Geographic Distribution of the Field Vole (*Microtus arvalis*) in the Czech Republic

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Abstract

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The ecological distribution and requirements of the field vole (*Microtus arvalis*) were studied, using data on its population density in individual districts of the Czech Republic from 1955 to 1990. The field vole was found to be distributed from lowlands to the sub-alpine level, i.e., from 150 to 1600 metres above sea-level. It inhabits continuously and reproduces regularly in nine different biotopes of the Czech Republic. Geographic areas of regular overcrowding of field voles correspond with areas of most suitable living conditions. Of climatic conditions the field vole prefers mainly moderately warm climatic regions, and these are inhabited by 79.52% of its population. The analysis of quantitative requirements of the field vole indicates that there is a correlation between the distribution of this species and medium values of ecological factors. High and extremely high field vole densities are regularly encountered in areas amounting to 10 057 km^2, of which the field biotopes cover 5 072 km^2.

Key words: field vole; geographic distribution; ecology; Czech Republic

The field vole (*Microtus arvalis* Pallas 1788) is one of the most serious pests of agricultural production in the Czech Republic. When the field vole population reaches overcrowding densities, it causes considerable damage to vast agricultural areas.

Despite this fact, not much attention has been paid so far to defining the areas of regular and frequent overcrowding by field voles and consequent damage to agricultural production.

Such a definition of calamitous overcrowding areas of the field vole on the territory of the Czech Republic has been attempted by FARSKÝ (1925) on the basis of data from the years 1920 to 1925. However, the methods used to create the maps were not quite exact. There have been no further attempts in this respect.

The reasons for population overcrowding of the field vole, as well as of other microtine rodents, have not yet been satisfactorily and clearly explained. Nevertheless, knowledge on the areas of regular overcrowding may be used in plant protection against this serious pest. For a compilation of theories on population fluctuations see, for example, publications by ODUM (1971), SCHWERDTFEGER (1968, 1975) and VLASÁK (1986) and recent works such as BEGON *et al.* (1996).

In the scientific literature there is a lack of geographic data maps on the quantitative distribution of the field vole in the Czech Republic, including a longer time series. Data on its quantitative distribution in relation to the elevation above sea-level and other ecological conditions are also lacking. Such data have not been published by KRATOCHVÍL *et al.* (1959) and other authors. It was the study of field vole habitats by PELIKÁN (1955), apart from other sources, that we used to classify habitats inhabited by the field vole in the Czech Republic.

It was our aim to:

1. use quantitative data on the field vole in the Czech Republic for the purpose of plotting a map of its geographic distribution and defining areas of regular overcrowding;
2. use those quantitative data to prepare a chart of its distribution in biotopes in relation to the elevation above sea-level;
3. evaluate the ecological requirements of the field vole using a geographic database of ecological factors.

MATERIAL AND METHODS

Data on the quantitative distribution of the field vole in the Czech Republic originated from two sources:

1. our own material obtained mainly in districts of Moravia (i.e., 3400 observations);
2. data obtained and published by the State Plant Protection Administration of the Czech Republic, and covering the whole country.

In all, we evaluated data from 75 districts of the Czech Republic obtained from 1955 to 1990. In each district at least 10 counts were made each year of the field vole population density. The counts were performed at two times, in spring (from March 15 to April 15) and autumn (from September 15 to October 30). Thus, for the 35-year period the data originated from at least 350 density counts from each district, resulting in a total of about 26 250 counts from the whole country during this period.

The method for determining the density of the field vole population is based on selecting a suitable locality and demarcating five squares of 10 × 10 m. Within these squares all the entrances to the underground burrows of the field vole are closed by raking. After 24 h the squares are inspected to determine the number of re-opened entrances (ANONYM 1999). Their number on the five squares of together 5 ares is multiplied by 20 and indicates the field vole density per hectare. In the following table it is shown how the field vole density is classified:

	degree of the field vole population density (individuals per hectare)		
season of the year	low (1)	medium (2)	high and extremely high (3)
spring (March)	1–40	41–100	101–200 and more
autumn (September)	500–999	1000–2000	2001–10500 and more

The separate counts of the population densities in each district during the years 1955 to 1990 were used to compute mean values for every year and for the whole period under study. These mean values were then used to plot a map showing the long-term quantitative field vole distribution in the Czech Republic. Such a map numerically encoded was saved as a database by the KORMAP set of programmes which enable statistical evaluation and comparison with quantitative ecological factors. To evaluate the ecological distribution of field voles we used common statistical programmes and procedures and a special set of geographic statistical procedures which are implemented in the KORMAP programme. In these procedures two quantitative maps are compared, i.e., invariably the map of the population density with any one of ecological factor data map files. These procedures result in a frequency table which enables computing regressions, correlation, and percentage of the field vole occurrence in various geographic areas of the Czech Republic.

Several data maps were used in the evaluation of ecological conditions of the geographic distribution of field voles. The hypsometrical data map was stepped by 200 m a. s. The climatic data map was divided into climatic regions, which were determined by temperature values such as maximums over 25°C, i.e., the number of the so-called summer days. Warm climatic regions have more than 50 summer days, moderately warm ones 20–60, and cold climatic regions less than 20 summer days. The climatic regions were divided into 9 sub-regions on the basis of climate moisture, and 19 climatic districts according to the mean air temperature in January. Other climatic factors, such as data map files of mean annual air temperatures and mean annual precipitation, were also compared with the geographic distribution of the field vole. Data maps of distribution of biotopes (meadow and grassland, arable fields) were used, as was the map of agricultural production types. The latter is divided into four categories: the maize-growing production type up to 200 m a. s., with a mean annual precipitation below 550 mm, and mean annual air temperature of 9°C and higher; for the beet-growing production type these values are 200 to 350 m, 500 to 600 mm, and 8–9°C; for the potato-growing type they are 350–600 m, 600 to 800 mm, and 6.5–8°C; the mountain production type is characterised by elevations of over 600 m a. s., 800 mm of annual precipitation, and a mean annual air temperature of 6.5°C and lower. Ped-

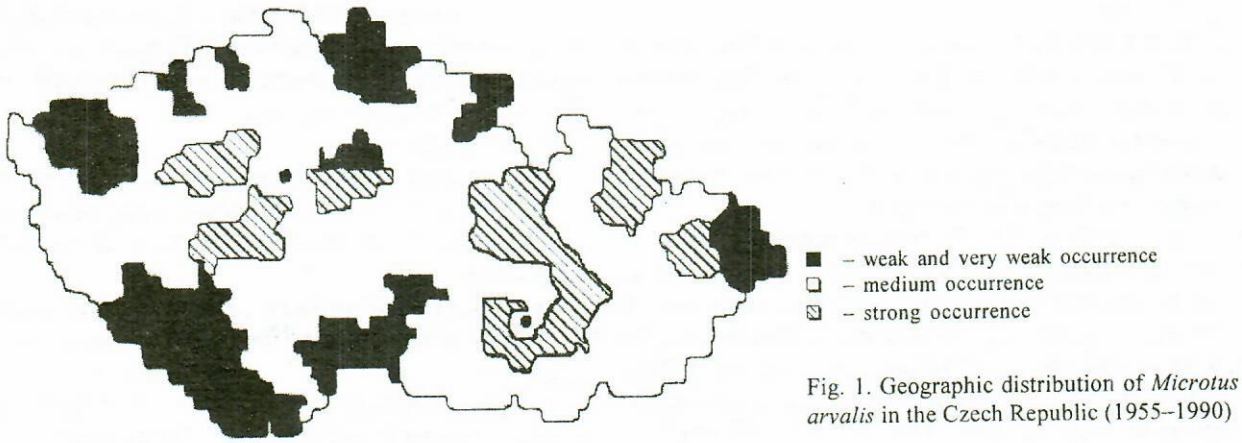


Fig. 1. Geographic distribution of *Microtus arvalis* in the Czech Republic (1955–1990)

ological data maps include the main soil types found in the Czech Republic.

Data maps of various ecological factors on the territory of the Czech Republic were compiled from atlases by GÖTZ *et al.* 1969; SYROVÝ *et al.* 1958; KOREŇ 1982. There are 50-year mean data in these atlases (for a detailed description see PIKULA & BEKLOVÁ 1987). These maps are saved on a 1 : 1 000 000 scale.

To evaluate the ecological distribution of field voles, we used a classification comprising 44 biotopes which are found in the Czech Republic (PIKULA 1976). The occurrence of the field vole in each of these biotopes was classified into one of three categories:

category 1 occurrence and reproduction of the field vole in this biotope is of a continuous character;
category 2 temporary occurrence of the field vole during overcrowding;
category 3 contemporary occurrence of the field vole during overcrowding; banks of subhydric and hydric biotopes.

Another classification of biotopes in the Czech Republic may distinguish zonal and azonal biotopes, natural and anthropogenic ones, forest and non-forest ones, subhydric and hydric ones. They are found in the whole profile of elevation above sea-level from lowlands to mountains (i.e., zonal biotopes) or are restricted to specific conditions and areas (azonal ones).

RESULTS

Areas of Regular Overcrowding of Field Voles and their Characteristics

The map of the quantitative distribution of field voles (Fig. 1) shows that only some areas in the Czech Republic are regularly affected by calamitous overcrowding (area 3 = high and extremely high population densities).

Overcrowding is common in these districts of Bohemia: Kolín, Kladno, Rakovník, Příbram, Prague-West, Ústí nad Orlicí and Svitavy. In Moravia the following districts suffer from overcrowding: Brno and its provinces, Vyškov, Prostějov, Nový Jičín and Bruntál.

The areas of regular calamitous overcrowding of the field vole cover a total of 10 057 km^2 (i.e., 12.79% of the Czech Republic). In these areas mainly field biotopes prevail.

All the areas with regular high and extremely high population densities have a lower or medium elevation above sea-level. They are represented mainly by river terraces and upland of moderately warm climatic regions. These areas may be characterised by 120–160 days of mean air temperature, 110–160 frosty days, mean temperature in January –3°C, in July 16 to 18°C, in April 6 to 8°C, in October 6 to 8°C, water precipitation during the vegetation period 350–500 mm, precipitation during winter 150–300 mm, 50–100 days with snow cover, 120–160 cloudy days, 40–60 clear days.

In individual districts we determined the ratio between agricultural and forest land and the field vole population densities.

County, district	Forest coverage [%]	Mean field vole density [%]
County of Central Bohemia (capital city of Prague)	27.3	
district of Kladno	17.6	1.8
district of Kolín	17.9	1.6
district of Nymburk	16.8	1.9
district of Prague-West	24.3	1.6
district of Příbram	44.1	1.5
district of Rakovník	38.2	1.9
County of East Bohemia (capital city of Hradec Králové)	30.0	
district of Svitavy	30.8	1.5
district of Ústí nad Orlicí	30.5	1.5
County of South Moravia (capital city of Brno)	28.9	
district of Brno and its provinces	33.2	1.6
district of Prostějov	25.6	1.9
district of Vyškov	29.3	1.7
County of North Moravia (capital city of Ostrava)	37.1	
district of Bruntál	45.0	1.7
district of Nový Jičín	21.7	1.5

The mean cover by forests in districts regularly affected by overcrowding of the field vole population is 28.85%, and the mean field vole density is 1.664. It was not possible to prove a supposed linear regression between forest cover and field vole population density. The coefficient of correlation of 0.192 (n = 13) is not statistically significant.

Low and medium field vole population densities (i.e., areas 1 and 2 in the map) cover 9450 and 39 405 km^2, respectively.

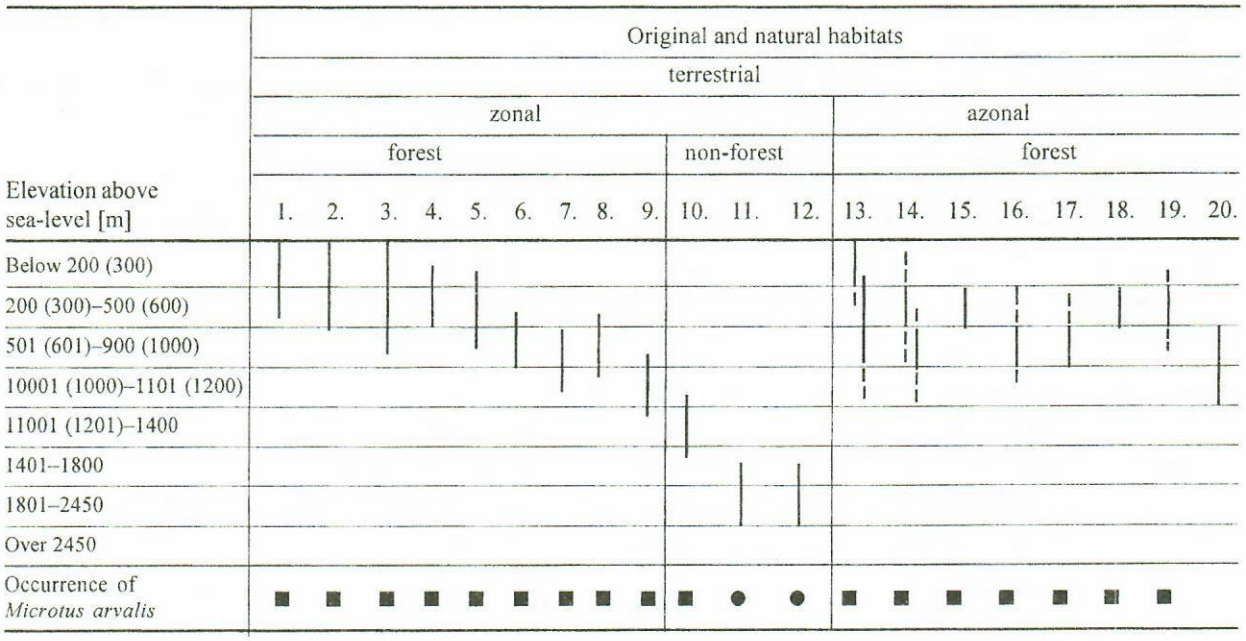
It is necessary to mention the possibility of calamitous field vole overcrowding under suitable conditions even in areas where its occurrence is normally medium. Such cases, however, are not regular and do not affect large areas. We do not suppose calamitous overcrowding in areas of low field vole occurrence (area 1 in the map).

The field vole inhabits nearly 50% of the territory of the Czech Republic. This area is much larger during overcrowding and emigration into other biotopes.

Ecological Distribution of the Field Vole in the Czech Republic

The occurrence of the field vole in different biotopes of the Czech Republic is presented in Table 1 and Fig. 2. They show that the main occurrence of the field vole is in anthropogenic terrestrial non-forest biotopes. Natural and autochtonous biotopes are entered by the field vole only during periods of overcrowding. It does not reproduce in these biotopes and the population remains low.

Table 1. Classification of the habitats of terrestrial vertebrates in the Czech Republic and distribution of *Microtus arvalis*



1. Subxerophilous oak forest; 2. Pubescent oak forest; 3. Oak and hornbeam forest; 4. Acidophilous oak forest; 5. Pine and oak forest; 6. Wood-rush beech forests; 7. Beech forests with rich-herbaceous layer; 8. Acidophilous mountain beech forests; 9. Mountain spruce forests; 10. Subalpine dwarf pine communities; 11. Alpine meadow habitat; 12. Habitat of alpine rocks and scree; 13. Lowland forests and alder stands; 14. Scree lime and ash forests; 15. Oak woods and birch woods on peat soils; 16. Calciphilous beech woods; 17. Calciphilous relic pine woods; 18. Water-logged oak and beech woods; 19. Acidophilous pine woods and relic pine woods on siliceous substrates;

● occurrence and reproduction of the field vole of permanent character
■ temporary occurrence during overcrowding
▲ banks

Thus, the field vole inhabits continuously or temporarily 41 out of 44 biotopes present in the Czech Republic. Continuous occurrence and reproduction was found in the following 9 (i.e., 69.23%) out of 13 anthropogenic, terrestrial non-forest biotopes: 1) meadows, 2) pastures, 3) grass boundaries and barrens, 4) orchards, 5) vineyards, 6) arable fields, 7) suburban biotopes, 8) urban biotopes, and 9) ruderal biotopes.

From the above survey it could be deduced that arable fields with perennial fodder plants are the most important biotopes for the existence and overcrowding of the field vole. However, it occurs also in other crops. At present it is becoming accommodated to winter crops such as rape and cereals. Apart from these biotopes, the field vole occurs also on fallow pieces of land which serve as refuges and sources for its spread. Grassy banks of motor-ways, roads, railway tracks, and barrens are further refuge biotopes. Every administrative district of the Czech Republic has a different proportion of the above-mentioned 9 biotopes, refuge areas, and main agricultural crop plants suitable for the field vole, so that its density varies greatly with these conditions.

The field vole has a so-called di-zonal distribution in the Czech Republic. It is mainly distributed in lowland areas and above the tree-line in meadows of sub-alpine areas (such sub-alpine areas, however, are found only in the Slovak Republic). In forest areas it may occur due to activities of man (i.e., formation of large forest clearings and grasslands in forests).

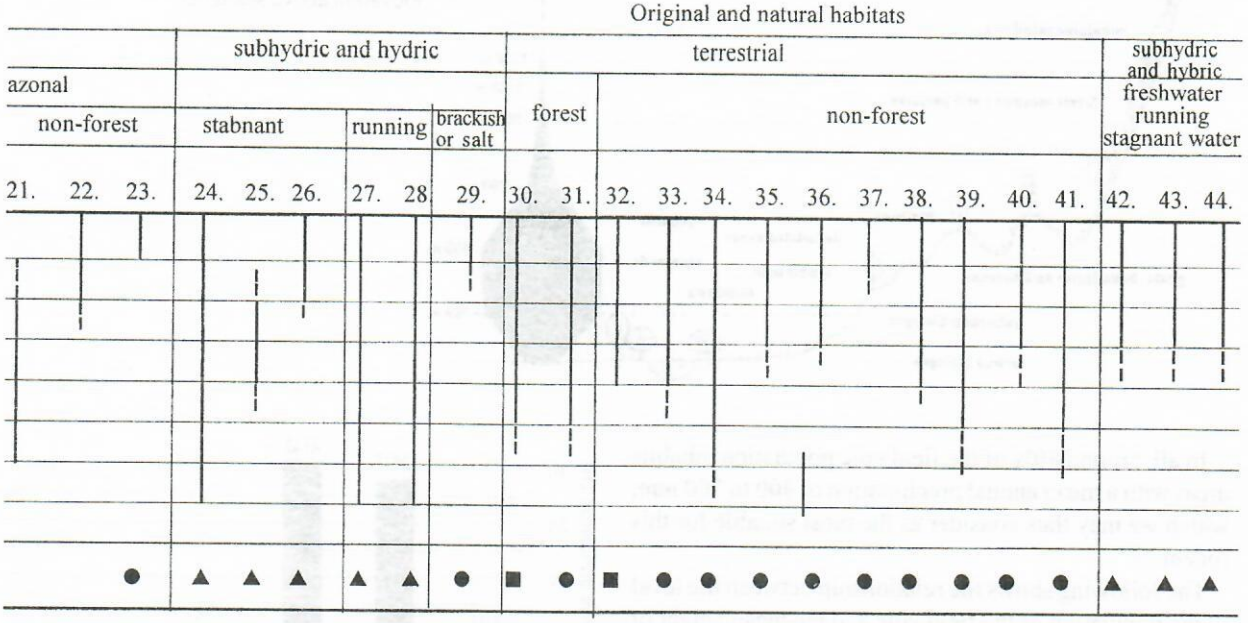
The field vole is distributed through about 50% of the Czech Republic. The extent of this area increases during periods of overcrowding and immigration into biotopes not normally occupied. The overall map of field vole distribution shows areas of low (1), medium (2) and high and extremely high occurrence (3). There is a mixture of suitable and unsuitable biotopes for the field vole in each of the areas on the distribution map.

areas of occurrence	their total area [km^2]	suitable biotopes
1 = low	9 450	5 072 (16.93%)
2 = medium	39 405	19 811 (66.14%)
3 = high and extremely high	10 057	5 072 (16.93%)

Ecological Requirements of the Field Vole

The ecological requirements of the field vole were evaluated using the quantitative distribution data in dependence on various ecological factors, by employing the procedures of the KORMAP set of programmes for comparing pairs of data maps.

The first relationship studied was the quantitative distribution of the field vole and elevation above sea-level.



substrates; 20. Water-logged spruce forests; 21. Habitats of rocks and rock fissures outside the alpine grade; 22. Habitats of aeolian sands and sand dunes; 23. Natural and seminatural xerothermic grassland habitats; 24. Habitats of original freshwater bodies; 25. Habitats of raised bogs and poor fens; 26. Rich and extremely rich mires (fens); 27. Habitats of natural water streams; 28. Habitats of springs; 29. Salt marsh habitats; 30. Habitats of secondary forests; 31. Habitats of forests clearings; 32. Habitats of shrubs and hedges open landscape; 33. Meadow habitats; 34. Pasture habitats; 35. Habitats of grassy ridges; 36. Habitats of orchards; 37. Habitats of vineyards; 38. Habitats of arable land; 39. Suburbane habitats; 40. Urbane habitats; 41. Ruderal habitats; 42. Habitats of artificial stagnant water bodies (fish-ponds, and other reservoirs); 43. Habitats of bottoms of permanently drained basins of stagnant water bodies; 44. Habitats of man-made, usually polluted, water streams and channels

Results of this comparison follow:

elevation above sea-level [m]	proportion of the field vole population [%]
150–200	9.07
201–400	38.17
401–600	41.42
601–800	9.83
801–1000	1.28
higher than 1000	0.23

The main distribution of the field vole in the Czech Republic lies in areas from 201 to 600 m above sea-level; they are inhabited by around 80% of the population (Fig. 3).

The influence of climatic factors on field vole density can be seen in the comparison of quantitative data in different climatic districts and regions:

climatic districts	proportion of the field vole population [%]
moderately warm and moderately moist districts	43.46
warm and dry districts with mild winter	20.18
moderately warm and dry districts	14.51
warm and moderately moist districts	11.04
moderately warm and very moist districts	4.84
moderately cool districts	3.17
moderately cold districts	2.57
cold mountain districts	0.23

The field vole was found to occur in eight climatic districts of the Czech Republic.

The occurrence of the field vole in individual climatic regions is presented in the following survey:

mean annual climatic regions	proportion of the field vole population [%]
warm climatic regions	17.08
moderately warm climatic regions	79.52
cold climatic regions	3.40

There are three climatic regions that are inhabited by the field vole in the Czech Republic. The center of the field vole distribution is in moderately warm climatic regions.

When evaluating the relationship between the quantitative distribution of the field vole and the mean annual precipitation we found:

mean annual precipitation [mm]	proportion of the field vole population [%]
400–700	78.91
700–1000	19.05
1000–1400	1.59
1400–1800	0.45

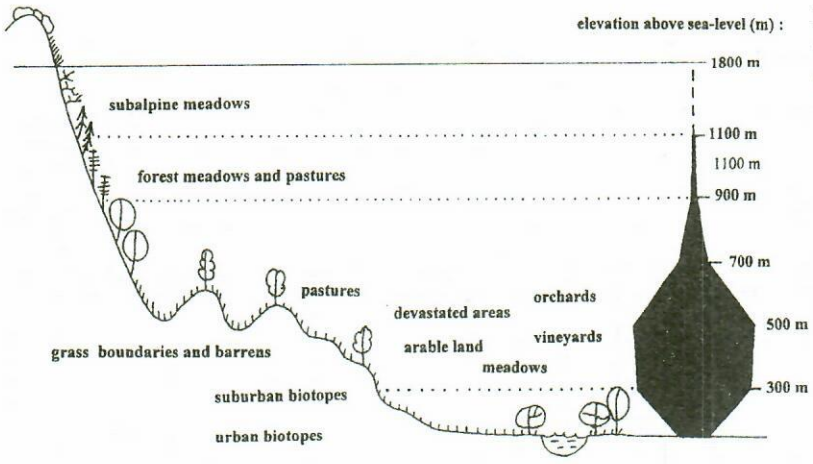


Fig. 2. The *Microtus arvalis* distribution with respect to ecological factors and elevation above sea-level

In all, around 80% of the field vole population inhabits areas with a mean annual precipitation of 400 to 700 mm, which we may thus consider as the most suitable for this rodent.

The following shows the relationship between the level of the population of the field vole and the mean height of snow cover:

mean height of snow cover [cm]	proportion of the field vole population [%]
up to 15	5.52
15–30	72.94
30–60	18.90
60–100	2.04
100–160	0.56
over 160	0.08

Most of the field vole population, i.e., 91.84%, is found in areas with a mean snow cover of 15 to 60 cm.

The distribution of the field vole population in relation to the mean annual air temperature can be seen from the following:

mean annual air temperature [°C]	proportion of the field vole population [%]
more than 10	0.38
8–10	28.87
6–8	65.38
4–6	4.84
2–4	0.45
0–2	0.45
less than 0	–

A total of 94.25% of the field vole population is found in areas with a mean annual air temperature from 6 to 10°C.

The proportion of the field vole population in areas of different soil types is illustrated in the following:

soil types	proportion of the field vole population [%]
black earth soils	7.33
brown soils	16.93
podsols	57.14
alluvial soils	9.98
rendzinas	4.84
sandy soils	3.55
stony soils	0.23

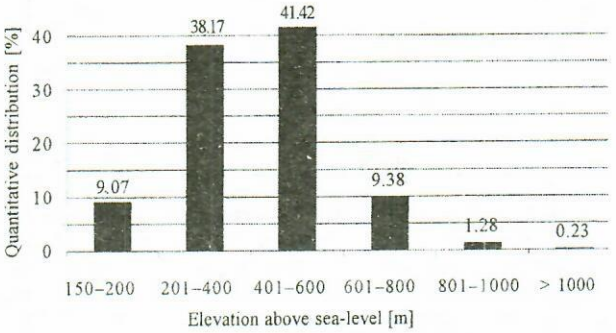


Fig. 3. Relationship between the *Microtus arvalis* quantitative distribution and the elevation above sea-level in Czech Republic (1955–1990)

The occurrence of the field vole in the agricultural landscape is concentrated on a few biotopes:

biotopes	proportion of the field vole population [%]
arable land	83.36
meadows, pastures, fallow land	16.21
devastated areas	0.43

The next survey shows at what level the field vole inhabits individual agricultural production types:

agricultural production type	proportion of the field vole population [%]
maize-growing	4.46
beet-growing	31.07
potato-growing	62.15
mountain production	2.32

DISCUSSION

The ecological distribution and ecological requirements of the field vole in the Czech Republic have so far not

been evaluated. The main biotopes in the Czech Republic were described by PELIKÁN (1955, 1982), but the author restricted his description to the field vole distribution in field biotopes, and omitted its occurrence in relationship to elevation above sea-level and in biotopes other than the field ones. He also found the presence of the field vole in reed growths of the Nesyt pond (PELIKÁN 1975), and compared the population densities of field voles of mown and un-mown meadows of the Bohemian–Moravian Highlands (PELIKÁN 1982). ZEJDA (1976) reported on the field vole population in lowland flood plain forests of south Moravia and even in spruce monocultures. GAISLER *et al.* (1967) described the occurrence of the field vole in stacks of straw. KRATOCHVÍL and PELIKÁN (1955) proved that the field vole moved to high elevations (the High Tatra in the Slovak Republic) due to the activities of man. It was found as high as 2100 above sea-level in the Belanské Tatra, and at 1320 m in the High Tatra. In the Tatra it is found in areas where the natural biotopes are disturbed. The main disturbances in the High Tatra were caused by grazing management, forest management, communications and settlement building from the second half of the last century. These changes enabled the field vole population to move into higher elevations (over 1000 metres), and we may suppose that this penetration has not yet ended. The events in the High Tatra demonstrate the process of spread of the field vole in the post-glacial period and in historic times not only in the Czech and Slovak Republics, but also in the whole of Europe. It is clear that the field vole is a eurytopic species of wide ecological valence, and the process of its spread has not stopped yet.

No other studies concerning the field vole ecology have been published in the Czech Republic, nor have the ecological requirements of this species been dealt with so far. PELIKÁN *et al.* (1979) mention the occurrence of the field vole from lowlands to mountains. There are brief notes on the ecological distribution of the field vole in works by ANDĚRA and HORÁČEK (1982) and SLÁDEK and MOŠANSKÝ (1985). According to KRATOCHVÍL *et al.* (1959) the field vole does not inhabit such biotopes as forests with the forest canopy shadowing the surface of the soil, biotopes without vegetation or with permanent snow cover, biotopes with high underground water level, rocky biotopes with restricted possibility to build underground burrows, and water environments.

Our results concerning the ecology of the field vole are applicable not only in the Czech Republic, but also in neighbouring countries such as Slovakia, Poland, Austria and Germany.

CONCLUSION

On the basis of data from 1955 to 1990 we evaluated the distribution of the field vole with respect to ecological factors and requirements of this species. It was found that:

1. The field vole is distributed from lowlands to subalpine zones, i.e. from 150 m to 1800 m above sea-level.

2. The main area of the field vole distribution is up to 400 (500) m (in alluvial areas it inhabits mainly river terraces with low underground water level in the soil profile).

3. The field vole continuously and regularly reproduces in 9 out of the total 44 biotopes of the Czech Republic. Most of the population inhabits anthropogenic biotopes from where it invades the natural ones.

4. The geographic distribution of areas with regular field vole overcrowding corresponds with its ecological requirements and lies in areas of up to 400 (500) m above sea-level.

5. The frequency of overcrowding varies with individual districts of the Czech Republic.

6. Of climatic conditions, the field vole population is found mainly in moderately warm regions (79.52% of the population), areas of a mean annual precipitation from 400 to 700 mm (78.91% of the population), areas of a mean annual air temperature from 6 to 10°C (94.25% of the population), and areas with a mean maximum height of snow cover from 15 to 60 cm (91.84% of the population).

7. Areas of podsol soil types are inhabited by 57.14% of the field vole population.

8. In the biotope of arable fields and within it the beet-growing and potato-growing types of agricultural production live 83.36% and 93.22% of the field vole population.

9. Areas of regular calamitous overcrowding of the field vole amount to 10 057 km^2 (of which field biotopes represent 5072 km^2).

10. Quantitative comparisons of the field vole distribution under various ecological factors indicate that this species prefers medium values of ecological factors.

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Souhrn

ZAPLETAL M., OBDRŽÁLKOVÁ D., PIKULA J., PIKULA, J. JR., BEKLOVÁ M. (1999): **Geografické rozšíření hraboše polního (*Microtus arvalis*) v České republice**. Pl. Protect. Sci., **35**: 139–146.

Ekologické rozšíření a nároky *Microtus arvalis* byly zkoumány na podkladě populační hustoty v jednotlivých okresech ČR v letech 1955–1990. Bylo zjištěno, že v ČR je *Microtus arvalis* rozšířen od nížin až po subalpinský stupeň, tzn. od 150 do 1600 m nad mořem. Pravidelné rozmnožování *Microtus arvalis* bylo zjištěno v 9 z 44 biotopů vyskytujících se v ČR. Geografické oblasti pravidelného rozmnožování korespondují s oblastmi nejvhodnějších životních podmínek. Z klimatického hlediska populace *Microtus arvalis* preferují mírně teplé oblasti, ve kterých v ČR žije okolo 79 % populace. Analýza kvantitativního rozšíření *Microtus arvalis* idikuje, že *Microtus arvalis* vyhledává oblasti s působením středních hodnot ekologických faktorů. Silné a extrémně silné populační hustoty jsou v ČR v oblastech o rozloze 10 057 km^2, z čehož polní biotopy zaujímají 5 072 km^2.

Klíčová slova: hraboš polní; geografické rozšíření; ekologie; Česká republika

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