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POPULATION DECLINE OF GROUND SQUIRRELS, *SPERMOPHILUS* (RODENTIA, SCIURIDAE), IN UKRAINE AND FORECASTING TRENDS

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Population Decline of Ground Squirrels, *Spermophilus* (Rodentia, Sciuridae), in Ukraine and Forecasting Trends. Mezhzherin, S. V., Tytar, V. M., Rashevskaya, A. V. & Potopa, A. V. — Population trends of ground squirrels (*Spermophilus citellus*, *S. suslicus* and *S. pygmaeus*) in Ukraine were assessed using census data from the Plant Protection Inspection Service (1937–2007). Comparing these data with observations from the first decades of the 21st century suggests that ground squirrel populations have declined significantly, with absolute numbers reduced by at least 0.2–0.9% and geographical ranges shrinking by 1–2.3% compared to their historical levels in the mid-1950s. The current situation provides grounds for a negative forecast for the next few decades.

Key words: ground squirrels, *Spermophilus*, population size, census data, monitoring, extinction, Ukraine.

According to the current taxonomy, the fauna of Ukraine comprises three ground squirrels species of the genus *Spermophilus* F. Cuvier, 1825. These are the speckled ground squirrel, *S. suslicus* (Güldenstädt, 1770), with the range covering the Forest-Steppe zone and the Steppe zone in Right-bank Ukraine, the little ground squirrel, *S. pygmaeus* (Pallas, 1778) inhabiting the Steppe zone of Left-bank Ukraine and the Crimea, and the European ground squirrel *S. citellus* (Lin-

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naeus, 1766), occupying a narrow range within Ukraine in the frontier areas of Vinnytsia and Chernivtsy Oblasts bordering Moldova. It is also sporadically encountered in the plain areas of Transcarpathia. In the late 1990s, *S. suslicus* was divided into two parapatric species/semi-species based on a slight but diagnostically reliable level of genetic divergence between the two geographical forms (Zagorodniuk, Fedorchenko, 1995; Frisman et al., 1999; Brandler et al., 2015). They included the speckled ground squirrel *S. (suslicus) suslicus*, occupying the North of Kharkiv and Luhansk Oblasts, and the Podolian ground squirrel *S. (suslicus) odessanus* (Nordmann, 1840), inhabiting Right-bank Ukraine, Podillia and Volyn Oblasts and the north-eastern part of Left-bank Ukraine. Given their close genetic relationship, they should be considered representatives of *S.* (superspecies *suslicus*). All four taxa are listed in the fourth Red Data Book of Ukraine (2021) and have a conservation status within Ukraine. The speckled ground squirrel (*S. suslicus* s.l.) is critically endangered on the IUCN Red List (Rusin, 1924); the European ground squirrel (*S. citellus*) is an endangered species (Ćosić et al., 2024); and the little ground squirrel (*S. pygmaeus*) is a species of least concern, although population declines have been noted in some parts of its range (Cassola, 2017).

In the first half of the 20th century, ground squirrels were widespread in the agricultural landscapes of Ukraine's Steppe and Forest-Steppe zones (Averin, 1915; Brauner, 1923). Following the prevailing doctrine of the time, they were treated as pests to be eradicated by any means necessary. Reports from the late 1930s (Sokur, 1961) claimed that at least 5.6 million ground squirrels were eliminated annually. The total number of specimens exterminated reached 23.6 million per year in the second half of the 1940s. Although most of the poisoned animals remained in their burrows, making it impossible to estimate the precise number of deaths, this eradication method was considered the most effective. Furthermore, ground squirrels were killed for their cheap fur. The annual yield of skins steadily constituted over 5 million per year in the 1950s and the first half of the 1960s (Sokur, 1961; Volokh, 2004). This enables us to estimate that 30–50 million ground squirrels were eradicated per year in the early 1950s (Mezhzherin, 2008).

The 1980s saw a dramatic decline in species numbers and a reduction in their ranges. According to preliminary estimates (Mezhzherin, 2007; 2009 a, b), the census size of ground squirrel populations in Ukraine had dropped by at least a hundredfold by the early 21st century. However, the catastrophe is primarily attributed to habitat loss, colony fragmentation and likely inbreeding rather than direct eradication programmes. These ecological and genetic circumstances did not allow the populations to recover after massive elimination and consequently caused their dramatic decrease (Rusin, 2013; Rashevskaya, 2018).

Nowadays, there is a lack of comprehensive research on the population dynamics and current distribution of ground squirrels in Ukraine, with only local studies and population status data available. These investigations were conducted in the Crimea (Dulitskiy et al., 2002), the Eastern Ukraine (Zagorodniuk, Kondratenko, 2006; Taranenko et al., 2008; Bronskov, Timoshenkov, 2010; Rusin, 2013), Steppe of the Right-bank Ukraine (Rashevskaya, 2018; Sokolov, 2020), and the Western Ukraine (Dykyi et al., 2018; Batochenko, 2021). However, reliable data is available for the period 1930–2000, which allows analysis of population changes in these species based on counts carried out by the State Plant Protection Inspection Service in each oblast of Ukraine. Systematising, analysing and summarising these data makes it possible to assess the abundance of the remaining populations, identify critical points in their development and justify their conservation status more accurately.

Material and Methods

This research is based on data from the Annual Reports of the State Plant Protection Inspection Service on the Development and Distribution of Pests and Diseases of Agricultural Crops from 1937 to 2007. It focuses on the sections of these reports relating to ground squirrels. These materials were taken from the archives of the Institute of Plant Protection, National Academy of Agricultural Sciences of Ukraine. Ground squirrel populations were monitored in 22 oblasts of Ukraine and the Autonomous Republic of Crimea, with the exception of the Ivano-Frankivsk, Rivne and Zakarpattia Oblasts (see Table 1).

Table 1. Species of ground squirrels and census coverage of administrative districts, regions and natural zones of Ukraine

Zones	Oblast (Administrative region)	Districts numbers*	Species
Podolia, Volyn	Ternopil	1/9	<i>S. (suslicus) odessanus</i>
	Khmelnyskyi	8/11	<i>S. (suslicus) odessanus</i>
	Vinnysia	11/13	<i>S. (suslicus) odessanus</i> , <i>S. citellus</i>
	Lviv	1/11	<i>S. (suslicus) odessanus</i>
	Chernivtsi	1/6	<i>S. citellus</i>
	Volyn	2/7	<i>S. (suslicus) odessanus</i>
Right-Bank Forest-Steppe	Zhytomyr	6/11	<i>S. (suslicus) odessanus</i>
	Kyiv	5/12	<i>S. (suslicus) odessanus</i>
	Cherkasy	9/9	<i>S. (suslicus) odessanus</i>
Right-Bank Steppe	Kirovograd	12/12	<i>S. (suslicus) odessanus</i>
	Dnipropetrovsk	12/12	<i>S. (suslicus) odessanus</i>
	Mykolaiv	9/9	<i>S. (suslicus) odessanus</i>
	Odesa	14/14	<i>S. (suslicus) odessanus</i>
North-Eastern Region	Chernyiv	8/11	<i>S. (suslicus) odessanus</i>
	Sumy	8/10	<i>S. (suslicus) odessanus</i>
Left-Bank Forest-Steppe	Kharkiv	12/12	<i>S. (suslicus) suslicus</i> , <i>S. pygmaeus</i>
	Poltava	12/12	<i>S. (suslicus) suslicus</i> , <i>S. pygmaeus</i>
Left-Bank Forest-Steppe, Crimea	Lugansk	9/9	<i>S. (suslicus) suslicus</i> , <i>S. pygmaeus</i>
	Zaporizhzhia	12/12	<i>S. pygmaeus</i>
	Kherson**	9/9	<i>S. pygmaeus</i> , <i>S. (suslicus) odessanus</i>
	Donetsk	9/9	<i>S. pygmaeus</i>
	AR Crimea	7/10	<i>S. pygmaeus</i>

*The numerator demonstrates the number of districts in which censuses were conducted in the 1950–1960s; the denominator indicates total number of districts in the oblast in the first half of the 1960s.

***S. (suslicus) odessanus* lives in the right-bank part, *S. pygmaeus* live in the left-bank part of the natural zone.

Ground squirrel censuses were conducted according to an officially approved methods (Omeliuta et al., 1986) in two stages: early spring (March–April) and during the period of young dispersal (late May–June). According to the rules, visual route surveys were first conducted in places where the animals were likely to be found, along a line transcend at least one kilometer long and five meters wide. These included pastures, perennial grass and grain crops, as well as adjacent ravines, roadsides, edges of forest belts, banks of canals, etc. When animals, open burrows, or fresh soil mounds were found, a census plot of 100 by 100 or 50 by 200 meters was established in an area of up to 200 hectares. In the morning, before sunrise, all detected burrows were covered and tamped down, and in the afternoon, the number of open burrows was counted. In this way, data was obtained both on the areas occupied by ground squirrels and on the density of their settlements.

The reports summarize the census data per region in tabular form, including the size of the covered area, the percentage of the area occupied by ground squirrels and the average number of inhabited burrows per hectare. Both arable and uncultivated land was surveyed. A total of 41 annual reports are available, containing complete accounting information.

The results obtained for 1940–1991 are comparable as during that period the same count methods and equal coverage were applied. However, from 1992 to 2007, the coverage was sharply reduced due to a dramatic decline in ground squirrel populations. This caused the census scale to decrease several times across the country and artificially increased the relative indices.

Given the obvious trend of a decline in numbers, the use of a unified method for recording ground squirrel burrows in all regions of Ukraine under the control of a single administrative service provides grounds for using standard statistical methods. Our research aimed to assess ground squirrel abundance based on parameters summarized in annual regional reports. We considered the following parameters: 1) the total census area; 2) the percentage of the area occupied by ground squirrels; 3) the number of inhabited burrows per hectare within the occupied territory; and 4) the total number of inhabited burrows. The latter estimate is obtained by multiplying the absolute area of occupied territory by the number of inhabited burrows per hectare.

Results and Discussion

Transition to crisis (comparison of 1950s and 1980s). The first half of the 1950s was characterised by the most intensive ground squirrel counts, when the populations still exhibited pristine population dynamics. The areas with the highest rodent densities were located in the Mykolaiv and Zaporizhzhia Oblasts and the Autonomous Republic of Crimea, where the rodents were found in over 70% of the studied areas (Fig. 1). Ground squirrels were found in 50–60% of inhabited zones in the Odesa, Kherson, Kirovohrad, Dnipropetrovsk and Donetsk Oblasts. In the Cherkasy, Kyiv and Luhansk Oblasts, inhabited areas covered 30–40%. In the north-east, in the Kharkiv, Poltava, Sumy and Chernihiv Oblasts, ground squirrel habitats covered 20–30% of the surveyed territories. In western Ukraine, in the Vinnytsia, Khmelnytskyi, Ternopil, Lviv and Volyn Oblasts, ground squirrel habitats covered 5–15% of the surveyed territories. However, the northern and western regions were not covered by complete censuses. In these areas, ground squirrels are represented by enclaves, which often have a high population density. On average, the regional occupation level during that study period amounted to 32.9% of the surveyed territories.

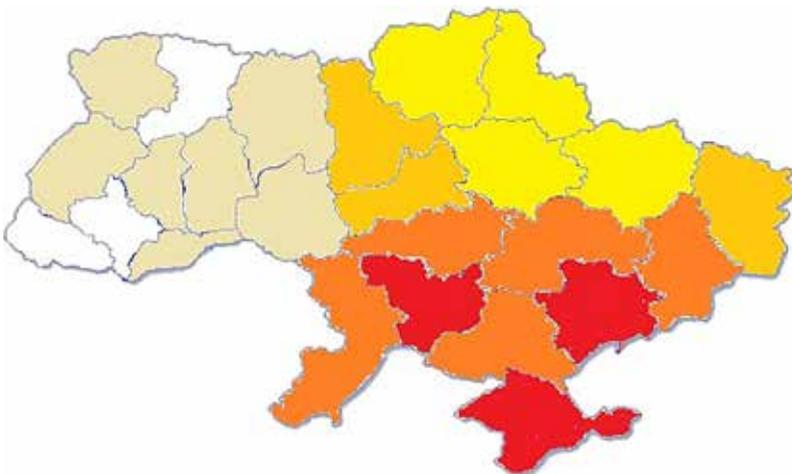


Fig. 1. Zones of ground squirrel censuses by State Plant Protection Inspection Service in 1950–1955 per oblasts of Ukraine. The average percentage of occupied areas per regions: over 70% — red; range 50–60% — orange; range 30–40% — orange-yellow; range 20–30% — bright yellow and range 5–15% — grey-yellow, no data/no censuses — white



Fig. 2. Zones of ground squirrel censuses by State Plant Protection Inspection Service in the 1980s per oblasts of Ukraine. The average percentage of populated areas: 5–1% — grey-yellow, less than 5% — pale pink, no data/ no censuses — white

By the end of the 1980s, in regions with a high number of ground squirrels, the occupation of areas decreased by 4–20 times (Fig. 2). In regions with a traditionally low occupation, the censuses ceased. Starting from the 1960s, Chernivtsy, Lviv, Volyn, Khmelnytskyi and Ternopil Oblasts were excluded from the counts as well as Chernihiv Oblast since the early 1980s, Zhytomyr Oblast since 1988, and Cherkasy Oblast since 1995. As a result, from the early 1950s to the end of the 1980s, the aver-

Table 2. A comparison analysis of ground squirrel censuses parameters obtained by Plant Protection Inspection Service in the initial and final periods

Parameters and indexes		Years		%
		1948–1955	2000–2007	
Total census areas (millions ha)	Σ	13.85	3.82	27.6
	M ¹ ± SE	0.70 ± 0.12	0.18 ± 0.07	25.7
	M ² ± SE	0.95 ± 0.13	0.27 ± 0.10	28.4
Occupied areas (millions ha)	Σ	42.0	1.03	2.4
	M ¹ ± SE	0.29 ± 0.07	0.06 ± 0.03	2.1
	M ² ± SE	0.47 ± 0.1	0.1 ± 0.05	2,1
Percentage of occupied areas	M ¹ ± SE	32.36 ± 5.08	5.08 ± 1,48	15.7
	M ² ± SE	43.40 ± 5.92	7.98 ± 1.94	18.4
Inhabited burrows per ha	M ¹ ± SE	4.58 ± 0.58	1.71 ± 0.39	37.3
	M ² ± SE	5.06 ± 0,56	2.76 ± 0,38	54.5
Total number of inhabited burrows (millions)	Σ	44.60	0.47	1.1
	M ¹ ± SE	1.68 ± 0,84	0.011 ± 0,011	0.7
	M ² ± SE	3.22 ± 1,16	0.034 ± 0.015	1.1

Note. % — percentage of the 2000–2007s index in comparison with the 1948–1955s index; Σ — summarised on the oblasts level values; M — averages and standard errors obtained from oblast level indices; upper index 1 — calculated from 21 oblasts; upper index 2 — calculated from 14 oblasts (it shows data where censuses continued into the 21st century).

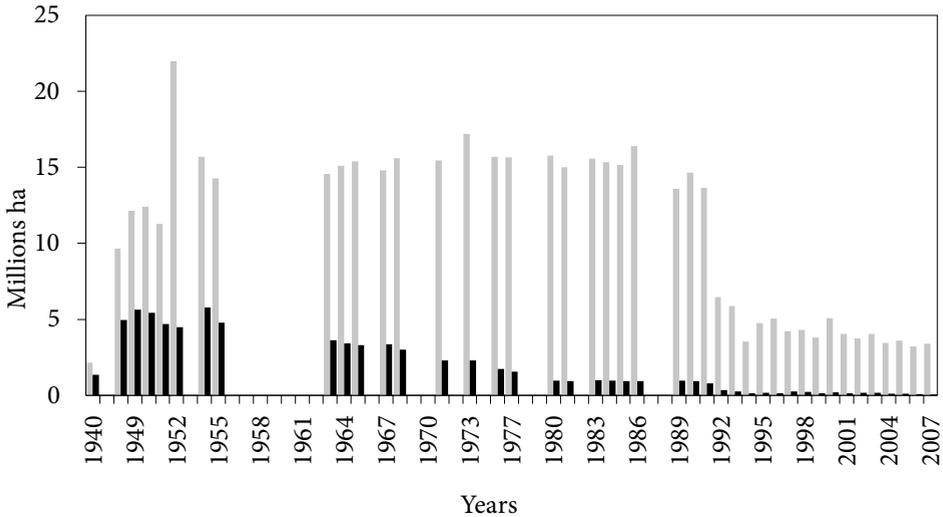


Fig. 3. The total size of the areas where Plant Protection Inspection Service conducted censuses of ground squirrels (grey) and the sizes of occupied areas (black) for the period of 1940–2007. Approximation by polynomial function. The correlation coefficient between the size of the occupied territory and the year of observation is highly significant ($r = -0.90$; $n = 42$; $p < 0.001$)

age occupation by ground squirrels in the administrative regions of Ukraine decreased by 7.5 times, making up only 4.3% of surveyed areas.

In the first half of the 1950s, the maximum population density was registered in the Crimea (9.8 burrows/ha), in enclaves of Chernivtsy (7.9 burrows/ha) and Volyn (7.8 burrows/ha) Oblasts along with Kharkiv (6.6 burrows/ha) and Donetsk (6.5 burrows/ha) Oblasts. The minimum values were reported from Lviv (0.1 burrows/ha), Zhytomyr (1.4 burrows/ha) and Khmelnytskyi (1.9 burrows/ha) Oblasts. The aver-

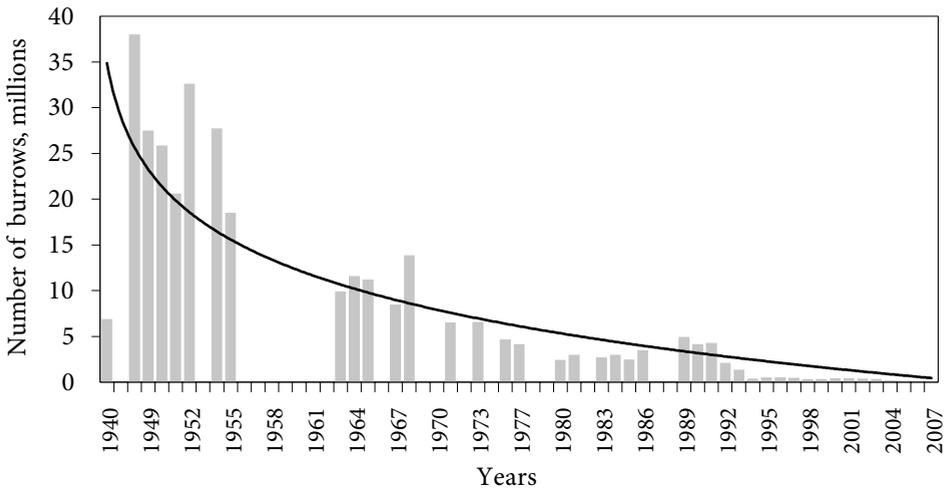


Fig. 4. Changes in the number of revealed inhabited burrows of ground squirrels (millions) during the censuses conducted by Plant Protection Inspection Service. A logarithmic function approximation. The value of the correlation coefficient between the number of occupied burrows and the year of observation is highly significant ($r = -0.84$; $n = 42$; $p < 0.001$)

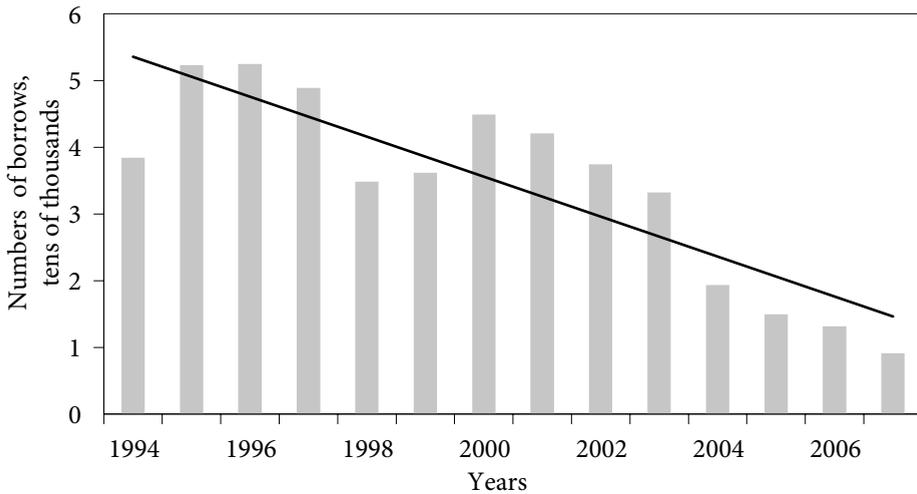


Fig. 5. Changes in annual average number of inhabited burrows by ground squirrel and its standard errors during the censuses conducted by the Plant Protection Inspection Service between 1994–2007. The area covered by the annual censuses decreased considerably and non-linearly (see Fig. 3). The correlation coefficient between the number of occupied burrows and year of observation is highly significant ($r = -0.87$; $n = 11$; $p < 0.001$)

age density at the regional level during that period made up 4.8 burrows/ha. In the late 1980s, this index dropped to 2.6 burrows/ha.

Crisis (comparison 1950s and 2000s). Over the 70 years of monitoring, its parameters have significantly changed (Table 2, Fig. 3–4). When comparing the surveyed areas in 1948–1954 and 2000–2007, the area of census decreased to 25.7–28.4%, average percentage of territory occupied by ground squirrels to 2.1–2.4%, number of burrows per hectare to 37.3–54.3% and number of inhabited burrows to 0.7–1.1% (Table 2).

The assessment of the number of burrows is principal since this approach allows partially leveling out the reduction in the census coverage in 1991–2007. Using this calculate on method, the drastic decrease in ground squirrel populations becomes very clear (Fig. 4). Between 1948 and 1955, an average of 1.68 million burrows were inhabited per year. However, this number plummeted to a mere 0.011 million, or just 0.7%, between 2001 and 2007. Comparing the maximum value obtained in 1948 (38 million inhabited burrows; censuses were conducted in only 17 regions that year) with that in 2007 (0.09 million) shows that ground squirrels currently comprise no more than 0.2% of their former numbers.

Current situation (2000–2024). Analysis of burrow numbers from 1994 to 2007 shows a 3.5 — fold reduction, whereas census coverage decreased by only 1.2 times (Fig. 5). This indicates an ongoing crisis.

Since 2000, reliable finds of ground squirrels have been confirmed in 16 oblasts of Ukraine (Fig. 6). These were either single burrows or small colonies consisting of between one and two hundred specimens. Large settlements consisting of several thousand individuals were much less frequent and only present in the early 2000s.

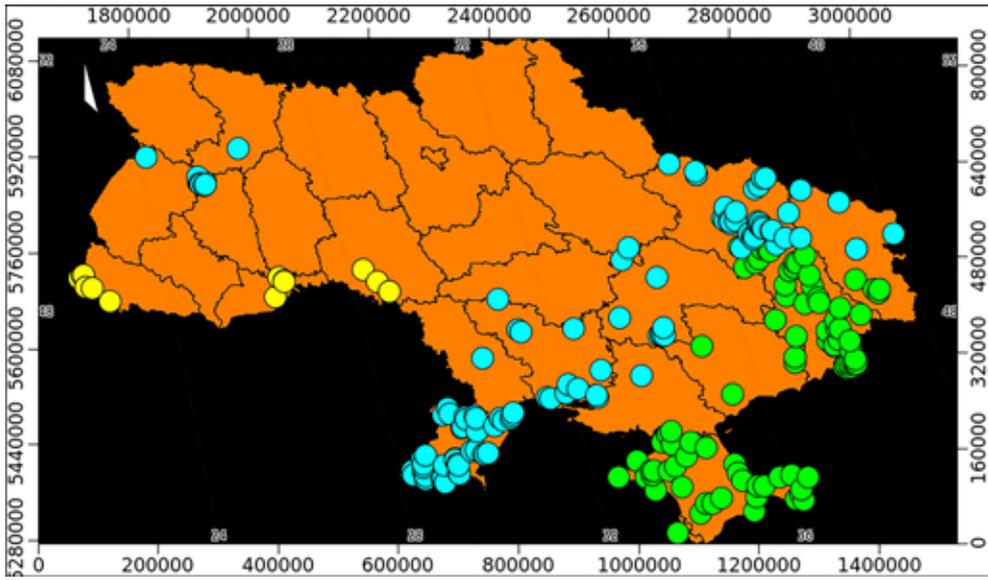


Fig. 6. Locations of ground squirrels records in Ukraine in 2000—2024s discussed in this paper: *S. citellus* — yellow circles, *S. (superspecies suslicus)* — blue, *S. pygmaeus* — green

Relatively numerous findings of populations of *S. (suslicus) odessanus* of 1–2 hundred individuals after 2010 have been reported only from Odesa Oblast (Rashevskaya, 2018). Colonies of the semispecies, numbering up to 100 (usually 10–20) specimens, at the end of 2010s remained in Lviv (Dykyi et al., 2018; Batochenko, 2021), Rivne (Batochenko 2021; Ilchuk, 2021), Kirovohrad, Dnipropetrovsk, Mykolaiv, Wright-Bank part of Kherson (Rashevskaya, 2018) Oblasts. The probable presence of populations *S. (superspecies suslicus)* was indicated Rusin (2013) in Poltava Oblast. A colony of Podolian ground squirrel was found Skliar et al. (2018) in the south of Sumy Oblast. The some few colonies were found in Kharkiv (Tokarsky, 2014; Viter, 2021) and Luhansk (Rusin, 2013) Oblasts.

The populations of *S. pygmaeus* were found in the first and at the very beginning of the second decade of the 21st century from Donetsk Oblast (Bronskov, Timoshenkov, 2010; Rusin, 2013) and the AR Crimea (Dulitsky et al., 2002; Gavryliuk, 2021). Isolated populations from several dozens to a few hundred individuals are still quite common. The only colony numbering 2–3 thousand individuals survived until 2009 (Rusin, 2013). Populations of the little ground squirrel are experiencing a dramatic decline, even in protected territories. In the Black Sea Biosphere Reserve the density of burrows per hectare has plummeted by nearly a hundredfold from the mid-1980s to the mid-2010s (Selyunina, 2015). In many cases, these animals are now so scarce that finding even a single burrow is a rare occurrence.

Only a few *S. citellus* colonies were recorded in the Chernivtsi and Vinnytsia Oblasts (Storozhenko, 2021; Vorona et al., 2019). These frequently only included findings of single individuals. Rare finds of colonies that took place in the 2000s in Transcarpathia were not confirmed in the 2010s, although the authors of the study (Barkaszi, Zagrodniuk, 2018) do not exclude presence of European ground squirrel in the region.

Assessment of remaining resources. According to the Plant Protection Inspection Service and well-known trends of the first decades of the 21st century, the assessments of current ground squirrel resources (the absolute number of mature individuals) in Ukraine are within 0.1–1% of those in the mid-20th century. However, we tend to assume that this value is even overrated, while the actual situation is much worse. Such a critical conclusion is firstly based on the fact that during 1992–2007 the counts were concentrated in the areas with still remaining quite numerous ground squirrel populations that led to the overestimation at the final census stages. Secondly, it is also impossible to rule out artificial underestimation of the population in the middle of the 20th century and overestimation at the end of the 20th and beginning of the 21st century (Rusin, 2013). In the former case, the aim was to demonstrate the effectiveness of the fight; in the latter, it was to preserve the traditional system of plant protection. In this regard, a good example is the situation in Kyiv Oblast, where, according to official statistics, the population size of the Podolian ground squirrel remained quite high until 2007. Nevertheless, zoologists are well aware that this species had almost disappeared from the southern part of the Kyiv Region (the Obukhiv and Kaharlytskyi Districts) by the early 1970s. In the neighboring Cherkasy Oblast, ground squirrels have not been counted since 1995.

The maximum number of ground squirrel inhabited burrows recorded within the territory of Ukraine, obtained in 1948, was about 38 million. This estimation are clearly underestimated so a number of oblasts are not included in census as well as AR Crimea, where in the 1930s plant protection stations counted about 27 million burrows at average density 11.7 burrows per ha (Dulitsky et al., 2002). As official censuses presumably only recorded 20–50% of burrows/colonies, it can be concluded that the ground squirrel population in Ukraine amounted to between one and two hundred million between 1930 and 1950. Attempts to estimate the total number of ground squirrels in the early 2000s (Bronskov et al., 2010) revealed a figure of just over 100,000 — only 0.1% of the previous estimate.

Thus, even after the eradication was completely ceased, the 21st century has brought a clear decreasing trend. These negative changes are primarily caused by genetic processes in small, isolated populations (Biedrzycka & Konopiński, 2007; Ćosić et al., 2013) and succession leading to overgrowth by dense vegetation. This is confirmed by observations in the Lviv and Rivne Oblasts carried out between 2015 and 2020 (Batochenko, 2021), which show that the size of local populations decreased by 2.5–10 times and that some populations became extinct when grazing stopped. Similar negative trends have been observed in the Odesa (Rashevskaya, 2018; Sokolov, 2020) and Donetsk (Rusin, 2013) Oblasts, which are core areas for ground squirrels in Ukraine.

Therefore, even after the eradication program ended, the number of ground squirrel populations continued to decline in places that initially seemed to have favourable conditions for them. It can be concluded that this decline will continue into the mid-2020s. Thus, it cannot be ruled out that the total number of ground squirrels in present-day Ukraine will amount to tens of thousands of individuals, meaning that the current population is estimated to be around 0.01% of the mid-1950s level. The grounds for this conclusion are as follows. Firstly, the 2010 *S. pygmaeus* population in the Left Bank Steppe was estimated at around 5,000 individuals (Rusin, 2013).

Secondly, experts estimate that there are no more than 5,000 little ground squirrels in Crimea, since official censuses indicate that their numbers have always been lower than in the Luhansk or Donetsk regions. Thirdly, the state of the speckled ground squirrel populations in the Right Bank Steppe was assessed. Thirty-eight populations of *S. (suslicus) odessanus* were identified here, most of which were found to consist of single burrows or a few sightings, with the largest colonies numbering no more than two hundred individuals (Rashevskaya, 2018). Fourthly, there has been a catastrophic decline in the size of Podolian ground squirrel populations in western Ukraine (Dykyi et al., 2018; Batochenko, 2021).

In any case, the catastrophic decline in population numbers and reduction in range of all four species of ground squirrel in Ukraine is undeniable: primary collapse occurred by the early 1970s, with extinction occurring by the end of the 20th century and into the 21st century. The situation with *S. suslicus* is especially dangerous (Shekarova et al., 2008). The greatest changes occurred at the western edge of their geographic range, as evidenced by populations in Ukraine and the Central Black Earth Region of the Russian Federation (Sapelnikov & Sapelnikova, 2021), as well as Eastern Poland (Ziółek et al., 2017).

Forecast of the existence of ground squirrels in Ukraine. Based on the current ecological situation and the characteristics of the population structure, the disappearance of ground squirrels from the western edge of their range can be attributed to a global trend. Consequently, we can confidently predict a further decline in population numbers and a reduction in the ranges of all four species. Furthermore, even if the currently available environmental protection measures are implemented, they do not guarantee the conservation of ground squirrels in Ukraine over the next few decades.

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