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POPULATION DYNAMICS OF THE MOUFLON (*OVIS ARIES MUSIMON*) IN SOUTH-WEST POLAND IN 1981–2020

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Abstract

Using hunting bags data, spatial and temporal changes in population densities of the mouflon in 1981–2020 in south-west Poland (29 358 km2, including 8411 km2 forests) have been analysed. In south-west Poland, the mouflon was introduced in 1902. The population increased from 5 to 134 individuals in 1925, reaching 1100 individuals in 1939. From the 1950s to 1972, the mouflon population in south-west Poland fluctuated around 200 individuals. Later, it began to decrease, reaching its minimum (36 individuals) around 1981. During the subsequent years of 1981–1990, the population increased to 219 individuals, and had reached 576 individuals by 2001. This exponential growth continued until 2011, when it reached its second (the first one with 1100 individuals was in 1939) maximum, fluctuating around 1400–1500 individuals until 2016. The maximum number of 1478 individuals was reached in 2016. In the following years it began to decline again, reaching the level of 1215 individuals in 2019. The crude population density ranged from 0.01 to 7.02 individuals per 1000 ha, whereas the ecological density ranged from 0.01 to 17.72 individuals per 1000 ha of forests in particular ecoregion in south-west Poland (based on the average from 2001–2020). The pattern of population growth in the whole of Poland was similar to that in Lower Silesia. Up to 1987 mouflons were restricted in Poland to Sudety Mts. and Świętokrzyskie Mts. In the subsequent years, more and more mouflons were successfully introduced in other parts of the country. However, at the beginning of the 21st century, 2/3 of mouflons still occurred in the Sudety Mts. The remaining mouflons live in isolated and small populations in the following provinces: Kujawsko-Pomorskie, Opolskie, Podkarpackie, Kieleckie, Pomorskie, Warmińsko-Mazurskie, and Wielkopolskie. The population in south-west Poland comprise therefore about half of that in the whole of Poland, but merely 8.6 % of the population in the Czech Republic, and 1.5% of the global population. A total of 3584 mouflons were shot in south-west Poland in 1981–2019. In 1981–1989, only 17 individuals were harvested, whereas 235 in 1990–1999, 1002 in 2000–2009, and 2277 in 2010–2019. Most harvested animals originated from Wałbrzych (n = 3525), much less from Legnica (n = 74) and Opole (n=40) hunting regions.

Cite as

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Динаміка чисельності муфлона (*Ovis aries musimon*) на південному заході Польщі протягом 1981–2020 років

Гжегож Копій

Резюме. Використовуючи дані мисливських трофеїв, проаналізовано просторово-часові зміни щільності популяції муфлона протягом 1981–2020 рр. на території південно-західної Польщі (29 358 км^2, з них 8411 км^2 лісів). На південному заході Польщі муфлон був інтродукований у 1902 р. У 1925 р. популяція зросла з 5 до 134 особин, а в 1939 році досягла 1100 особин. З 1950-х до 1972 р. популяція муфлона на південному заході Польщі коливалася на рівні 200 особин. З того часу вона почала зменшуватися, досягнувши свого мінімуму (36 особин) приблизно в 1981 році. Протягом наступних 1981–1990 років популяція зросла до 219 особин, а до 2001 року — до 576 особин. Це експоненціальне зростання тривало до 2011 р., коли вона досягла свого другого максимуму (перший раз 1100 особин був у 1939 р.), коливаючись на рівні 1400–1500 особин до 2016 р. Максимальної чисельності 1478 особин досягнуто у 2016 р. У наступні роки вона знову почала знижуватися, досягнувши рівня 1215 особин у 2019 р. Загальна щільність популяції коливалася від 0,01 до 7,02 особин на 1000 га, тоді як екологічна щільність коливалася від 0,01 до 17,72 особин на 1000 га лісів у конкретному екорегіоні на південному заході Польщі (на основі середнього показника за 2001–2020 роки). Характер зростання популяції у всій Польщі був подібним до того, що спостерігався у Нижній Сілезії. До 1987 р. муфлони в Польщі були зосереджені в Судетах і Свентокшиських горах. У наступні роки все більше і більше муфлонів успішно інтродукували в інших частинах країни. Однак на початку XXI ст. в Судетських горах все ще мешкало 2/3 муфлонів. Решта муфлонів живуть ізольованими і невеликими популяціями в наступних воєводствах: Куявсько-Поморському, Опольському, Підкарпатському, Келецькому, Поморському, Вармінсько-Мазурському та Великопольському. Таким чином, популяція муфлонів у південно-східній Польщі становить близько половини населення всієї Польщі, але лише 8,6% популяції Чеської Республіки і 1,5% світової популяції. Загалом 3584 муфлонів було відстріляно на південному заході Польщі протягом 1981–2019 років. У 1981–1989 роках було впольовано лише 17 особин, у 1990–1999 роках — 235, у 2000–2009 роках — 1002, а в 2010–2019 роках — 2277. Більшість добутих тварин походить з Валбжихського (n = 3525); значно менше з Легницького (n = 74) та Опольського (n = 40) мисливських регіонів. Польська популяція оцінюється приблизно в 3000 особин.

Ключові слова: екологія дикої природи, динаміка популяцій, інтродуковані види.

Introduction

The mouflon *Ovis aries musimon* is one of the three representatives of the family Bovidae in Poland. Its natural range is restricted to the Lesser Caucasus (eastern Turkey, Armenia, and Azerbaijan) and the Zagros Mts. in Iran. However, since the Neolithic, it has been domesticated and/or introduced to many places in Europe. The introduced mouflons were regarded as a subspecies of the wild mouflon (*Ovis gmelini*), but today they are considered as feral descendants of the domestic sheep *Ovis aries* [Gentry *et al.* 2004].

In 1902, the mouflon was introduced in the Sudety Mts. (Lower Silesia, Poland), from a stock that originated from Sardinia and Corsica [Pax 1925]. A rationale for this introduction was hunting. After several repeated introductions, the mouflon has established viable populations in some regions of Poland, so that at the beginning of the 21st century, there were c. 3000 individuals. Most of them (68%) occur in Lower Silesia, south-west Poland [Nasiadka *et al.* 2015, 2021].

Although the mouflon is an attractive and highly valued game animal, its population should be regularly monitored to prevent the species from degeneration [Bobek *et al.* 2014]. If it reaches a too high level of population density, it may cause some damage to the natural environment [Szczęśniak 2011], which can be especially acute in natural areas, such as national parks, landscape parks or nature reserves.

This paper presents data on the development of the mouflon population in south-west Poland from its first introduction in 1902 until 2020, with a year-to-year analysis of spatial and temporal

changes between1981 and 2020. A more detailed analysis is applied here compared to other studies, as numbers are given for each year and for each hunting district.

Study area

The study area comprised two provinces (actual voivodships) in south-west Poland, i.e. Opole Province (Województwo Opolskie) and Lower Silesia Province (Województwo Dolnośląskie). These include the following hunting regions (former voivodships as of 1975–1999): Opole, Wrocław, Legnica, Wałbrzych, and Jelenia Góra. Nowadays, the Opole hunting region is entirely located within the 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.

The total surface area of such defined study area is 29 358 km^2, which constitutes 9.4% of 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. There are 42 districts, 240 counties (gminas), 127 towns and 3406 villages. The number of people living in this area was 3.87 million 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 varies (Fig. 2). 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 south-west Poland is 10.6˚C, for the Sudeten Mts is 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 PIB 2021]. The long-term (1901–2000) average precipitation for Wrocław is 583 mm per annum (in the 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, the rainfall was above the long-term average in most decades (except for 1901–1910); while in the second half of 20th century, the rainfall was below the long-term average (583 mm) in most decades (except for the years 1971–1980) [Dubicka *et al.* 2002]. In south-west Poland, snow cover lasts for 30–40 days per year in the lowlands, 40–50 days in the uplands, and 70–80 days in the mountains. In 1981–2020, the most snowy winters were in 2005–2006 and 2009–2010, whereas the least snowy winters were in two successive winters between 1988–1990 and 2006–2008 [Czarnecka 2012; Kopij & Panek 2016: Kopij 2022].

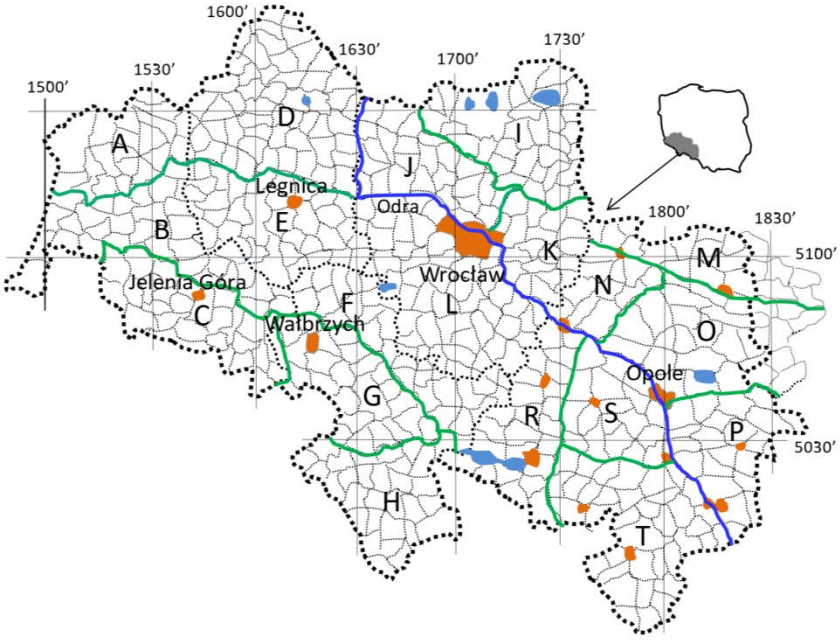

Fig. 1. The study area in south-west Poland divided into hunting districts, 5 hunting regions and 19 ecoregions.

Рис. 1. Територія дослідження, південний захід Польщі, поділена на мисливські округи: 5 мисливських районів і 19 екорегіонів.

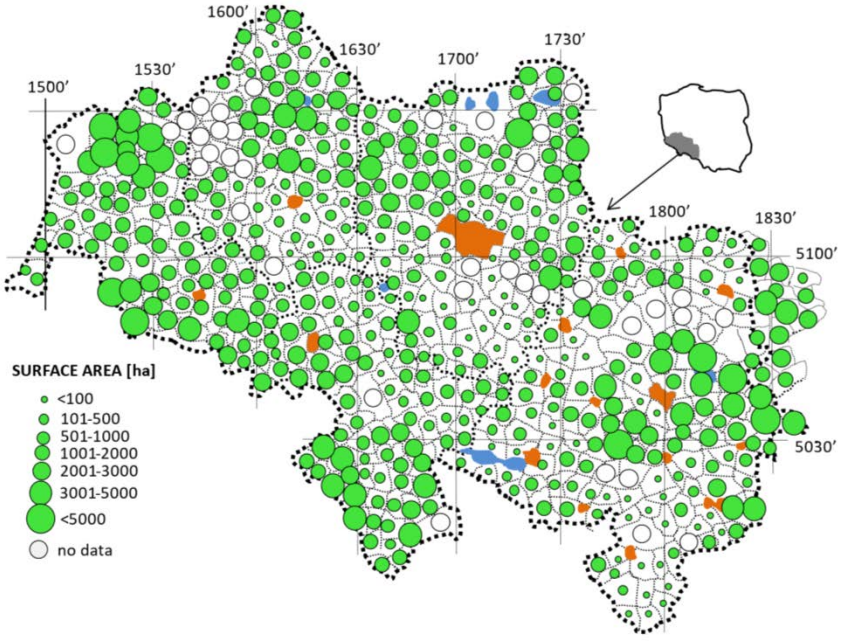

Fig. 2. Forest cover in particular hunting district in south-west Poland in 2020.

Рис. 2. Лісовідновлення в окремих мисливських районах на південному заході Польщі у 2020 році.

Material and Methods

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 mouflons harvested (hunting bags) and the number of these estimated (quotas) for each hunting district (hunting ground, management area) located in south-west Poland, i.e. in five hunting regions (HR): Opole, Wrocław, Wałbrzych, Legnica, and Jelenia Góra.

In the entire period of 1980–2020, estimations were based on the same rules as applied to other game mammals in south-west Poland [Kopij 2022, 2023; Kopij & Panek 2016]. At the beginning of spring of each year, members of a hunting club of a given hunting district and staff of forest districts located within this hunting district attempted to estimate the numbers of mouflons in their respective hunting district. This estimation was based on direct field observations conducted throughout the year in a given hunting district, as well as on the subjective opinions of experts.

During drive counts, forest compartments were selected for a survey. Such compartments cover about 10% of the surface area of a given hunting region. Each selected compartment was surrounded by observers, who were spaced from one another at a distance of 50–100 m, so that visual contact was maintained. The observers on three sides were stationary, while those on the remaining side moved inside the compartment, 'combing' the whole area of this compartment. All observers recorded all mouflons passing through the line of observers on their right side only, and the observers recorded all mouflons entering or leaving the surveyed compartment [Zalewski *et al.* 2018]. Observations were analysed, summarised and assumed as estimations.

According to the Polish Hunting Code, male mouflons can be hunted from 1 October to the end of February, females and young mouflons from 1 October to 15 January (Dz. U. 2020.1683).

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

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

Results and Discussion

In south-west Poland, the mouflon occurs in Lower Silesia and Opole Silesia provinces. In Lower Silesia, it occurs in the Sudety Mts. and at five isolated sites in the lowlands: 1) 31/36 hunting districts in Legnica Hunting Region (HR); 2) 8 hunting district in Legnica HR; 3) 69 hunting district south-east of Legnica; 4) 32/51 hunting districts near Bolesławiec in Jelenia Góra HR; 5) 4/5 hunting districts in Dolnośląskie Forests in Jelenia Góra HR (Figs. 3–4). To date, no mouflons were introduced to Wrocław HR in Lower Silesia.

No mouflons occurred in Opole Silesia (Opole Hunting Region) before 2010 [Kopij, 1996, 2017; Kopij *et al.* 2015]. In 2003, mouflons were introduced to the Opawskie Mts. in the southern part of this region (Prudnik Forests Inspectorate). In 2011–2020, some individuals came to the Opawskie Mts. from the Czech Republic and with the introduced animals they have established a small population near Trzebinia (109 hunting district in Opole HR).

In the same decade, seven animals have been introduced to Chełm Hill around St Anna Mt. in the eastern part of Opole HR (90/91 hunting districts). In 2017, several mouflons were kept in an enclosure in Głubczycki Forest near Głubczyce. These animals are intended to be released to this forest and to the eastern part of the Opawskie Mts. (Mokre and Opawice forest districts).

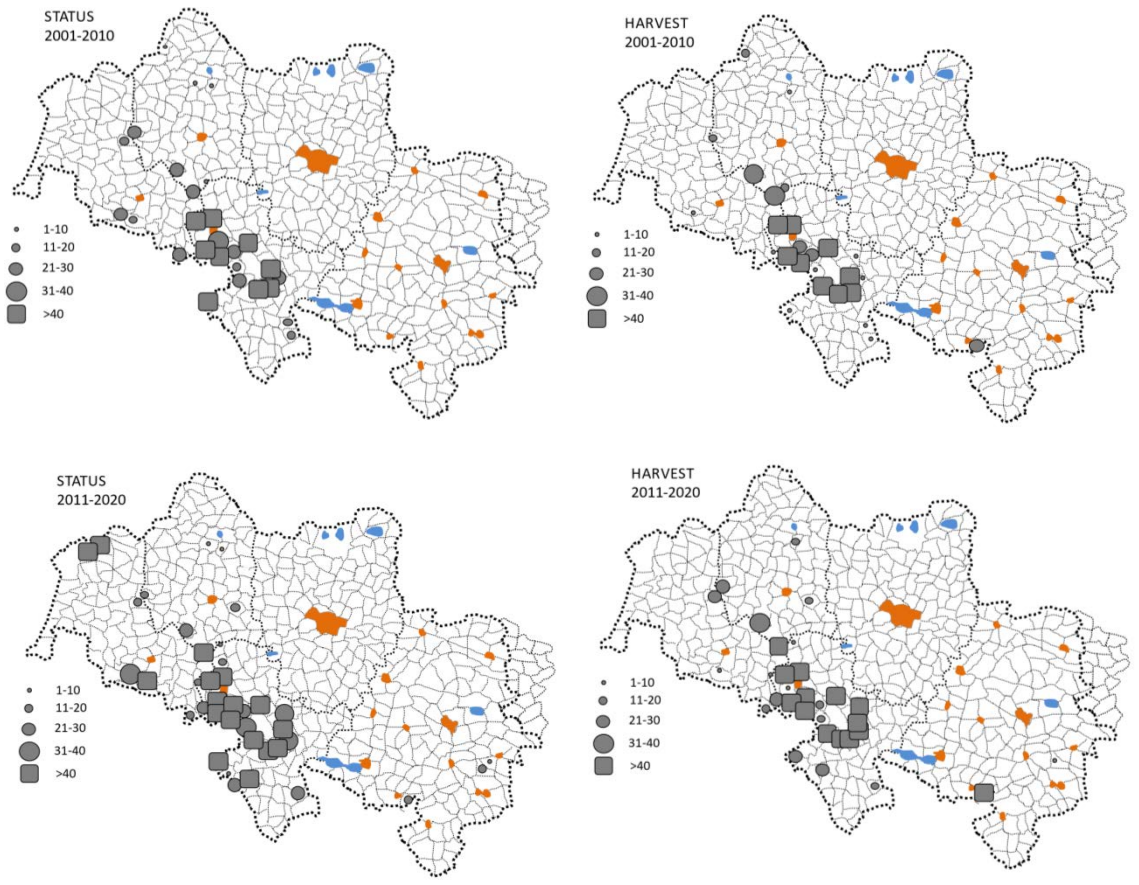

Fig. 3. Estimated mean number (maps in left column) and the number of harvested (maps in right column) mouflons in particular hunting districts in south-west Poland in 2001–2010 and 2011–2020.

Рис. 3. Розрахункова середня чисельність (карти в лівій колонці) та кількість добутих муфлонів (карти в правій колонці) в окремих мисливських районах на південному заході Польщі протягом 2001–2010 та 2011–2020 років.

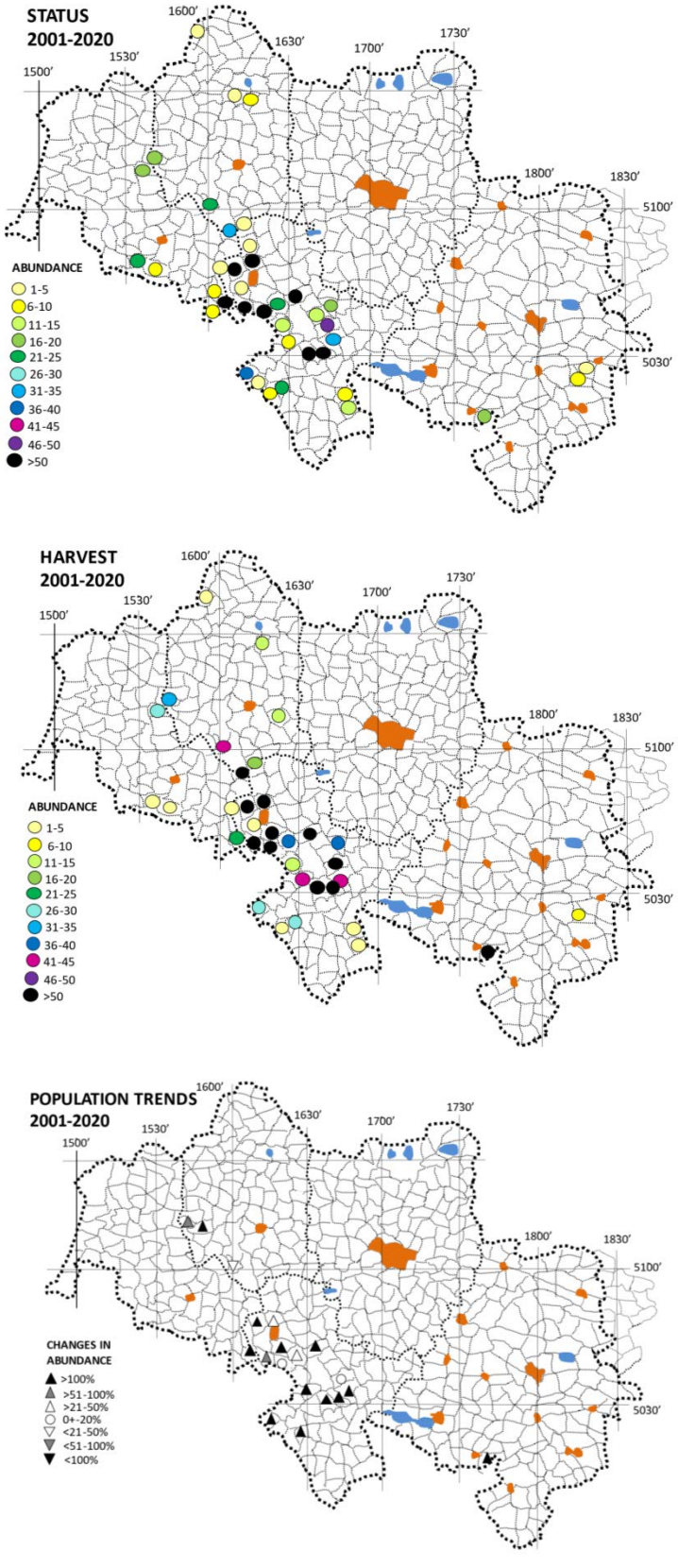

Fig. 4. Total abundance and population trends of mouflons in particular hunting districts in south-west Poland in 2001–2020.

Рис. 4. Загальна чисельність та динаміка чисельності муфлонів в окремих мисливських районах на південному заході Польщі протягом 2001–2020 рр.

Table 1. Population densities (individuals per 1000 ha) of the mouflon (average from 2001–2020). Symbols in the first column (C, E, F, …) refer to those in Fig. 1. Ecological density refers to the number of harvested mouflons/1000 ha of forest, whereas the crude density refers to the number of harvested mouflons/1000 ha of the total surface area

Таблиця 1. Щільність популяцій (особин на 1000 га) муфлона (середнє за 2001–2020 рр.). Символи в першій колонці (C, E, F, ...) відповідають даним на рис. 1. Екологічна щільність означає кількість добутих муфлонів на 1000 га лісу, тоді як загальна щільність — кількість добутих муфлонів на 1000 га загальної площі

#	Region	Hunting districts	Surface area [ha]		%	Popul. density	
			general	forests	forests	ecol.	crude
	Jelenia Góra Hunting Region						
C	West Sudeten Mts.	54, 55, 66, 71, 78, 80	28 332	20 249	71.5	0.01	0.01
	Legnica Hunting Region						
E	Southern (hills) part	62, 67, 69, 71, 72, 78	29 400	3754	12.8	0.16	0.02
	Wałbrzych Hunting Region						
F	Sudeten Upland	6, 7, 21, 31, 38, 39	26 700	3730	14.0	0.11	0.01
G	Middle Sudeten Mts.	10, 18, 23, 25, 28, 30	26 715	10 576	39.6	17.72	7.02
H	East Sudeten Mts.	54, 67, 69, 70, 72, 82	16 191	9491	58.6	0.09	0.05
	Opole Hunting Region						
P	Eastern part of the Opole Province	82, 83, 91, 123, 126, 129	41 259	20 721	50.2	0.02	0.01
T	Głubczyce Plateau	105, 109, 132, 133, 138, 146	34 320	2258	6.6	6.04	0.26

The crude population density ranged from 0.01 to 7.02 individuals per 1000 ha, whereas the ecological density ranged from 0.01 to 17.72 individuals per 1000 ha of forests in particular ecoregion in south-west Poland (Table 1).

In south-west Poland, the mouflon was introduced in 1902: five individuals were released in the Sowie Mts. [Pax 1925]. By 1915, this stock had increased to 4 rams and 16 ewes [Pax, 1925]. In 1920, 6 individuals were also introduced to the Karkonosze Mts. There were at least six additional introductions in the Sudety Mts. until 1945 [Kopij 2017]. As a result, the population increased to 134 individuals in 1925 [Pax 1925], reaching its maximum in 1939, i.e. 1100 individuals according to Nowak [1968], but only 200–300 individuals according to Nasiadka *et al.* [2021]. The number of 1100 individuals given for the year 1951 [Szczepkowski, 1951a–b] is evidently an error. Graczyk and Bereszyński [1992] estimated the number at 350–380 individuals in 1948, while Nowak [1968] estimated the number at 180–200 individuals in 1955. It looks as if Szczepkowski [1951a–b] assumed that the number from 1939 remained at the same level until 1951. However, due to illegal hunting, the population decreased during the Second World War, with only 350–380 animals recorded in 1948 [Graczyk & Bereszyński 1992].

From the 1950s until 1972, the mouflon population in south-west Poland fluctuated around 200 individuals [Nowak 1968; Kopij 2017), and later it began to decrease, reaching its minimum (36 individuals) around the year 1981 (Fig. 5). The population decreased, therefore, to the level of the early 1920s. However, in 1981–1990, the population recovered to 219 individuals, and to 576 individuals by the year 2001. This exponential growth continued until 2011, when it reached its second (the first one with 1100 individuals was in 1939) maximum, fluctuating around 1400–1500 individuals until 2016. The maximum number of 1478 individuals was reached in 2016. In the following years, it began to decline again, reaching the level of 1215 individuals in 2019 (Figs 5–6).

This general growth pattern in south-west Poland was especially evident in the Wałbrzych HR. There were only 20 mouflons in 1981. The population gradually increased until it reached c. 1300 animals in 2016, then it began to decrease, reaching a level of 1052 individuals in 2019 (Fig. 5). In Jelenia Góra HR, the population increased from 16 individuals in 1981 to 99 individuals in 1999, and then it began to decrease to 12 individuals in 2001. It again increased to 105 individuals in 2013, and again decreased to 52 individuals in 2019. In Legnica HR, only 8 animals were introduced in 1990, the population increased to 99 in 2005 and to 167 in 2015, and then it decreased to 99 in 2019. In Opole HR, 12 mouflons were introduced in 2002, the herd increased to 39 in 2009 and then began

to decrease, reaching the initial number 12 in 2019 (Fig. 5). The rapid increase of the mouflon populations in 2001–2020 was evidenced in most hunting districts (see Fig. 4).

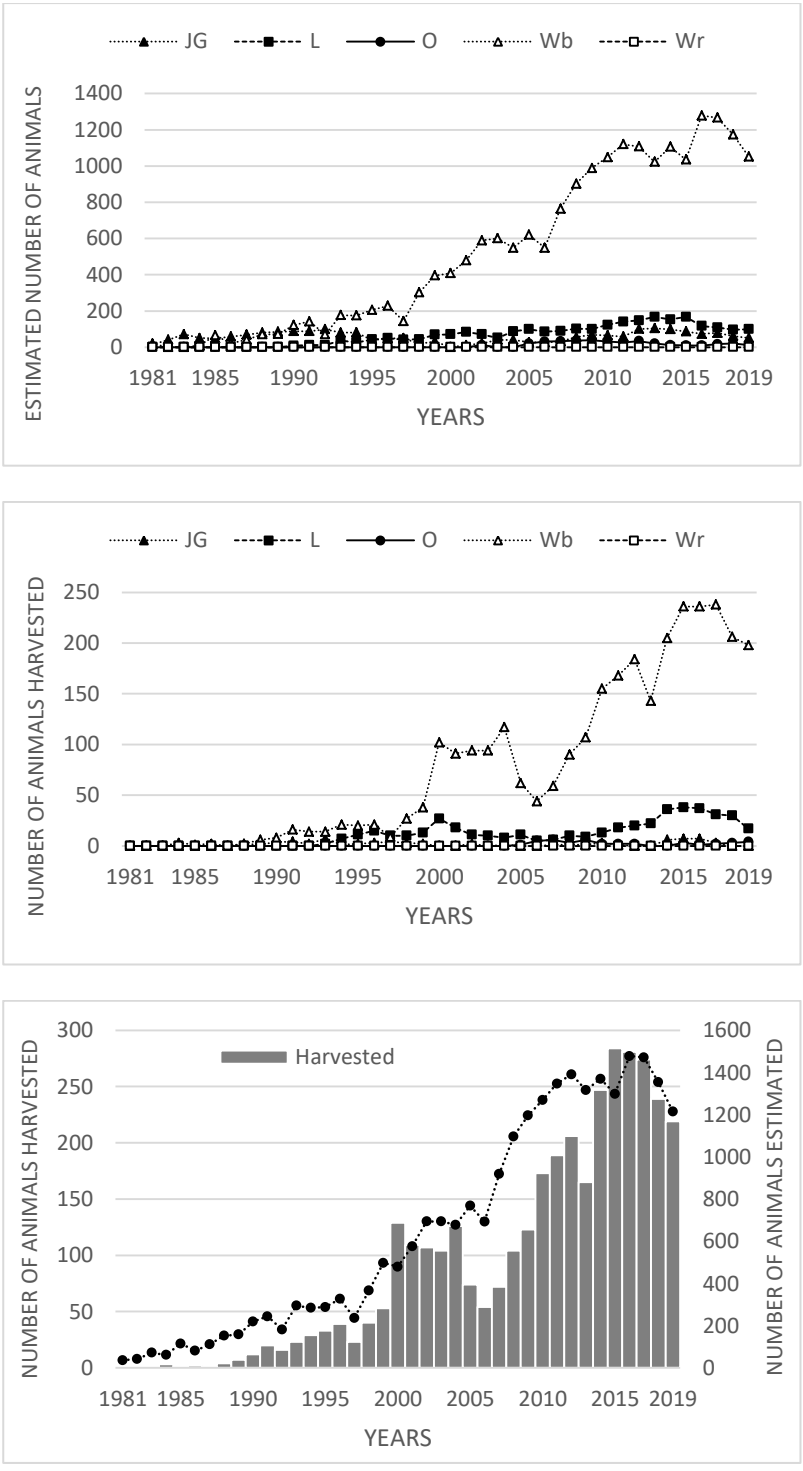

Fig. 5. Changes in the number of estimated and harvested mouflons in particular hunting regions (above) and in the whole of south-west Poland (below) in 1981–2020.

Рис. 5. Зміни кількості облікованих та добутих муфлонів в окремих мисливських регіонах (вгорі) та в цілому на південному заході Польщі (внизу) протягом 1981–2020 рр.

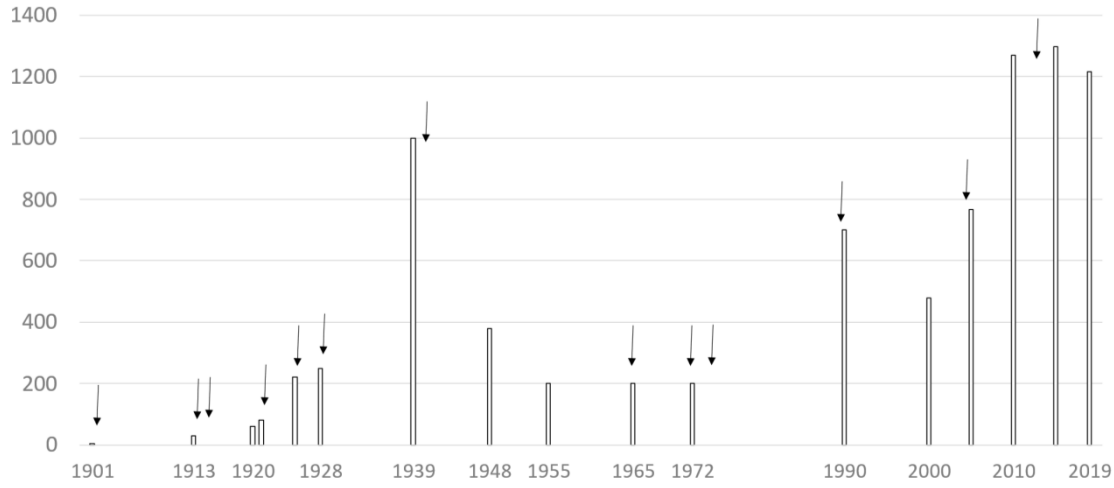

Fig. 6. Population dynamics of the mouflons (number of estimated individuals) in south-west Poland from its first introduction in 1902 to 2019. Arrows indicate introductions (after [Kopij 2017], with minor modifications).

Рис. 6. Динаміка чисельності муфлона (кількість облікованих особин) на південному заході Польщі з моменту його першої інтродукції в 1902–2019 рр. Стрілками вказано інтродукції (за [Kopij 2017], з невеликими змінами).

In total, 3584 mouflons were shot in south-west Poland in 1981–2019. In 1981–1989, only 17 individuals were harvested, whereas 235 in 1990–1999, 1002 in 2000–2009, and 2277 in 2010–2019. Most harvested animals originated from Wałbrzych (n = 3525), much less from the Legnica (n = 74) and Opole (n = 40) hunting regions (see: Fig. 5).

The global population size of clear mouflons is over 100 000, with 90% of the population in Europe, mainly in the Czech Republic (17 500), Germany (15 600) and Hungary (11 000) [Macdonald & Barrett 2001]. The Polish population is estimated at approximately 3 000 animals (Nasiadka *et al.* 2021]. The remaining mouflons live in isolated and small populations in the following provinces: Kujawsko-Pomorskie, Opolskie, Podkarpackie, Kieleckie, Pomorskie, Warmińsko-Mazurskie, and Wielkopolskie. The population in south-west Poland comprises therefore about half of that in the whole of Poland, but merely 8.6% of the population in the Czech Republic, and 1.5% of the global population.

In this study, the numbers of mouflons are based on hunting bags statistics and quotas. These numbers are slightly different from those given by Nowakowski *et al.* [2007]. They have counted 1447 (806 rams and 641 ewes) and 1324 mouflons in 2005 and 2007, respectively [Nowakowski *et al.* 2007]. In 2005, mouflons reached the highest population density in the following forests inspectorates: 10 ind./100 ha in Wałbrzych, 6 ind./100 ha in Jugów and Bardo, 4 ind./100 ha in Świdnica and Jawor, and 3 ind./100 ha in Lądek Zdrój. Much lower population density was recorded in Szklarska Poręba, Kamienna Góra and Duszniki Zdrój (1–2 ind./100 ha) and Złotoryja (<11 ind./100 ha) [Nowakowski *et al.* 2009].

Bobek *et al.* [2014] recorded similar numbers. They have estimated the Silesian population in 2014 at c. 2000 individuals, with 2/3 in the Sudety Mts. The main populations in the Sudety Mts. were recorded in the Sowie/Bardzkie Mts. (c.1000 ind.), Wałbrzyskie/Kamienne Mts. (c. 500 ind.), Kaczawskie Mts. (c. 350 ind.), Śnieżnik/Bialskie/Złote Mts. (c. 100 ind.), Stołowe Mts. (64 ind.), and Karkonosze Mts. (50–70 ind.).

The pattern of population growth in the whole of Poland was similar to that in Lower Silesia. Up to 1987 mouflons were restricted in Poland to the Sudety Mts. and Świętokrzyskie Mts. [Kupczyński 1975; Pucek & Raczyński 1983; Pucek 1984]. In the subsequent years, more and more mouflons were successfully introduced in other parts of the country.

However, at the beginning of the 21st century, 2/3 of muflons still occurred in the Sudety Mts. From 1954 to 1972, the population increased from c. 50 to c. 100 individuals. From 1972 to 1987, it increased to c. 500 ind., reaching c. 1500 ind. in 1993–2002 and further increasing to c. 2800 ind. by 2007, and 2901 ind. by 2014. In 1982–2014, populations increased in all mountains of the Sudety, except for the Karkonosze Mts., where the population decreased, and the Kaczawskie Mts. where it fluctuated [Nasiadka *et al.,* 2021].

There are several factors affecting the population size of mouflons in south-west Poland. Snowy winters and low winter temperature in mountains may cause high mortality especially among young animals. However, mouflons often migrate to lower parts of mountains in winter feeding on cultivated plants in arable lands. Lambs may be killed by foxes, racoon dogs, and stray dogs. Poaching may be a problem in some regions. Lack of protection and supplementary feeding in winter may contribute to low survival rates. Diseases and parasites can also play an important role. Mouflons may become a source of Lyme disease and salmonella infections in pets and farm animals [Gliński & Żmuda 2021]. They are also reservoirs of numerous parasites. The following endoparasites were recorded in mouflons living in Poland: *Cystocaulus nigrescens*, *Dicrocoelium dendriticum*, *Dictyocaulus filaria*, *Dictyocaulus viviparus*, *Muellerius capillaris*, *Neoascaris* sp., *Protostrongylus kochi*, *Strongyloides* sp., *Trichocephalus* sp., *Trichostrongylus* sp., and *Trichuris ovis* [Sołtysiak & Bartczak 1991; Bartczak & Okulewicz 2014; Balicka-Ramisz *et al.* 2017; Pacoń 1994; Pacoń *et al.* 2007].

For proper management, information on diet composition, niche breath and its overlap with other ungulates are necessary for assessing carrying capacity in the context of the guild of other ungulates, especially the red deer *Cervus elaphus*. In the same time, reliable population estimates of mouflons and other ungulate species is required, as well as proper assessment of the food base. The mouflon is a variable grazer, feeding on a wide range of plants. Marchend *et al.* [2013] listed 661 plant species consumed by the mouflon and calculated their overall diet composition as follow: grass—35%, forbs—24%, shrubs—16%, other—25%. If too much grass biomass is present in the mouflon's diet, it may indicate food shortage in the habitat [Bobek *et al.* 2014]. If excessive density is reached by mouflons or/and other ungulate species, the herd must be reduced or the habitat must be enriched (e.g. by clear cutting) and improved by supplementary feeding. If the density remains excessive for a prolonged time, the horns of rams often show abnormal growth. Sharp tips of abnormally coiled horns may cause neck wounds and subsequently death of 4–5 years old animals [Bobek *et al.* 2014; Wajdzik *et al.* 2014].

Mouflons may cause some damage to natural vegetation, decreasing local herb layer diversity and causing local extinction of specialised forest and rupicolous plant species [Szczęśniak 2011]. This may be, therefore, a problem in some protected areas such as national parks and reserves, where thermophilous forms of linden–maple forests and rupicolous habitats prevail. Mouflons should be restricted or dislocated from such areas, as management of mouflons in natural habitats must not collide with nature conservation.

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Handling of materials. All manipulations with living animals were carried out using non-lethal techniques and in compliance with the current legislation of Poland.

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