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VOLE ABUNDANCE IN AGRICULTIRAL LANDS OF UKRAINE: ANALYSIS BASED ON ARCHIVES OF THE MIDDLE 20th–EARLY 21st CENTURIES

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Vole Abundance in Agricultural Lands of Ukraine: Analysis Based on Archives of the Middle 20th–Early 21st Centuries. Mezhzherin, S. V., Rashevska, A. V., Potopa, A. V. — The research on the **spatial distribution** and long-term dynamics of the voles *Microtus arvalis* (Pallas, 1778), *M. levis* Miller, 1908, *M. socialis* (Pallas, 1773) in agricultural landscapes of Ukraine was carried out using the census data of the State Plant Protection Inspection Service during 1948–2006. It revealed that the maximum density of colonies and regular abundance outbreaks occurred in Western and North-Western regions and the Forest-Steppe zone of Right-bank Ukraine. These areas either only supported *M. arvalis* or this species significantly dominated over *M. levis*. The low abundance with relatively stable populations was reported from the Left-bank Steppe oblasts, occupied by *M. levis* and *M. socialis*. Two main changes in abundance are distinguished over time. The first was a dramatic increase throughout Ukraine in the 1980s when a considerable part of arable lands were used for plantations of perennial grasses, and the second was a gradual decrease, especially pronounced in western oblasts of Ukraine among populations of *M. arvalis*. The comparison of the average population parameters between the early period of research in 1948–1954 and its final stages in 2000–2006, indicates a 2.8-fold decrease in the number of inhabited burrows. Given the additional circumstances, the decrease could be even higher, 5–8 or even 10 times. This reduction is mainly associated with the loss of meadow ecosystems. The population decline and the absence of mass reproduction in agroecosystems of voles provide a basis for prohibiting rodenticides in fields.

Key words: censuses, mouse-like rodents, agricultural landscapes, *Microtus*, long-term dynamics, rodenticides, Ukraine.

Studies on animal resources, assessment of their status and losses chiefly induced by human activities, are among current priority issues of zoology and ecology (Butchart et al., 2010; Barnosky et al., 2011). The key factors putting the populations at risk and leading to negative dynamics include the destruction of historically developed landscapes and ecosystems, hunting and chemical extermination, global climate change (Hughes, 2000; Alford & Richards, 2009; Cardillo et al., 2006; Dirzo & Raven, 2003; Sanchez-Bayo, Wyckhuys, 2019).

The analysis of the species composition and population size carried out in the past decades throughout vast areas indicates a reduction in the species diversity primarily due to the elimination of rare animals and a decrease in the population sizes of common species (Dirzo et al., 2014). The studies of mammals mainly focused on usually the most vulnerable large species (Schipper et al., 2008; Ritchie, 2022). The situation with small species, in particular mouse-like rodents, making up the bulk of the mammal biomass in ecosystems, still remains poorly studied. However, the available reports on the number dynamics of mouse-like rodents, primarily herbivores (Cornulier et al., 2013; Gouveia et al., 2015; Wan et al., 2022), allow suggesting that their populations in human-modified areas tend to decrease.

Of particular interest is the dynamics of mouse-like rodent populations in anthropogenically altered landscapes, particularly in agricultural habitats. These are areas that are usually studied in great detail, and the changes to them are often radical (Millán de la Peña et al., 2003; Heroldová et al., 2007; Gentilia et al., 2014). In this regard, the censuses of rodent pests, systematically performed by State Plant Protection Inspection Services in Ukraine from the 1930s to the 2000s, are highly valuable. The abundance of mouse-like rodents in agricultural lands and adjacent areas was monitored since the mid-1950s in all oblasts of Ukraine according to specially developed methods suitable to vole colonies registration (Omeliuta et al., 1986). This provides a unique opportunity to assess the population dynamics within such a big European country like Ukraine, 54% of which area is ploughed, and to reveal more global trends taking the literary data into account. In addition, this study has another specific purpose. Until now, the official agricultural policy of Ukraine has considered mouse-like rodents dangerous agricultural pests. Consequently, toxic substances are massively and often directly applied to the crop, harming the whole biota. However, if a dramatic decline in mouse-like rodent populations is identified, it will put under question their current status as a dangerous pest and can be used as a justification to forbid the use of rodenticides.

Material and Methods

This research is based on data from the annual reports of the State Plant Protection Inspection Service for the period from 1948 to 2006. A total of 46 reports were used, obtained from the archive of the Institute of plant protection of the National Academy of Agrarian Sciences of Ukraine. In 1948–1954, the monitoring covered 15 important agricultural oblasts. In some western oblasts as well as the Sumy Oblast the censuses were not regular. The first reports do not include The Cherkasy Oblast, formed in 1954 as well as the Autonomous Republic of Crimea, which became part of Ukraine in the same year. Since the mid-1960s, counts were carried out in all oblasts.

The censuses of mouse-like rodents were conducted according to the developed methodology (Omeliuta et al., 1986), focusing on the vole colonies. This procedure involves the steps as follows. Firstly, it visually reveals the location of colonies by burrows and mounds in the ground as characteristic evidence of their presence. In the autumn and spring seasons, the plantations of perennial grasses and winter crops are investigated, while in the summer the survey encompasses perennial grasses, vegetables and other crops, including areas along the roads, forest shelter belts and reclamation canals. The transect method is used to count colonies when the boundaries between them are obvious. In this case, a 1 km-long route is made within the surveyed area and all burrows are counted within a 5 m-wide strip. In case with overlapping colonies, the area is divided into plots and the number of burrows is

Table 1. **Geographic regions, oblasts, types of vole community and vole species composition in agricultural lands throughout Ukraine**

Regions	Oblasts	Types of community	Species
North-West and West	Rivne	A-1	*M. arvalis*
	Volyn	A-2	*M. arvalis*
	Lviv	A-3	*M. arvalis*
	Ivano-Frankivsk	A-4	*M. arvalis*
	Zakarpattia	A-5	*M. arvalis*
	Chernivtsy	A-6	*M. arvalis*
	Ternopil	A-7	*M. arvalis*
	Khmelnytskyi	A-8	*M. arvalis*
	Vinnytsia	A-9	*M. arvalis*
	Zhytomyr	AAL-1	*M. arvalis, M. levis**
Centre and North-East	Kyiv	AAL-2	*M. arvalis, M. levis**
	Cherkassy	AAL-3	*M. arvalis, M. levis**
	Chernyhiv	AAL-4	*M. arvalis*, M. levis*
	Sumy	ALL-1	*M. arvalis*, M. levis*
	Kirovohrad	ALL-2	*M. arvalis*, M. levis*
	Poltava	L-1	*M. arvalis*, M. levis*
	Kharkiv	L-2	*M. arvalis*, M. levis*
South	Dnipropetrovsk	ALL-3	*M. arvalis*, M. levis*
	Mykolaiv	ALL-4	*M. arvalis*, M. levis*
	Odesa	ALL-5	*M. arvalis*, M. levis*
	Luhansk	L-3	*M. levis*
	Donetsk	L-4	*M. levis*
	Kherson**	LS-1	*M. levis, M. socialis*
	Zaporizhzhia	LS-2	*M. levis, M. socialis*
	AR Crimea	LS-3	*M. levis, M. socialis*

* In vole colonies the species is in clear minority; ** In the Right-Bank part of the region *M. levis is* predominant, in the Left-Bank part — *M. socialis.*

calculated within the count area of 0.25 ha. Since not all colonies might be inhabited, at the end of the day researchers slightly trample down the burrows and in the morning they count the number of opened ones.

The Inspection Service reports present generalised census parameters by oblasts: square area of surveyed sites; percentage of sites where the colonies were found; average number of inhabited burrows per hectare. Correspondingly, the characteristics used in the resource assessment were as follows: the size of sites where the censuses were conducted; the square area of inhabited sites as a percentage of the total census area; the average number of inhabited burrows per hectare within inhabited sites; the absolute number of inhabited burrows, calculated as the product of the average number of inhabited burrows on the area of occupied territories. These parameters were analysed using standard statistical procedures: comparison of averages by periods and regions based on t-test; verification of the reliability of trends by correlation analysis; approximation of regressions using Excel algorithms.

The censuses per administrative regions (Table 1) were summarised by species composition of voles in agricultural lands and by three main geographic regions based on climate zoning of Ukraine (Babichenko et al., 1983).

The main inhabitant of most agricultural landscapes in Europe is the common vole *Microtus arvalis* (Pallas, 1778) (Heroldová et al., 2007; Jacob et al., 2020). The similar situation partly occurs in Ukraine (Sokur, 1965; Omeliuta et al., 1986), whose colonies usually were the census priority. However, in addition to this species, two more species of voles are widespread in the agricultural lands. The range of *M. arvalis* covers the western, central and northern parts of Ukraine. In the southern and eastern parts, this species replaces *M. levis* Miller, 1908 whereas in the zone of dry steppes of the Left-bank Ukraine and the Crimea, the main species of agricultural landscapes is *M. socialis* (Pallas, 1773), where it practically displaces *M. levis* in the agricultural lands (Zagorodniuk, 2005; Mezhzherin, Lashkova, 2013; Mezhzherin et al., 2017). Mice of the genera *Mus* and *Apodemus* s. l. are also found in high numbers especially in agricultural landscapes of Steppe but their burrows are almost invisible in uncultivated areas or solitary in crops that make their contribution to the counts insignificant compared to the vole colonies.

Results

Spatial distribution. The regions compared according to the average values of abundance parameters of mouse-like rodents for the period 1948–2006 show the following trends (Table 2). The maximum values were reported from the regions with almost exclusive encounters of *M. arvalis* (A regions) or from the areas where this species significantly dominates over *M. levis* (AAL regions). The minimum abundance were in the regions occupied only by *M. levis* (L regions) and in the regions inhabited by *M. socialis* and *M. levis* (LS regions). The values similar to the latter were obtained in the regions where agrosystems chiefly supported *M. levis* (ALL regions). This pattern applies to all three parameters, whereas the most obvious differences are in the number of inhabited burrows per hectare (Table 2; Fig. 1).

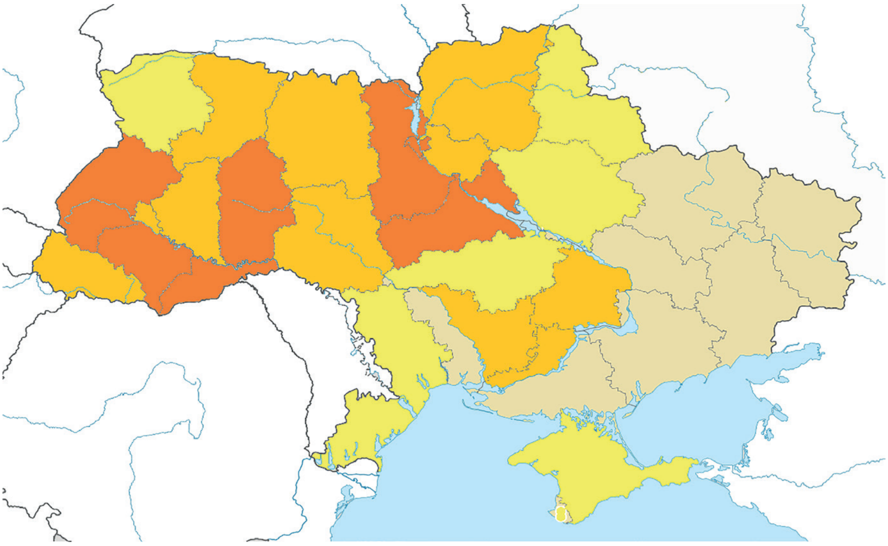

Fig. 1. The density of vole colonies in agricultural lands per oblasts: grey-yellow — averagely 3–5 inhabited burrows per ha, yellow — 6–10, orange — 10–15, red — more than 15

Table 2. **The means and standard errors of census parameters of voles populations for 1948–2006 with different community vole types in agricultural lands throughout Ukraine**

Types of community	Surveyed area, thou. ha	Inhabited area, %	Number of inhabited burrows per ha	Number of revealed inhabited burrows, thou.	N
A	306.6 ± 13.8	50.8 ± 1.1	14.7 ± 1.0	801.9 ± 58.9	352
AAL	332.6 ± 18.4	43.2 ± 1.4	16.9 ± 2.0	923.0 ± 141.4	159
ALL	722.7 ± 29.5	29.0 ± 1.2	6.7 ± 0.8	245.0 ± 43.9	205
L	760.3 ± 32.2	23.6 ± 1.0	4.6 ± 0.3	117.0 ± 13.3	168
LS	747.7 ± 32.5	24.2 ± 1.0	4.8 ± 0.85	123.3 ± 16.5	119

Note. N — total number of annual censuses per oblast.

Table 3. **The means and standard errors of census parameters of voles populations for 1948–2006 in geographic regions of Ukraine**

Regions	Surveyed area, thou. ha	Inhabited area, %	Number of inhabited burrows per ha	Number of revealed inhabited burrows, thou.	N
North-West and West	340.3 ± 13.3	48.8 ± 1.0	14.7 ± 0.9	757.2 ± 56.2	393
Centre and North-East	596.3 ± 28.6	39.1 ± 1.1	12.1 ± 1.3	629.7 ± 85.5	282
South	747.7 ± 19.5	22.4 ± 0.7	4.7 ± 0.4	120.2 ± 15.5	328

Note. N – total number of annual censuses per oblast.

The abundance parameters in natural zones vary in accordance with the species composition (Table 3). The maximum values were registered in the West and North-West of Ukraine (Forest and Western Forest-Steppe zones), the minimum values were in the Steppe of the South of Ukraine; intermediate values were re-

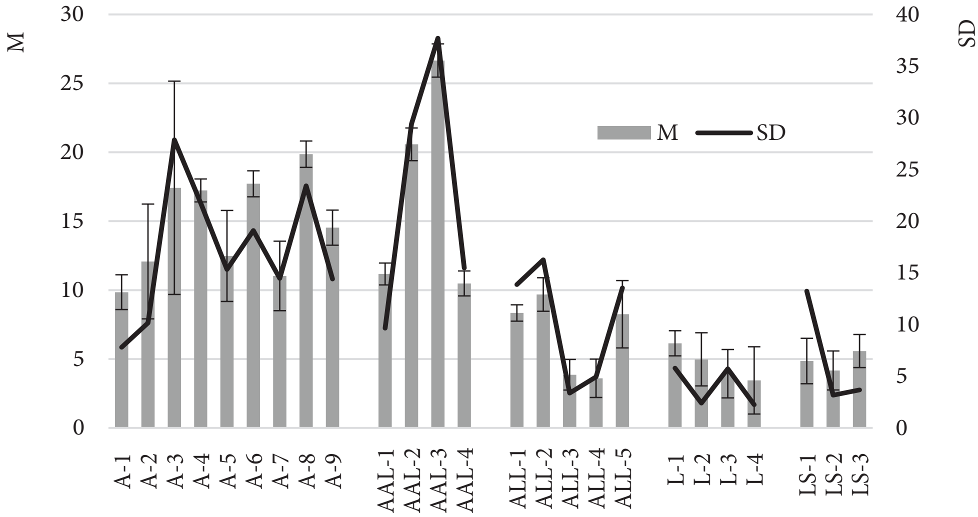

Fig. 2. The average number of vole burrows per ha of inhabited areas (M) with standard errors and standard deviations (SD), calculated using average annual indices in oblasts for 1948–2006. Region abbreviations are explained in Table 1

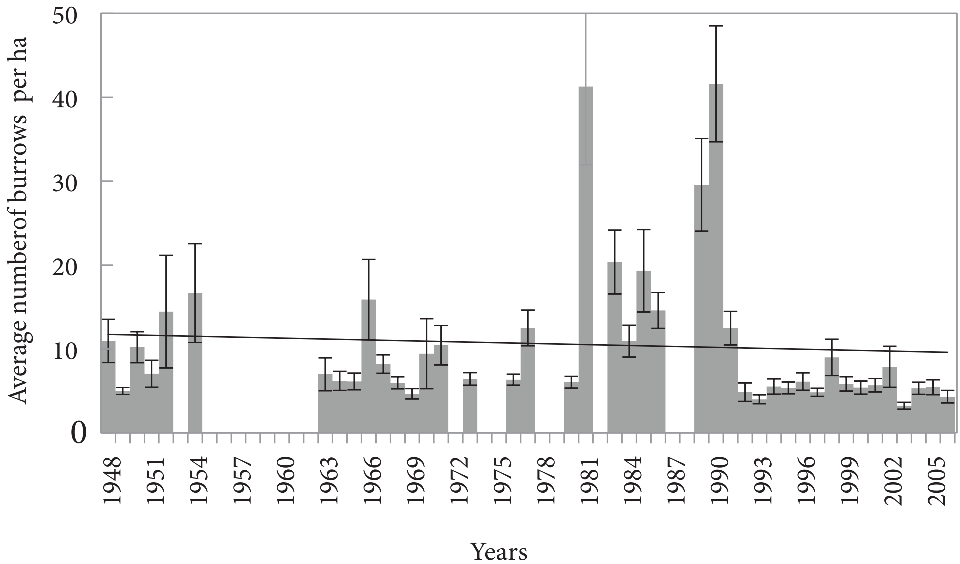

Fig. 3. The dynamics of the average annual number of burrows per ha in the mouse-like rodent censuses in 1948–2006. Planks indicate standard mean errors. A linear function approximation was used

corded in the Right-bank and Left-bank Forest-Steppe zone and in the north-east of the Forest zone.

The maximum level of annual fluctuations in population numbers is recorded in those areas where the main species was *M. arvalis* and, correspondingly, there the average abundance indices reach their peak, i. e. in western regions of Ukraine and in the Right-Bank Forest-Steppe zone (Fig. 2). This relationship is proved by the correlation coefficient ($r = 0.93$; $n = 25$; $p < 0.001$), calculated between the average number of burrows per hectare and the standard deviation of this index per region.

Temporal studies. Long-term changes in the abundance of mouse-like rodents in 1940–2006 are present according to all indices that, however, have different information content (Table 4). Thus, the percentage of areas where the inhabited colonies were found was relatively stable between 1948–1990 and then surged in 1991–2006. The latter was attributed to focusing on areas with maximum abundance and as a consequence, the coverage of censuses was reduced. In this regard, a more valuable parameter is the number dynamics of burrows per ha since it demonstrates more natural trends.

Temporal studies. Long-term changes in the number of burrows per ha are due to both a gradual decline in annual averages from 1940 to 2006 and a jump in values associated with population explosion in the 1980s (Fig. 3). However, if excluding the period from 1981 to 1991, it is obvious that the density was decreasing gradually. This fact is confirmed by the correlation analysis ($r = -0.50$; $n = 35$; $p < 0,01$). At the initial stage of the censuses immediately after the cultivation of virgin lands and the early start of rodent control in 1948–1954, the vole population density was quite high equaling the average burrow density between decades ranged between 8.8 (SE = 1.4) and 9.8 (SE = 1.0). The lowest values were in 2000–2006 equaling to 4.86 burrows per ha (SE = 0.46) which means almost a threefold decrease ($t_{st} = 3,38$; $df = 13$; $p < 0,01$).

Table 4. **The means of census parameters of voles populations and their standard errors in different periods throughout Ukraine**

Periods	Surveyed area, thou. ha	Inhabited area, %	Number of inhabited burrows per ha	Total number of counted inhabited burrows	Number of years
1948–1954	9163 ± 1151	30.4 ± 3.92	13.6 ± 2.54	35923 ± 7604	6
1963–1968	16222 ± 597	26.0 ± 1.42	8.8 ± 1.4	38790 ± 8215	7
1970–1977	18107 ± 582*	24.3 ± 1.24	9.8 ± 0.97	43597 ± 5721	6
1980–1989	16131 ± 415	28.9 ± 2.12	22.2 ± 4.86*	116353 ± 35259*	10
1990–1999	11607 ± 630	37.9 ± 2.11*	9.49 ± 3.87	46981 ± 23380	10
2000–2006	7189 ± 412*	39.4 ± 1.48*	4.86 ± 0.46*	14251 ± 2132*	7

* extreme values.

Table 5. **The means of inhabited burrows per ha, their standard errors (SE) and number of annual censuses per oblast (N) accordingly to community vole types and periods**

Types of community	1948–1980		1981–1990		1991–2006	
	M ± SE	N	M ± SE	N	M ± SE	N
A	14.31 ± 1.44	145	31.0 ± 3.45	63	7.99 ± 0.44	144
AAL	10.06 ± 1.91	67	49.14 ± 7.72	28	9.92 ± 1.37	64
ALL	5.11 ± 0.66	90	18.74 ± 3.9	35	3.27 ± 0.23	80
L	4.80 ± 0.33	76	7.68 ±1.66	28	2.25 ± 0.22	64
LS	4.04 ± 0.39	50	11.25 ± 3.9	21	2.88 ± 0.26	48

Table 6. **The means of inhabited burrows per ha (M), their standard errors (SE) and the number of annual censuses per oblast (N) accordingly to periods and geographic regions**

Regions	1948–1980		1981–1990		1991–2006	
	M ± SE	N	M ± SE	N	M ± SE	N
West and North-West	13.5 ± 1.3	163	30.6 ± 3.12	70	8.13 ± 0.44	160
Centre and North-East	7.97 ±1.11	121	34.67 ± 5.52	49	6.72 ± 0.81	112
South	4.25 ± 0.37	144	10.73 ± 2.08	56	2.57 ± 0.12	128
Ukraine in total	8.82 ± 0.62	428	25.38 ± 2.21	175	5.96 ± 0.31	400

The population dynamics of mouse-like rodents in the agricultural landscapes of Ukraine has species-specific (Table 5) and regional features (Table 6). The comparison of the early 1948–1980 and late 1991–2006 study periods shows that the maximum differences are observed in the areas occupied only by *M. arvalis* (A type) or *M. levis* (L type); reliable differences were also in the regions with mixed colonies of ALL, LS types; differences in the areas with AAL type communities were not statistically significant. In the north-western and western regions, the number of burrows per hectare decreased by 1.6 times, similar differences were in the steppe zone. In the central and north-eastern regions, the differences are not significant. In the entire Ukraine, they decreased by 1.5 times (Table 6).

Discussion

The conducted analysis of censuses in the agricultural landscapes of Ukraine shows the uneven abundance of the populations of *M. arvalis, M. levis, M. socialis* in space and inconstancy in time.

The highest density of burrows per hectare is found in the populations of the western, north-western and Right-Bank regions of the Forest-Steppe zone, where *M. arvalis* is a single or dominating species among the studied ones. These territories are also a zone of traditional abundance outbreaks of voles in agricultural lands (Sokur, 1965). The minimum indices are in the south-eastern oblasts and the Autonomous Republic of Crimea, where *M. socialis* burrows and, to a lesser extent, *M. levis* are available in the fields. The general trend of spatial distribution is as follows: the population abundance of voles in agricultural lands decreases from the north-west to the south-east direction according to the main climatic vector of Ukraine. Moreover, the higher the share of *M. arvalis* individuals in the colonies, the higher the population density. This pattern of abundance distribution is associated not only with the vole species composition but also with the climate features of Ukraine, where two poles are usually distinguished (Babichenko et al., 1984). The north-western pole is characterised by a relatively humid moderate continental climate, while the south-eastern one has a dry continental climate. Since meadows with dense perennial vegetation and a developed root-permeated sod are the most suitable habitats for voles of the subgenus *Microtus*, they definitely prefer the zone with a more humid climate.

Populations of mouse-like rodents (Hansson, Henttonen, 1988) and especially voles (Mihok et al., 1985; Gouveia et al., 2015) are characterised by temporal changes. As this study has shown, the territory of Ukraine is no exception. At the same time, changes in the population size of voles inhabiting agricultural lands can be characterised as a decline in combination with amplitude dampening. At the same time, the negative dynamics of vole populations have their own characteristics. The percentage of inhabited areas out of the total studied area demonstrates a fairly stable index, and the changes are associated with the dynamics of the population density. This is a fundamental difference between the depression of voles and ground squirrels populations within Ukraine. The latter have seen a catastrophic reduction in the area of inhabited territories, amounting to 1–2%, while the density of the remaining populations has decreased only 2–3 times (Mezhzherin et al., 2025).

Changes in the voles population density can be described by two patterns. The first is a gradual decrease in the number of inhabited burrows, which is especially evident when comparing the results of the early 2000s with the assessments of the late 1940s and 1950s. From 1991 to 2006, the amplitude of fluctuations is less pronounced. This trend has specific regional pattern since the decrease in numbers occurs only in the zones of the climatic poles and is more obvious in the western and north-western regions than in the eastern and south-eastern ones.

The second is a rise in numbers in the 1980s, accompanied by sharp fluctuations between years. This outbreak was recorded throughout Ukraine and ascribed to large-scale sowing of perennial grasses at that period. The importance of the clover and alfalfa plantations as a key factor for the voles abundance in agricultural landscapes in this period is confirmed by direct observations. Thus, in the first half of the 1980s, 73% of *M. arvalis* (Teslenko, Zagorodniuk, 1986) and 74% of *M. levis* (Zagorodniuk, Teslenko, 1986) were found in crops of these grasses.

The assessment results showing an approximately threefold reduction in the voles abundance between the early censuses of 1948–1954 and the final counts of 2000–2006 are similar to the changes reported from Central Europe for 1985–2010 (Gouveia et al., 2015).

However, some circumstances allow us to assume that this reduction is underestimated. Firstly, in the early censuses of 1948–1954, there is a lack of information for seven of the nine western regions, in which the voles population figures are averagely higher than in other Ukrainian areas, so the assessments of that period are generally underestimated. Secondly, on the contrary, the abundance in the censuses of 2000–2006 is overestimated, since those counts covered smaller areas but with a higher population density. Thirdly, given the fact that the censuses had been conducting for decades by the same organizations and checkmen, a learning effect could have happened. Fourthly, there are grounds for assuming that the rodent population was artificially overestimated in the last years of the censuses to support the bureaucratic system of plant protection. Eventually, it means that the real decline in the voles of agricultural landscapes of Ukraine is significantly more large-scale and is not confined to a simple conclusion from the census figures. We assume that these differences are at least three times exceed the results of a simple comparison between the study periods making the real drop in numbers equal to 5–8 times or even 10 times. In fact, this supposed level of changes corresponds to the observations carried out by the authors in the agricultural lands of Central Ukraine over the last 40 years.

The dramatic decline in the size of vole populations in the agricultural landscapes of Ukraine is confirmed by additional circumstances. Numerous observations conducted by the authors during 2016–2024 in different seasons on agricultural lands of the Right Bank of the Kyiv Region showed the absence *of M. arvalis* colonies. The exception was the case of the appearance of small single colonies during two seasons after ploughing the floodplain meadow. Whereas in the mid-1950s on the Right Bank and the West during peak periods the number of burrows per hectare could be from 30 to 100 thousand (Sokur, 1965). In the latter case, the entire field was covered with burrows, and the crops were completely destroyed (Turianin, 1958).

The main reason for decrease in the vole population abundance in agricultural landscapes of Ukraine is the significant loss of area of meadows and steppe habitats, first of all due to their ploughing, during the last decades of the 20th century (Natural resource aspect of Ukraine's development, 2001) and continues now. Another factor is the change of agricultural patterns with an emphasis on growing industrial crops and removing the perennial grasses that provide shelter for the voles. Secondary factors in the vole elimination include chemical extermination, climate change and as consequence disruption of the water regime, leading to the degradation of meadow ecosystems.

Therefore, the reduction in the size of vole populations in agricultural lands of Ukraine is primarily induced by ecosystem changes. This negative trend appears to be continued and no abundance outbreaks could be expected. The rapid increases in population size of rodents have not been actually observed in the agricultural landscapes of Ukraine for at least 30 years. Taking the present status of the populations into account, the idea of voles as dangerous pests of agriculture is not only outdated but also completely mistaken. In this regard, very eloquent is the fact that in the mid-20th century, the species diversity of rodent pests was equal to 22 species (Brovdiy et al., 1974), and now 11 species are classified as endangered and listed in the Red Data Book of Ukraine (2009). Moreover, the species have catastrophically reduced their abundance despite being assessed in the past as hundreds of thousands and even, for ground squirrels (Mezhzherin et al., 2025), hundreds of millions of individuals.

A well-pronounced trend of the decline in voles in the agricultural landscapes of Ukraine shows that the further eradication by using rodenticides in the cornfields will not assist an increase in crop yields. However, according to dedicated research (Millot et al., 2017), the application of toxic substances can cause the death of other vertebrate species, in some areas even entailing mass mortality. All the above-mentioned make it reasonable to prohibit the use of rodenticides in Ukrainian fields at the legislative level.

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