK, Ireland, Denmark, Netherlands, Belgium, Luxemburg, Portugal, Belarus and Albania it is protected all year round. In 19 European countries it is also listed in Red Lists (Kurek et al. 2022).

The badger can be regarded rather as a harvester than a hunter. Its main food consists of vegetables and small and easily captured animals, such as worms and insects (Davison et al. 2006). In Central Poland, the mean number of young per breeding female was estimated at three, and the annual recruitment of young at 0.68 per adult animal. The average family size was 3.5 (young and adults) or 2.1 (only adults) individuals (Goszczyński & Skoczyńska 1996).

Controlling the badger populations, and especially the badger-human conflicts became therefore an important part of game management. Crucial for this management is a knowledge on its distribution, abundance, habitat preference. This may be regionally varied, and may also change with time. It is therefore important to monitor its population on a regular basis. In this paper, the badger population was studied in SW Poland over the last 40 years. The aim was to map its distribution and abundance on high-resolution maps, as well as to trace its year-to-year changes in its the distribution and abundance.

STUDY AREA

The study area comprised two provinces (actual voivodships) in south-western Poland, i.e. Opole Province (województwo opolskie) and Lower Silesia Province (województwo dolnośląskie). These include the following hunting regions (former voivodships in the years 1975–1999): Opole, Wrocław, Legnica, Wałbrzych and Jelenia Góra. Nowadays, the Opole hunting region is entirely located within Opole Province, while the four other hunting regions are located within the Lower Silesia Province. Opole, Wrocław and Legnica hunting regions are basically lowlands, while there are mountains in the southern parts of the Wałbrzych and Jelenia Góra hunting regions (Fig. 1).

The total surface area of such defined study area is 29 358 km^2, which constitutes 9.4% of the Poland's surface area. The land is located almost entirely within the Odra drainage system. Forests occupy 8411 km^2, i.e. 28.6% of the study area (Fig. 1). There are 42 districts, 240 counties (gminas), 127 towns and 3406 villages. The number of people living in this area was 3.87 mln in 2020.

Each hunting region is covered with a net of hunting districts (Fig. 1). Although all hunting districts include both forested and arable grounds, the proportion between them is varied. There are also meadows and pastures, human settlements (towns and villages), rivers and water bodies, waste and industry areas in each hunting district. The average annual air temperature in the lowlands in SW Poland is 10.6˚C, for Sudeten Mts 9.0˚C (the average for Poland is 9.9˚C). This average has increased form 7.6˚C in 1981–1990 to 9.3˚C in 2020 (0.29˚C per 10 years) (IMiGW 2021). The long-term (1901–2000) average precipitation for Wrocław is 583 mm per annum (in Sudeten Mts. the average is doubled). The

amount of rainfall may greatly vary from year to year (318–892 mm) (Dubicka et al., 2002). In the first half of the 20th century, in most decades (except for 1901–1910) the rainfall was above the long-term average; while in the second half of 20th century, in most decades (except for the years 1971–1980) the rainfall was below the long-term average (583 mm) (Dubicka et al., 2002). In SW Poland, snow cover lasts for 30–40 days per year in lowlands, 40-50 days in uplands for, and 70 – 80 days in mountains. During the years 1981–2020 the most snowy winters were in 2005/2006 and 2009/2010, whereas the least snowy winters were in two successive winters 1988–1990 and 2006–2008 (Czarnecka 2012).

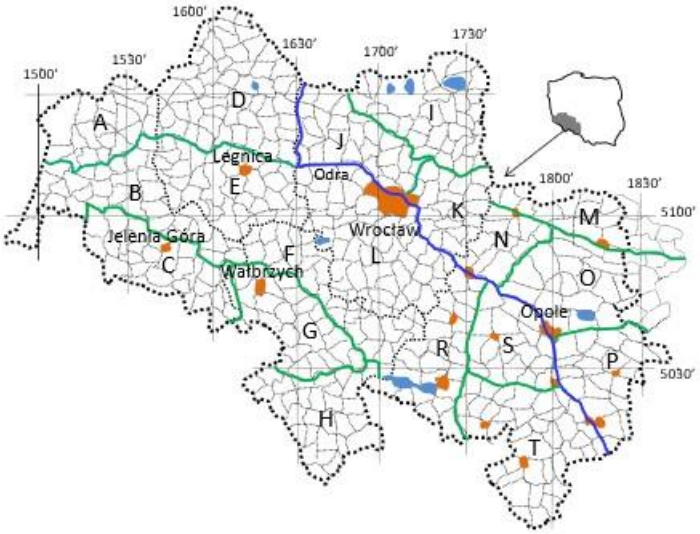

Fig.1. The study area, SW Poland, divided into hunting districts, 5 hunting regions and 19 ecoregions.

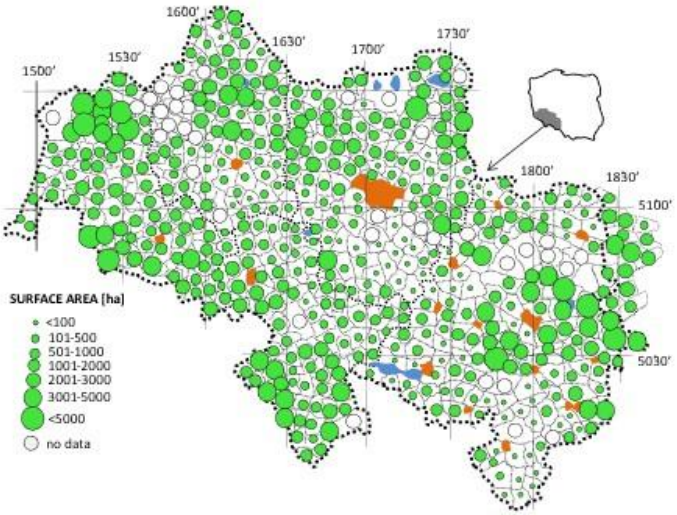

Fig. 2. Afforestation in particular hunting district in SW Poland in 2020.

Table 1. Population densities (individuals per 1000 ha) of the badger (average from 2001–2020)

#	Region	Hunting districts	Surface area [ha]		%	Popul. density	
			general	forests	forests	ecol.	crude
	Jelenia Góra Hunting Region						
A	Lower Silesian Forests	5, 7, 12, 15, 16, 20	33211	27782	83.7	0.4	0.4
B	Silesian-Lusatian Lowland	31, 33, 39, 40, 43, 52	25500	6438	25.2	1.6	0.4
C	West Sudeten Mts.	54, 55, 66, 71, 78, 80	28332	20249	71.5	0.5	0.3
	Legnica Hunting Region						
D	Northern (lowland) part	1, 2, 17, 18, 33, 35	22795	8467	37.1	2.3	0.8
E	Southern (hills) part	62, 67, 69, 71, 72, 78	29400	3754	12.8	6.1	0.5
	Wałbrzych Hunting Region						
F	Sudeten Upland	6, 7, 21, 31, 38, 39	26700	3730	14.0	1.7	0.1
G	Middle Sudeten Mts.	10, 18, 23, 25, 28, 30	26715	10576	39.6	0.7	0.2
H	East Sudeten Mts.	54, 67, 69, 70, 72, 82	16191	9491	58.6	0.7	0.4
	Wrocław Hunting Region						
I	Barycz Valley and Trzebnica Hills	2, 7, 8, 13, 15, 16	30127	10091	33.5	0.3	0.1
J	Głogów-Milicz Depression	10, 30, 32, 45, 47, 59	27803	9090	32.7	0.4	0.1
K	Oleśnica Plain	71, 85, 86, 95, 96, 107	27283	9154	33.6	1.3	0.4
L	Wrocław Plain	67, 79, 90, 100, 113, 116	28938	1884	6.5	3.0	0.2
	Opole Hunting Region						
M	Northern part of the Opole Province	3, 7, 12, 14, 15, 16	32497	4375	13.5	1.0	0.1
N	Brzeg Land	17, 19, 20, 21, 50, 51	33704	11738	34.8	0.7	0.3
O	Stobrawa Forests	28, 33, 34, 35, 36, 39	38926	32444	83.3	0.2	0.2
P	East-central part of the Opole Province	82, 83, 91, 123, 126, 129	41259	20721	50.2	0.2	0.1
R	Nysa Land	74, 76, 78, 114, 120, 122	34320	2258	6.6	1.9	0.1
S	Niemodlin Forests	47, 59, 64, 67, 96, 101	41259	20721	50.2	0.3	0.2
T	Głubczyce Plateau	105, 109, 132, 133, 138, 146	34320	2258	6.6	5.7	0.2

* Symbols in the first column (A, B, C…) refer to these in Fig. 1.
Ecological density refers to the number of harvested badgers/1000 ha of forest, whereas the crude density refers to the number of harvested badgers/1000 ha of the total surface area.

MATERIAL AND METHODS

In the case of badgers, estimates are almost invariably based on a secondary index of abundance, notably sett surveys, latrine use or game-bag data from the hunting grounds (Griffiths & Thomas 1993, Tuyttens et al. 2001). In larger areas, the badger numbers can also estimated through a questionnaire (Matyáštík & Bičík 1999, Nadolska 2002, Nadolska & Bartmańska 2003).

This study is based on records from the years 1981–2020 kept by the Polish Hunting Association Research Station in Czempiń near Poznań. Records refer to the number of badgers harvested (hunting bags) and the number of these estimated (quotas) for each hunting district (hunting ground, management area) located in SW Poland, i.e. in five hunting regions (HR): Opole, Wrocław, Wałbrzych, Legnica and Jelenia Góra.

According to Polish Hunting Code, badgers can be hunted from 1 September to 30 November (Dz. U. 2020.1683).

For each hunting district the following parameters were calculated: the total surface area (including towns, villages, roads), the percentage of arable ground coverage and the percentage of forest coverage. These calculations were made by the Polish Hunting Associations and were continually updated if any changes in the land use structure took place.

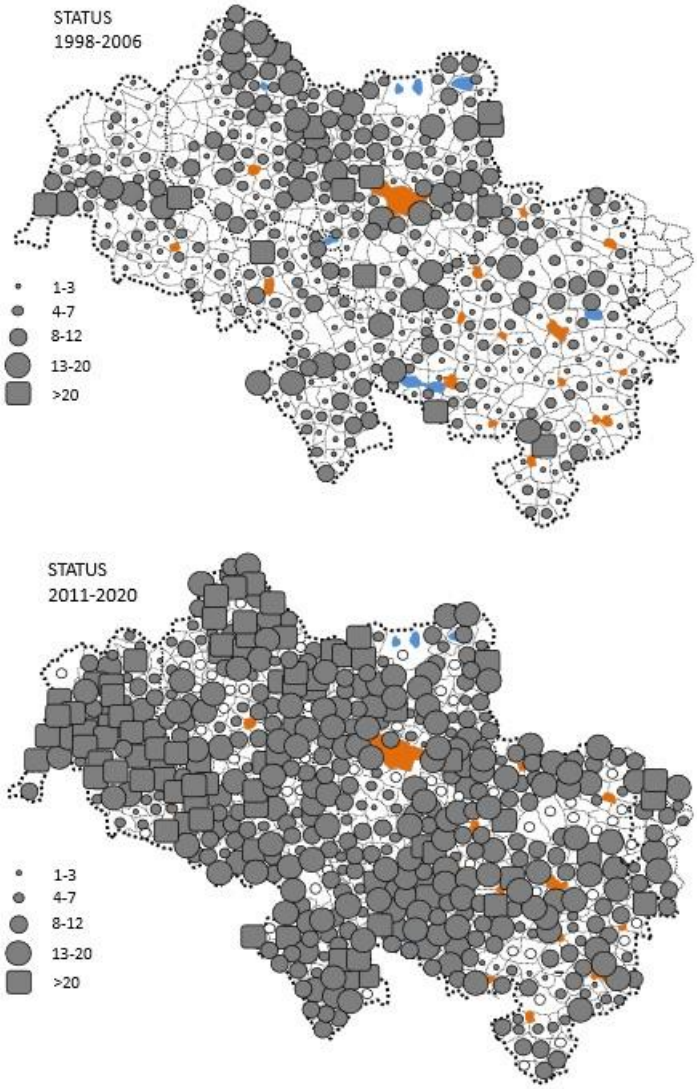

Fig. 3. Estimated mean numbers of the badger in particular hunting districts in SW Poland during the years 1998-2006 and 2011-2020.

In the winter of each year members of a hunting club of a given hunting district and staff of forest districts located within this hunting district attempt to estimate numbers of badgers and other game mammals in their respective hunting district (Kopij 2022, 2023a, 2023b). Numbers of badgers in particular hunting district were estimated by den counts. In the entire period 1980-2020, estimations were based on the same rules (Zalewski et al. 2018).

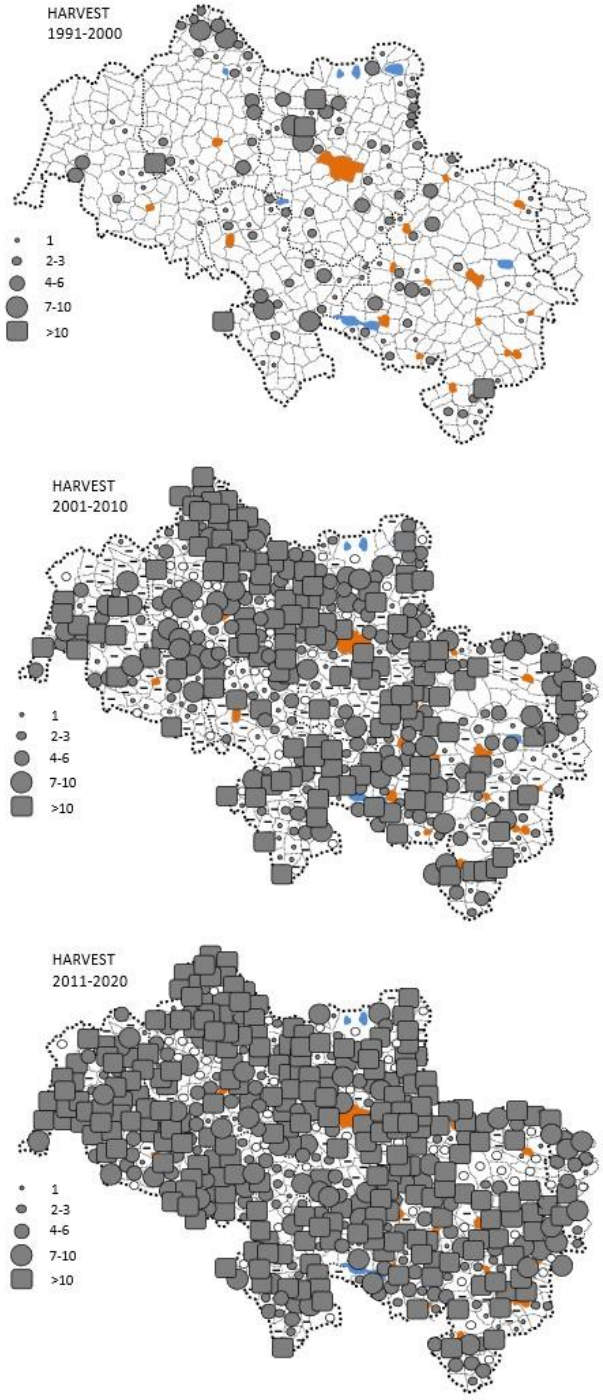

Fig. 4. The number of harvested badgers in particular hunting districts in SW Poland during the years 1991-2020.

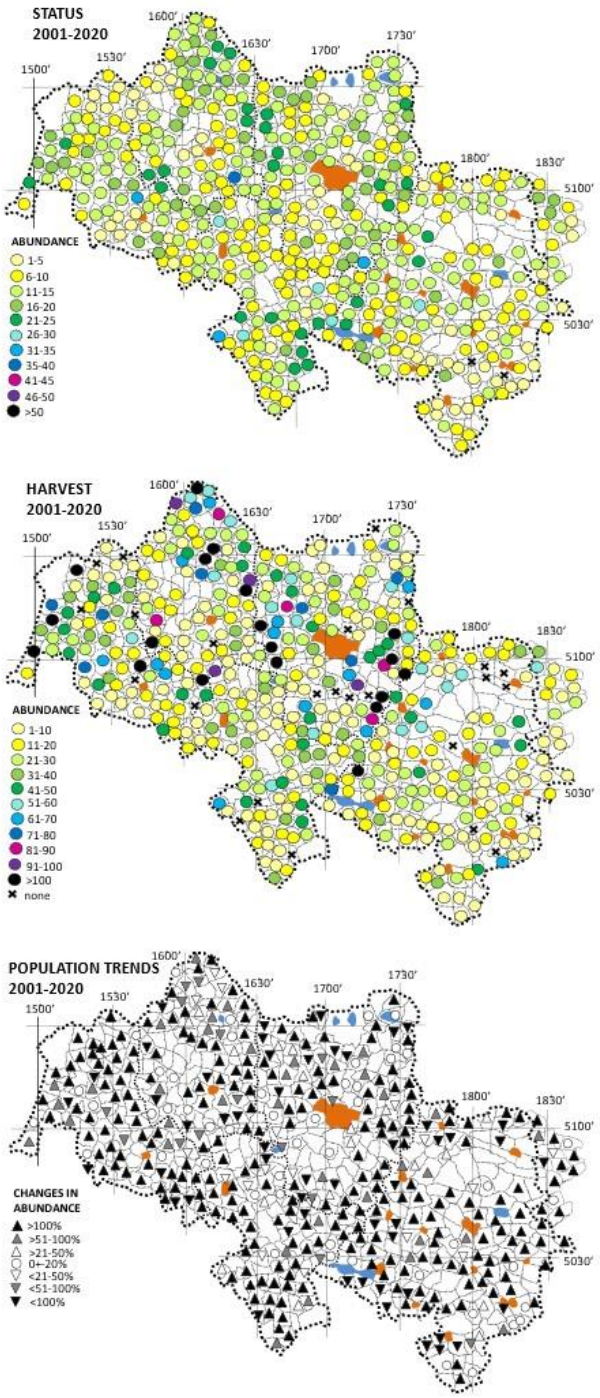

Fig. 5. An overall abundance and population trends of the badger in particular hunting districts in SW Poland during the years 2001-2020.

Counting dens is the most efficient and most often used method (Zalewski et al. 2018). Dens are searched for throughout the year, but mostly in autumn, and plotted on a map. Each den is revisited in early spring to record whether it is occupied or not; and again in late spring in order to determine whether it is occupied by breeding animals (the presence of young animals, their excrements left around the den, presence of prey remnants and playing grounds). Each den occupied in early spring is an equivalent of 2-2.5 individuals; dens with young animals are used to calculate a density of breeding groups. Setts were classified into 3 categories: permanent (main) if cubs were present almost on yearly basis, with (3)-4 entrances within an area larger than 100 m^2; subordinate with cubs present in some years only, with 2-4 entrances within an area of 10-100 m^2; temporary (irregular), without cubs, occupied between October and April only, with 1-2 entrances only within an area smaller than 10 m^2 (Matyáštík & Bičík 1999).

Harvested numbers are expressed as the total number of badgers shot in a given hunting district in a given hunting season. Each hunting season begins on 1st of April and ends on 31st of March of the next year. For each ecoregion (Fig. 1), six hunting districts were randomly selected to calculate mean population density in each ecoregion. Population density is expressed as the mean number of red foxes harvested per one hunting season and per total surface of a hunting district (crude density) or per the surface of afforested area within the hunting district (ecological density). The densities are expressed as the number of individuals harvested per 1000 ha. The mean value (long-term average) is based on data from 20 years (2001-2020). The ratio between the crude density and ecological density was calculated by dividing the ecological density by the crude density.

Harvested numbers are expressed as the total number of badgers shot in a given hunting district in a given hunting season. Each hunting season begins on 1st of April and ends on 31st of March of the next year.

Both crude and ecological densities was calculated for all ecoregions distinguished in SW Poland (Fig. 1). If crude density (number of individuals harvested per 1000 ha of total surface area) is lower than 1, it is regarded low, 1-10: moderate, >10: high (Griffiths & Thomas 1993). If ecological density (number of individuals harvested per 1000 ha of wooded area) is lower than 1, it is regarded very low, 1-2: low, 2-4: moderate, 4-6: high (good), >6: very high (very good) (Štollmann 1967).

RESULTS

In 1998-2006, the northern part of Dolnośląskie Province constituted the stronghold of the badger population in SW Poland. However, in 2011-2020, the population was more evenly distributed across the whole region (Fig. 3).

Harvesting in 1991-2000, in most hunting districts, the badger was not harvested at all. Only in 5 hunting districts (including one in Opole HR) more than 10 badger were shot in that period, and only in 6 other 7-10 badgers were

harvested. However in the subsequent decade (2001-2010), it was harvested in most hunting districts, and in nearly half of these districts more than 6 individuals were harvested. In 2011-2020, the badger was hunted in all except 14 hunting districts in Dolnośląskie Province and 9 hunting districts in Opolskie Province (Fig. 4).

In 2001-2020, the badger was the most numerous on the border of Opole and Dolnosląskie provinces, in the northern parts of Wroclaw HR and Opole HR and in Sudety uplands. The lowest density numbers were recorded in SE part of Opole HR, SW Wrocław HR, northern part of Wałbrzych HR, S part of Legnica HR and Bory Dolnośląskie (Fig. 3).

In 2001-2020, harvesting was higher in Dolnośląskie than Opole Province. It was the highest in the Odra river valley and in Sudety Uplands (Fig. 4).

In 2001-2020, an increase in harvesting (>50%) was recorded in 261 hunting districts including 77 in Opole HR, 50 Wrocław HR, 38 Legnica HR, 52 Jelenia Góra HR and 44 Wałbrzych HR. An decrease in harvesting (>50%) was recorded in 61 hunting districts (20 in Opole HR, 16 in Wrocław HR, 13 in Legnica HR, 7 in Jelenia Góra HR and 5 in Wałbrzych HR), while stable numbers were recorded in 49 hunting districts (Fig. 5).

Before 1999, the badger was harvested in SW Poland only occasionally. From 1999 till 2020, there was a steady increase from c. 200 in 1999 to c. 1100 in 2019. This increase in harvesting was a result of a parallel increase in numbers of badgers between 1996 (1000 individuals) to 2013 (c. 6500 individuals). Although in subsequent years, the population growth levelled off, the harvesting was still in increase until 2019. This population increase between 1996 and 2013 was recorded in Opole HR and Wrocław HR. In Jelenia Góra HR the population continue to grow until 2019, while in Legnica HR and Wałbrzych HR, it begun to slightly decrease after the year 2013. Harvesting was on an increase between 1996 till 2019 in all hunting regions, but a decrease was recorded in Wrocław HR in the same period (Fig. 6).

Crude population density of the badger in SW Poland in 2001-2020 was everywhere below 1 ind./1000 ha of the total area. The ecological density, however, ranged from 0.2 to 6.1 ind./100 ha of wooded area. It was the lowest (0.2-0.4) in most afforested ecoregions (Stobrawa Forests, Niemodlin Forests, Barycz Valley), the highest – in most deforested regions such as southern part of Legnica HR (6.1) Głubczyce Plateau (5.7), Wrocław Plain (3.0).

DISCUSSION

In Poland, including the south-western part, the badger was regarded as rare (Pax 1925, Kopij 1996, Kowalczyk et al. 2000, 2003; Nadolska 2002; Nadolska, Bartmańska 2003; Roca et al. 2014). The major finding of this study is that the badger once a rare game species in the south-western part of this country, became common throughout the region as a result dramatic increase in the years 2000-2020. In Britain badgers live in clans comprising on average 6 adult animals (both males and females) with home ranges (50-150 ha), without

territories. However, in many other countries in continental Europe, including Poland, badgers live usually single or in pairs holding much larger territories. For example, in the Białowieża Primeval Forest, mean territory size was 1300 ha, ranging from 800 to 2600 ha (Kowalczyk et al. 2003). Also the population density is much higher in Britain than in the continental Europe. While in UK, on average 94 individuals /1000 ha or 15 setts per 1000 ha were recorded; in continental Europe 6.3 individuals (1.6-5.2) per 1000 ha or 1.7 setts (0.4-6.5) per 1000 ha was the average value (Kowalczyk et al. 2000, Byrne et al. 2013). In Białowieża Forests in 1996-1999 there were 1.6 ind./1000 ha (0.4 setts per 1000 ha). It was even lower in Białowieża National Park (10900 ha), with only three established territories (Kowalczyk et al. 2004). Population density is negatively correlated with forest cover, probably because biomass of earthworms is higher in open habitats (meadows, pastures) than in forests.

In 1993, in the northern Maravia (11 067 km^2), bordering with SW Poland, the population density was 1.2 ind./1000 ha of the total area; and 3.1 ind./1000 ha of the wooded area. It was the highest in Ostrava district (8.3), and the lowest in Bruntal district (0.8). In Jesenik and Opava districts it was 1.3. The presence of the badger was conformed in 383 out of 789 hunting districts (48.5%), with permanent occurrence reported from 310 districts (39.3%); there were 789 setts (4.5 per 1000 ha), including 195 permanent and 218 subordinate (Matyáštík & Bičík 1999). In southern Moravia (15028 km^2), the population density in 1996-1999 doubled that in northern Moravia (crude: 2.2 ind./1000 ha; ecol.: 7.6 ind./1000 ha; and 0.8 and 2.8 setts/100 ha respectively); the badgers were recorded in 657 out of 964 (68.2%) hunting districts; and the total population was estimated at 3366 individuals (Bičík et al. 2000). In Hungary, population density was estimated at 1-3 ind./1000 ha, or 3-11 setts per 100 ha (Kozak & Heltai 2006).

In countries such as France, Benelux, Estonia and the former Yugoslavia, the overall badger population density (country-wide scale) was low (<1 ind. per 1000 ha); in Germany, Austria, Czech Republic, Bulgaria, Latvia, Lithuania, Finland, the density was 3-4 ind./1000 ha; while in Sweden and Britain it was higher than 10 ind./1000 ha (Griffith & Thomas 1997). Against this background, the population density in SW Poland in 2001-2020 was low (crude density below 1 ind./1000 ha in all ecoregions). It was similar to an overall density in Poland in mid-1990's (Griffith & Thomas 1997) and in the northern Moravia in 1993 (Matyáštík & Bičík 1999). However, it should be emphasized that the numbers from SW Poland refer to the number of harvested badgers. The real numbers could have been 2-3 times higher. If so, the crude population density would be higher than 1 ind./1000 ha in most ecoregions distinguished in SW Poland.

Long-term data on badger population dynamics are scarce (van Apeldoorn et al. 2006). In Poland, such data are available only from one small study area (89 km2) near Rogów in Central Poland; during a 16-year period (1979-1995), the density of badgers increased there from 1.6 individuals to 2.6 ind. per km2 of wooded area (Goszczyński & Skoczyńska 1996). In the Czech Republic, in the northern Maravia (11 067 km^2), bordering with SW Poland, 737 individuals were

counted in 1983, whereas in 1993 the number increased to 1306 individuals. The numbers therefore almost doubled over 15 years (Matyáštík & Bičík 1999). In southern Moravia, 2.5-fold increase in badger numbers was recorded between the years 1983 and 1996-1999 (Bičík et al. 2000). In Hungary, badger population increased by 60 % between 1987 and 2000, and their area of occurrence has also expanded with occupying new habitats (Heltai et al. 2001). In Fennoscandia, the badger has expanded its, range up to the Arctic Circle during the years 1950-1990 (Bevanger & Lindström 1995). In the Netherlands, near Utrecht, in a mixed farmlands (c. 100 km^2, increasing maize cultivation; pastures) and forest (Van Apeldoorn et al. 2006); continuous increase has been recorded from 4 individuals in 1983 to 41 individuals in 2001. However, in Belarussian part of the Białowieża Forest in 1946-61 the density was 1.3 ind./1000 ha (0.3 setts per 1000 ha), but in 1979-99 it was even lower: 0.6 ind. (0.2 setts) per 1000 ha (Kowalczyk et al. 2000). In SW Poland, the increase in badgers numbers over the last 23 years (1997-2019) was 5-6-fold (Fig. 4), much faster than in Central Poland (Goszczyński & Skoczyńska 1996) or in Moravia bordering in the south (Matyáštík & Bičík 1999, Bičík et al. 2000).

Factors governing badger's distribution and abundance are those favouring both sett location (soil type, slope, vegetation cover), forest type, human activity, abundance and availability of earthworm, competitors and predators, parasites and diseases (Mysłajek et al. 2012, Roca et al. 2014). Badgers prefer ecotone zone (forest/open fields with pasture, meadows etc. with the presence of sandy places for the establishment of dens). In Moravia, Czech Republic, out of 499 setts: 33.1% were found in mixed forests, 26.1% in coniferous forests, 16.2% in deciduous forests, and 11% quarry (Matyáštík & Bičík 1999). The ecotone is important habitat requirement, as in the humid forest, earthworms constitute its staple food, while in farmlands both earthworms and cultivated plants (especially maize). Insects, snails, rodents, frogs, lizards, mushrooms, berries and other plants supplement the diet (Zabala et al. 2002, Zabala & Zuberogoitia 2003, Kauhala & Ihalainen 2014). In farmlands with forest fragments in SW Poland maize is becoming increasingly important component of the badger diet (Kochan et al. 2011; G. Kopij, own observ.), as it is in the case of other game mammals (Kopij 2022, 2023a; Kopij & Panek 2016).

The hedgehogs *Erinaceus europaeus*, can be an important prey of the badger, and a strong negative spatial relationship has been shown between hedgehogs and badgers (Young et al. 2006). The fox *Vulpes vulpes,* and racoon dog *Nyctereutes procyonoides* are potential badger's food competitors (Mysłajek et al. 2012). In SW Poland the fox is by the order of magnitude more numerous than the badger (Kopij et al. 2015, Kopij 2023b), but the overlap between badger and fox diet was proved low (Canova, Rosa 1993). Also the racoon dog, although an alien species, is in SW Poland more common than the badger (Kopij 2017). Raccoon dog diet was in all study sites more diverse than badger diet. Both diet composition of these carnivores and their habitat preferences do not indicate severe competition. Overlap of diets between these two carnivores was the smallest in the most diverse area and highest in a managed area with fields and industrial forests (Kauhala & Kowalczyk 2011, Kauhala & Ihalainen 2014).

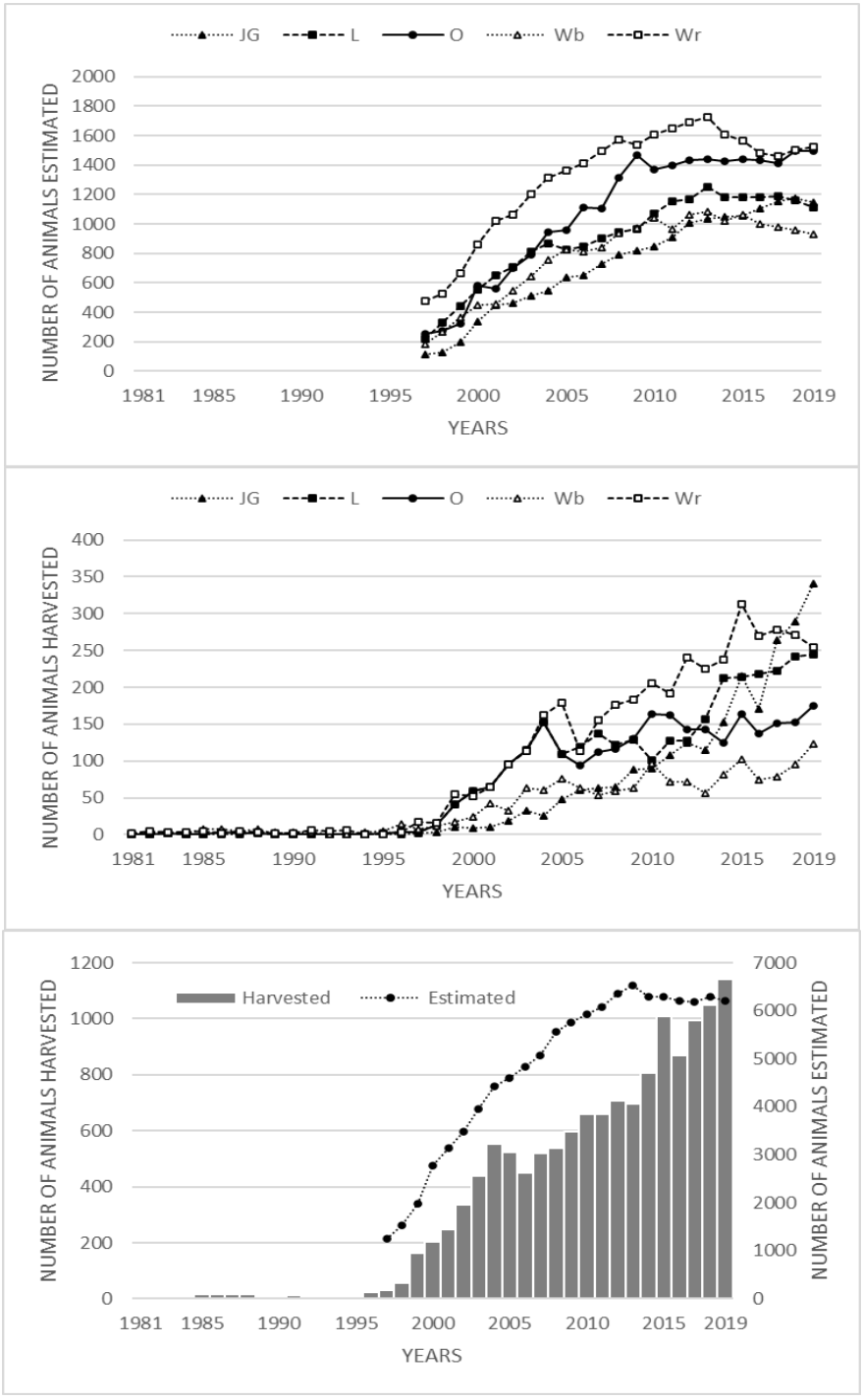

Fig. 6. Changes in the number of estimated and harvested badgers in particular hunting regions and overall in SW Poland during the years 1981-2020.

The badger is a vector of bovine tuberculosis (bTB). This multi-host zoonosis is caused by *Mycobacterium bovis*. Recent field studies demonstrated significant benefits of Bacillus Calmette–Guérin (BCG) vaccination on reducing badger susceptibility to infection. The badger suffers quite often from rabies, possible transmitted by foxes. Collision with vehicles is another important and increasing cause of badger mortality (Griffith & Thomas 1997).

Selective culling may increase badger ranging, reducing local scale badger genetic relatedness and increasing *Mycobacterium bovis* prevalence (exacerbating cTB) (Bielby et al. (2014). Culling (in order to prevent disease spread) may induce disturbance to badger social structure, facilitating wider cTB dissemination. It has been suggested that even at very low population density level, selective culling may cause similar deleterious effects by increasing ranging of individuals and greater mixing between social groups (Byrne et al. 2013, Allen et al. 2022). It is therefore advisable, to not intensify culling in the presence of cTB and other contiguous diseases.

CONCLUSIONS

In the years 2000-2020, the badger has rapidly increased in numbers (almost 5-fold) in SW Poland, possible as a result of increased areas of maize cultivation (corn may constitute its important food) and climate change (milder and shorter winters). This increase was much faster than in the neighbouring Moravia, Czech Republic, and Central Poland. The crude population density remained relatively low everywhere (1 ind./1000 ha of the total area), but the ecological density ranged from 0.2 to 6.1 ind./1000 ha of wooded area.

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