

# UNUSUAL HABITAT OF EUROPEAN GROUND SQUIRREL (*Spermophilus citellus*) POPULATIONS IN AGRICULTURAL LANDSCAPE

## NEOBVYKLNÉ PROSTŘEDÍ POPULACÍ SYSLA OBECNÉHO (*Spermophilus citellus*) V ZEMĚDĚLSKÉ KRAJINĚ

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**Abstract:** The European ground squirrel is typically found in open, forestless habitat – an adaptation attributed to anti-predation strategy of maintaining a clear view and warning colony members against predators. There have been, however, instances of this species occurring in heterogeneous habitats with a significant proportion of shrubs and trees. How has the species adapted to these habitats and are they suitable for its long-term survival? Our study deals with ten ground squirrel populations occurring in such non-open habitats in the Czech Republic. For eight of these populations, we present a brief description of the localities and the developments of their abundance in last two decades. At two populations – Hrušovany u Brna and Velké Pavlovice – occurrences of ground squirrel burrows were mapped and habitats in their colonies were botanically classified. Ten different habitats were identified at Hrušovany and the average grain size of the mosaic was 0.16 ha (median 0.097 ha). At Pavlovice, there were 13 habitats, and the average grain was 0.44 ha (median 0.196 ha). At both localities, most of the ground squirrel burrows were found in maintained orchards and vineyards (73% in Hrušovany, 83% in Pavlovice). A non-negligible number of burrows was found in crop fields, but this habitat is probably inhabited only temporarily.

**Key words:** Marmotini, distribution, environmental conditions, endangered species, heterogenous landscape

## INTRODUCTION

Ground squirrels of the tribe Marmotini typically inhabit open, forestless habitats such as steppes, semi-deserts and deserts, tundra or alpine meadows (MURIE & MICHERNER 1984, NOWAK 1999, VAN HORNE 2007, THORINGTON et al. 2012). They are considered a keystone species of these particular ecosystems. The preference for

an open environment along with diurnal activity and living in colonies is a part of ground squirrels anti-predation strategy, which consists of systematic visual inspection of the surroundings and warning of group members against potential predators (e.g., BLUMSTEIN 2007). Environments with high vegetation that restricts their view are usually considered unsuitable for ground squirrels as it greatly increases the risk of predation (GILLIS et al. 2005). However, there is a single species, Woodchuck (*Marmota monax*), of tribe Marmotini which typically inhabits woodland-field ecotones (KWIECINSKI 1998) and there are a few other cases of ground squirrel occurrence in forest or shrub habitats (SHARPE & VAN HORNE 1998, SPITZNENBERGER & BAUER 2001, GILLIS et al. 2005, HANNON et al. 2006, ŘÍČANKOVÁ et al. 2006, MATĚJŮ et al. 2008, WERNER et al. 2015). Occurrence of the species in such a habitat does not mean that the habitat is optimal or viable. Reproduction and survival values can be lower and the population is dependent on the immigration of individuals from source populations living in habitats that are more suitable. For example, research has shown that Arctic ground squirrel (*Urocitellus parryii*) sink populations in forest environments are supported by populations in adjacent open tundra (GILLIS et al. 2005, WERNER et al. 2015). For an isolated population to be viable under the risk of high predation, some advantage, offered by the habitat, such as richer food supply, must compensate for it. For example, according to HANNON et al. (2006) Uinta ground squirrel (*Urocitellus armatus*) seems to be capable of adapting to variation in the structure of the vegetation and will likely thrive by sagebrush occurrence in the habitat as long as an abundance of grasses are available to provide fattening seeds for foraging.

The preference for open habitats is also quintessential for the European ground squirrel (*Spermophilus citellus*, Linnaeus 1766). Typical sites of occurrence of this species were primarily the steppes of Central and South-Eastern Europe, and secondary the open habitats of the agricultural landscape – mostly meadows and pastures (GRULICH 1960, RUŽIĆ 1978, RAMOS et al. 2014). Anthropogenic habitats, such as short-cut lawns at airfields, camps, golf courses, playgrounds or parks, borders or embankments of roads and railways are also successfully inhabited by the European ground squirrel, sometimes in very high densities (SPITZNENBERGER & BAUER 2001, HOFFMANN et al. 2008, MATĚJŮ et al. 2008, 2011, RAMMOU et al. 2021). It has been repeatedly documented that when such European ground squirrel habitats are no longer maintained and becomes overgrown with high vegetation, the animals leave the site and the colony disappears (KRYŠTUFEK 1999, SPITZNENBERGER & BAUER 2001, AMBROS 2008, KOSHEV 2008, MATĚJŮ et al. 2008, 2010, KENYERES et al. 2018). When a species such as the European ground squirrel becomes listed as endangered, one of the most common measures to protect and support their populations involve the frequent mowing of vegetation and removal of bushes and trees (KIS et al. 1998, MATĚJŮ et al. 2010, JANÁK et al. 2013 KENYERES et al. 2018, PETLUŠ et al. 2021). On the other hand, it is known from the territory of Austria and the Czech Republic that ground squirrel populations also occur in the highly heterogeneous environment of gardens, vineyards and orchards, where there is a large portion of shrub and tree vegetation (SPITZNENBERGER & BAUER 2001, MATĚJŮ et al. 2008, MATĚJŮ & BRZOBHATÁ 2022). Moreover, its colonies were also reported in olive groves in Greece (RAMMOU et al. 2021).

So, there is an apparent paradox when species adapted to open habitats also occur at sites with a high proportion of view-obstructing vegetation. Systematic data on this phenomenon in the case of the European ground squirrel is missing.

The main aim of our work is to provide a detailed description of the unusual European ground squirrel habitat of vineyards, orchards and gardens, in order to contribute to the discussion on how the species adapted to open habitats may successfully inhabit also areas with a high proportion of view-obstructing vegetation. Because of the endangered status of the species, we also discuss suggestions of future activities to support populations in this described habitat.

## METHODS

### **Study areas**

In our study, we evaluated all known localities with occurrence of European ground squirrels (hereafter referred to as the ground squirrel) in the Czech Republic since 2004 (58 in total). We selected localities where the occurrence of ground squirrels has been proven in orchards, vineyards, or gardens for more than one season and where their reproduction has been proven. An overview of all those identified ground squirrel populations and their habitat is provided. A detailed study was then carried out at the locations of Velké Pavlovice and Hrušovany u Brna. At the time of the study, these two populations 1) had favourable conservation status, 2) showed long-term independent survival, 3) each one consisting of several hundreds of individuals inhabiting an area of several hectares. Therefore, they could be subjected to detailed study and assessment (other eight localities did not fulfil all those conditions). The detailed study includes habitat survey and mapping of ground squirrel burrows.

### **Long-term monitoring of populations of ground squirrel**

Regular monitoring of the known ground squirrel populations in the Czech Republic has been carried out since 2004. Monitoring is based on repeated field controls of all populations at least once a year at the turn of June and July. During each control, all individuals active on the ground were counted using binoculars. In the case of smaller populations, individuals were counted in their entire range all at once. For larger populations, a census was done for the sub-areas from multiple locations and then added to a total number. The estimation of size of the population is based on personal experience of experts and the following data: (a) number of individuals observed during all visits in the particular year; (b) area of the population. Estimation of population size is done for summer period (including young from the given year). Moreover, borders of ground squirrel colony were designated based on the observations. In our study, for each described locality, an approximate area of occurrence is marked based on the data from all the years the locality was monitored. Sites are classified according to general habitats (e.g., airfield, vineyard). Detailed data from each control are published in yearly reports (e.g., MATĚJŮ & BRZOBOHATÁ 2022, last published summaries in MATĚJŮ et al. 2008, 2010).

### **Habitat survey**

Habitat survey has been carried out in the localities of Velké Pavlovice and Hrušovany u Brna during the years 2018–2019.

Habitats were mapped in the areas of population occurrence (APO). Recognizable functional units of land (hereafter plots) were identified based on different vegetation formations, characteristics and physiognomy. Plots were marked to the printed aerial maps. For each plot, types of habitats and types of management of herbal vegetation (see below) were recorded.

Definitions of habitat types:

**Vineyard:** linear plantation of woody liana grape vine (*Vitis vinifera*) of various ages. Even in the case of vineyards, there are differences between individual plots in the way that herbaceous vegetation is managed, in inter-rows and under the grapevine plants. Herbal vegetation is either reduced by herbicides, or ploughed or regularly mowed.

**Orchard:** plantation of fruit trees (especially plums, apricots, peaches, cherries, sour cherries, apples, pears) and walnuts. The undergrowth is subjected to different types of management. It is mostly regularly mowed or rarely grazed or abandoned, which allows the development of various succession vegetation. Herbaceous vegetation is also reduced by herbicides or by ploughing. Occasionally, in some orchards, potatoes or other vegetables are grown in the undergrowth.

**Garden:** flower/vegetable bed and small garden near to houses, cottages or freely in the cultural landscape in a mosaic within the mowed grass, arable land for growing annual crops. In addition, fruit trees or currant bushes and a solitary line of grapevine could be part of it. The most commonly represented are potatoes, legumes, tomatoes, onions, courgette or other vegetables.

**Arable crop field** (hereafter “crop field”): agricultural area/field regularly ploughed, usually with a single-species culture or not yet sown. Parts of regularly ploughed fields can also be left fallow for one or few years.

**Ruderal:** arable land, highbrow ruderal vegetation affected by eutrophication, absence of management and garden waste disposal.

**Pasture:** currently grazed area, whole-season grazed fenced plots, usually with horses.

**Anthropogenic short-cut lawn** (hereafter short-cut lawn): mown grassland mostly of a cultural character without the presence of old growth, due to regular mowing for most of the year short-stemmed vegetation.

**Tall lawn:** mostly regularly unmown vegetation with a layer of old growth, if mowed, then only occasionally. May also be burned, predominantly in areas left fallow where scrub succession has not yet occurred or is blocked.

**Steppe and xerophilous grassland** (steppe grassland hereafter): natural habitat belonging to the vegetation of *Festucion valesiacae*, *Cirsio-Brachypodion pinnati*, *Koelerio-Phleion phleoidis* in a varying state of degradation and successional stage. The majority of these plots are not managed, only a small number of stands are mowed or grazed.

**Shrubland:** is usually patch or line of abandoned dense bushes and abandoned patches with various successional vegetation. They consist of *Rosa canina*, *Syringa vulgaris*, *Lycium barbarum*, *Sambucus nigra*, *Rhamnus cathartica*, *Ligustrum vulgare*, *Prunus spinosa*, *Euonymus europaeus*, *Cornus sanguinea*, with scattered trees *Juglans regia*, *Prunus avium*.

**Tree stands:** this category represents various types of woodies stand e.g. tree plantations (*Populus x sieboldii*), stands of early successional woody species (*Populus tremula*, *Prunus avium*, *Acer pseudoplatanus*, *Populus alba*, *Alnus glutinosa*, *Morus alba* and others), stands of invasive trees (*Robinia pseudoacacia*, *Acer negundo*, *Amorpha fruticosa*, *Ailanthus altissima*).

**Tree alley:** linear formation with trees at regular spacing along roads and paths with lawns or grasslands in the undergrowth.

**Building:** built-up area with houses, cottages, sheds and immediate surroundings with roads and sidewalks.

Description of types of management:

**Ploughed:** arable land area with deep ploughing by a tractor.

**Mowed grass:** area with vegetation cover periodically mowed by a tractor.

**Grazed:** fenced plot area with saved vegetation and presence of herbivorous animals during the whole-season (usually horses).

**Combined ploughed/mowed:** area with inseparable management, combination and mosaic of manual/tractor ploughing and mowing in orchards and vineyards, also with application of herbicides.

**Temporarily left fallow** (hereafter fallow): part of arable crop field temporarily without ploughing for one or a few years with presence of shorter weedy plants (usually annuals).

**No management:** area without an active longer-term human management with spontaneous processes of succession.

### Mapping of ground squirrel burrows

Detailed mapping of ground squirrel burrows has taken place in the study localities Velké Pavlovice and Hrušovany u Brna. It has been carried out during the years 2018–2022 in months, when ground squirrels are active (April-August). Survey was carried once at specific places, the whole area was gradually surveyed in total during these years. Predefined areas were searched for the occurrence of ground squirrel burrow openings (BO hereafter) as the basis for ground squirrel occurrence. The area covered for ground squirrel occurrence survey was based on regular national monitoring of ground squirrel populations, previous projects/activities in the area and the ground squirrel observations collected from local people. All BOs were recorded. Each BO of the ground squirrel was marked by a GPS device. The entire area was gradually searched by patrolling back and forth in parallel transects 5 meters from each other (with a deviation of about 1m depending on the visibility and barriers, which for example in vineyards meant every second row). Some patches could not be mapped because they were inaccessible or impassable (e.g., with growing crop, impenetrable vegetation, fenced plots).

Based on the mapping of BOs, the area of population occurrence (APO) was defined. The areas for both localities were created as minimum convex polygons around all BOs with a 36m buffer (to add the home range areas, TURRINI et al., 2008), exclusive of clearly unsuitable habitat for ground squirrels (dense forest or shrubland, built-up area) at the edges of the polygon.

## Data analyses

Data was analysed in ArcGis (© ESRI). All data processing was conducted in R (v4.2.1) (R Core Team, 2022), using *tidyverse* (v1.3.2) (WICKHAM et al. 2019) for data manipulation. Minimum, Q1, median, Q3, “maximum” ( $Q3+1,5*IQR$ ) and outliers are plotted in figures. Source of orthophoto maps is ČÚZK <https://geoportal.cuzk.cz>.

## RESULTS

### Overview of populations in heterogeneous agricultural habitats

Ten (17.2%) of the 58 ground squirrel populations in the Czech Republic within the period 2004–2022 occur fully or partially in the habitat of vineyards, orchards and gardens (Table I), all of them in the South Moravian region. Seven populations are

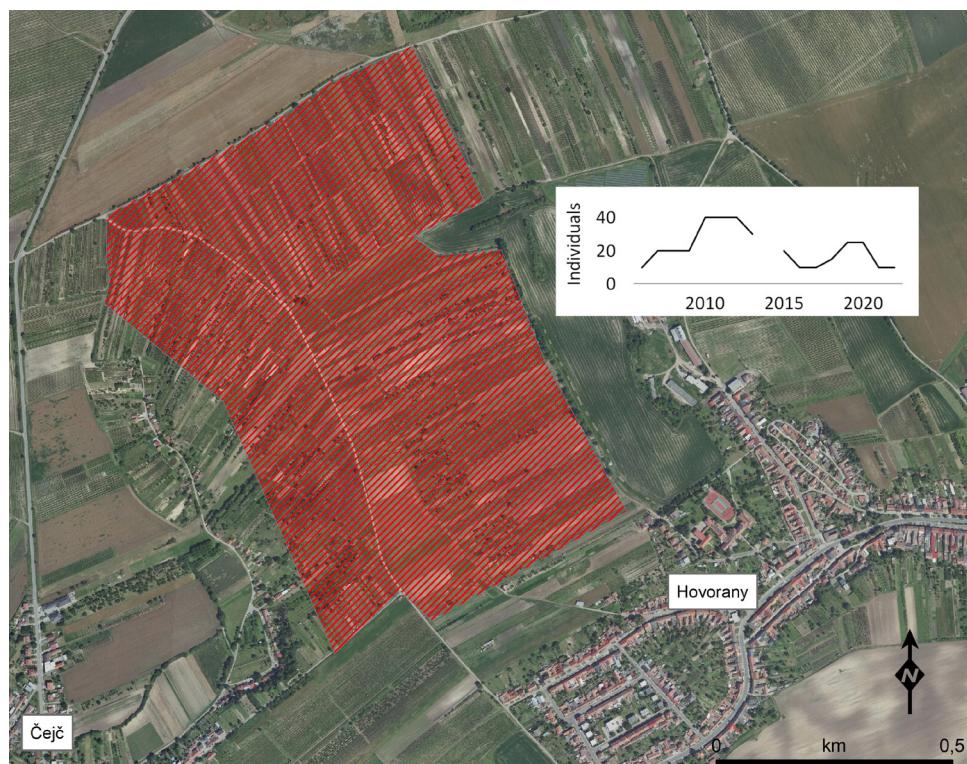


Fig. 1. Aerial map of Čejč locality with red marked area of European ground squirrel population occurrence within monitoring period (2006–2022). Figure of development of the population size is included.

Obr. 1. Ortofoto mapa lokality Čejč, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2006–2022). Graf vývoje velikosti populace je vložen do obrázku.

Table I. List of European ground squirrel populations living in described habitat of vineyards, orchards and gardens in the Czech Republic within the period 2004–2022. Climate = climatic region according to QUITT 1971; maximum = maximum size of the population within the monitored period, \* the first number indicates individuals living in described agricultural habitat, the number in brackets indicates the size of the whole local population including individuals on the airfield/playground; distance = distance to next known population, \*\* direct connection to occurrence of ground squirrels on the Austrian side (no exact distribution data from Austria are available)

Tab. I. Přehled lokalit populace sysla obecného v prostředí vinic, sadů a záhumenek v České republice v období 2004–2022. Klima = klimatická oblast dle QUITT 1971; maximum = maximální zaznamenaná velikost populace, \* první číslo udává počet jedinců ve sledovaném prostředí, číslo v závorce celková velikost lokální populace včetně jedinců na letišti, fotbalovém hřišti; vzdálenost = vzdálenost k další známé populaci, \*\* přímá návaznost na výskyt syslů na rakouské straně hranice (přesná aktuální data o výskytu syslů v Rakousku nejsou dostupná)

locality	coordinates	altitude (m a.s.l.)	climate	maximum (ind.)	distance (km)
lokalita	souřadnice	nadmoř. výška (m n.m.)	klima	maximum (jedinci)	vzdálenost (km)
Čejč	48.9583611N 16.9660278E	254	T4	40	8.0
Hnanice	48.7990556N 15.9792222E	283	T2	*30 (60)	**0.0
Hrušovany u Brna	49.0304722N 16.5850556E	194	T4	400	15.5
Jaroslavice	48.7405000N 16.2330000E	230	T4	*25 (55)	1.0
Miroslav	48.9322500N 16.2988333E	234	T2	*40 (840)	15.8
Újezd u Brna	49.1097222N 16.7630556E	211	T4	10	9.9
Slavkov u Brna	49.1605278N 16.8737222E	232	T2	30	9.9
Svatobořice-Mistřín	48.9828889N 17.0700000E	211	T4	15	3.3
Valtice	48.7307500N 16.7382222E	280	T4	15	**0.0
Velké Pavlovice	48.9108333N 16.8041667E	206	T4	600	12.8

independent isolated populations with no support from other populations. In three cases on the state border these populations are connected to neighbouring populations in Austria. In seven cases ground squirrels occur only in agricultural land (orchards, vineyards, gardens, crop fields). In three cases (Miroslav, Hnanice and Jaroslavice), besides agricultural habitats the ground squirrels also inhabit turfed airport runways or playgrounds there.

**Čejč** (Hodonín district): Fine mosaic of gardens, vineyards, orchards and crop fields between Čejč and Horovany villages cover ca. 1200 ha (Fig. 1). Occurrence of ground squirrels was first reported and checked in 2006. Population trend and size is unclear as the potential area of occurrence is very large and ground squirrels

are found there in very low densities: a few dozen individuals in an area of about 200 ha.

**Hnanice** (Znojmo district): Occurrence of ground squirrels in the Hnanice locality has been known since 2015. The population was almost certainly based on individuals coming from neighbouring Austrian population (authors' observation, ENZINGER

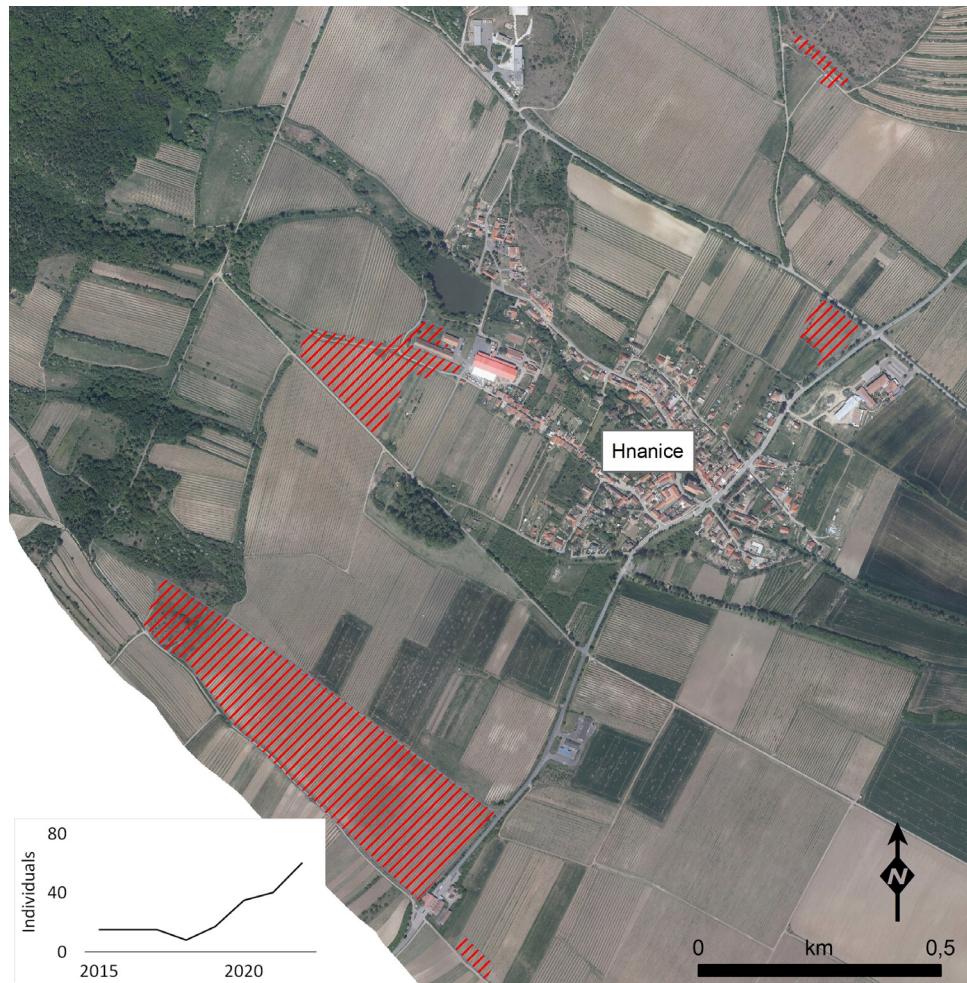


Fig. 2. Aerial map of Hnanice locality with red marked area of European ground squirrel population occurrence within monitoring period (2015–2022). Figure of development of the population size is included.

Obr. 2. Ortofoto mapa lokality Hnanice, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2015–2022). Graf vývoje velikosti populace je vložen do obrázku.

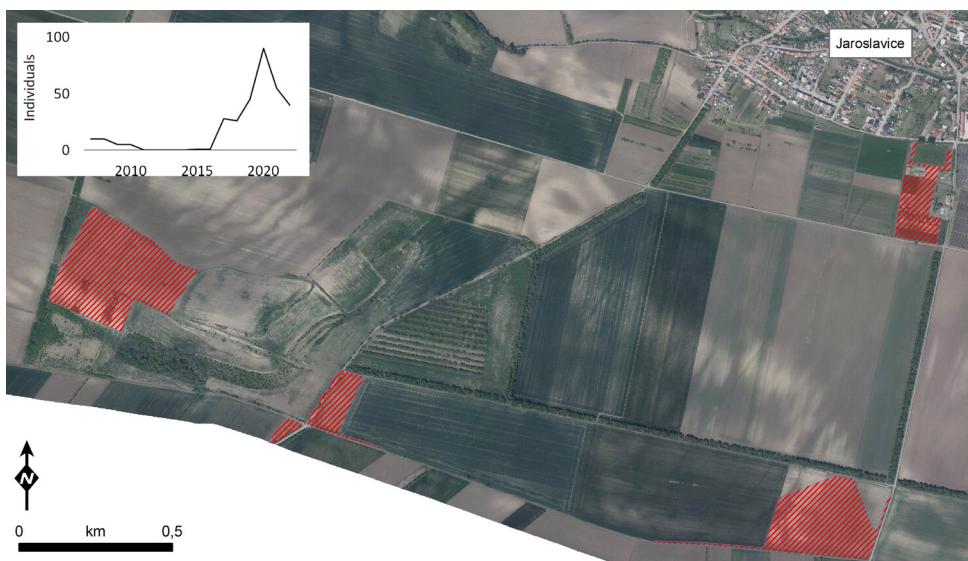


Fig. 3. Aerial map of Jaroslavice locality with red marked area of European ground squirrel population occurrence within monitoring period (2007–2022). Figure of development of the population size is included.

Obr. 3. Ortofoto mapa lokality Jaroslavice, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2007–2022). Graf vývoje velikosti populace je vložen do obrázku.

& WALDER 2006), where the species is widely distributed. The prevalent part of ground squirrel habitat in Hnanice area is made up of vineyards, but also patches of steppe habitat, pastures, and places with anthropogenic short-cut lawns such as meadows and a playground. Grass strips along roads and embankments are also important. Small, but at least partially connected groups of ground squirrels are scattered within the area (Fig. 2). The subpopulation occurring on the lawns close to factory Lenza and adjacent vineyards appears to be almost established. Other parts seem to be in the stage of colonisation and have/need support from Austria. The total area of habitat around Hnanice that would be suitable for ground squirrels is difficult to determine. Its appearance is a mosaic of different habitats. However, by estimation, it could be even more than several tens of hectares. At present, however, the area inhabited by ground squirrels covers only a few hectares. The importance of the locality lies in the connection to other suitable habitats (pastures, vineyards, orchards) along the entire southern border of Podyjí national park, which is a potential area of several thousand hectares.

**Jaroslavice** (Znojmo district): Occurrence of ground squirrels in Jaroslavice locality is known since 2007. The population was formed thanks to individuals coming from neighbouring Austrian population (authors' observation, ENZINGER & WALDER 2006). Small more or less connected groups of ground squirrels are scattered at several sites with variable fluctuation in the number of individuals (Fig. 3). Groups



Fig. 4. Aerial map of Miroslav locality with red marked area of European ground squirrel population occurrence within monitoring period (2008–2022). Figure of development of the population size is included.

Obr. 4. Ortofoto mapa lokality Miroslav, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2008–2022). Graf vývoje velikosti populace je vložen do obrázku.

occupy three vineyards, an orchard, small alfalfa fields and football playground. Individual animals also have burrows in grassy embankments and strips around dirt roads in the neighbourhood of vineyards. The subpopulation occurring on the football field and in the adjacent orchard and alfalfa field appears to be well established. Other parts of the population seem to be in the stage of colonisation and have/need support from the Austrian population. The total area of habitat around Jaroslavice that would be suitable for ground squirrels is difficult to determine. Its appearance is

mosaic. However, by estimation, it could be up to a few tens of hectares. At present the area inhabited by ground squirrels reaches about 10 hectares.

**Miroslav** (Znojmo district): The ground squirrel population was established through the release of ca. ten individuals in the area of airfield in 2006. Since then, the population has steadily increased to several hundreds of individuals and after occupying the whole airfield, individuals began to spread to the nearby agricultural land and steppe hills. The core of the local population stays at the airfield, but groups of ground squirrels are scattered in alfalfa fields, vineyards, gardens and orchards in the area of 1200 ha (Fig. 4). Their occurrence in these habitats is very rare and mosaic-like, and also highly variable over time, so it is difficult to determine how large an area is populated by them. In fact, they probably occupy a few hectares. The population in agricultural habitat is in the stage of colonisation and has constant support from the airfield.

**Slavkov u Brna** (Vyškov district): fine mosaic of gardens, vineyards, orchards and crop fields northwest of the town in close vicinity of a golf course. This mosaic contiguously covers at least an area of approx. 170 ha and ground squirrels have been observed scattered throughout almost the whole of this area (Fig. 5). So, their

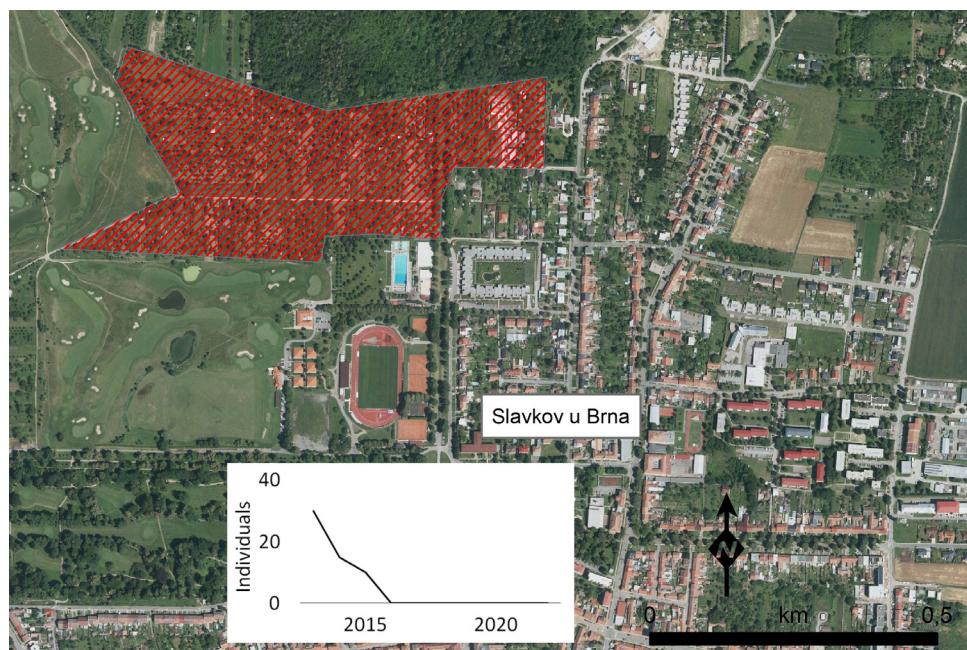


Fig. 5. Aerial map of Slavkov u Brna locality with red marked area of European ground squirrel population occurrence within monitoring period (2013–2015). Figure of development of the population size is included.

Obr. 5. Ortofoto mapa lokality Slavkov u Brna, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2013–2015). Graf vývoje velikosti populace je vložen do obrázku.

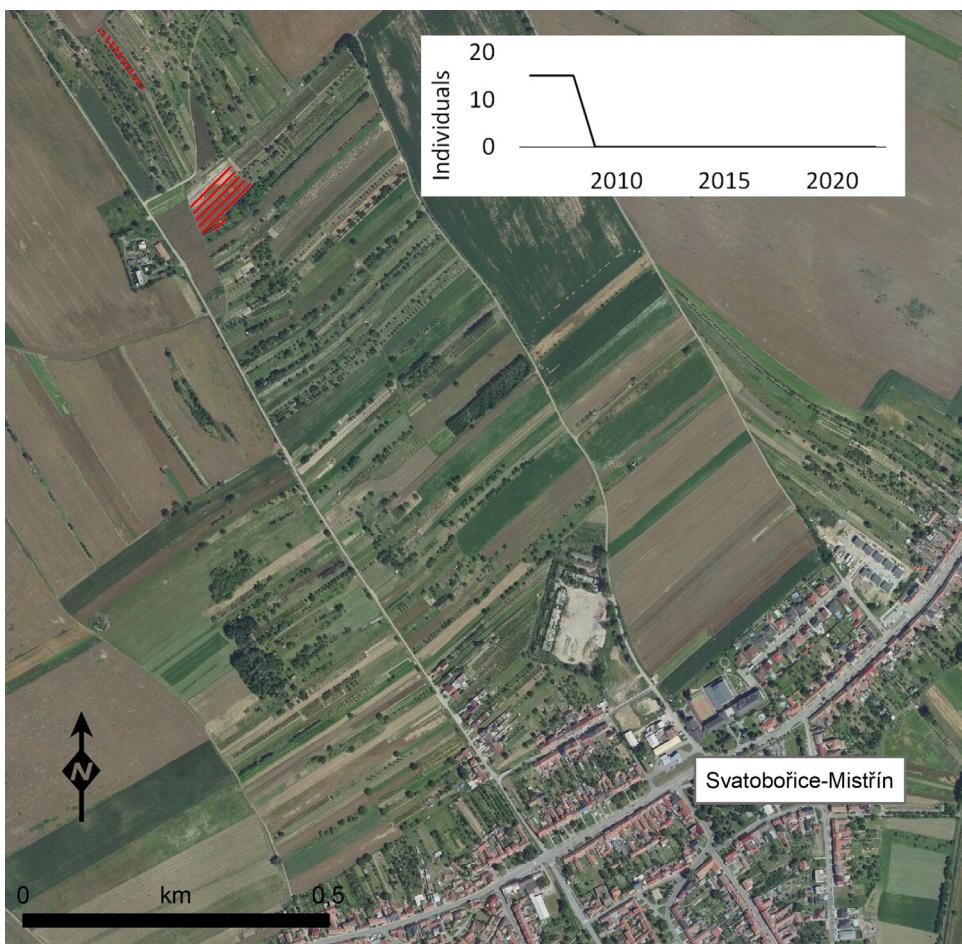


Fig. 6. Aerial map of Svatobořice-Mistřín locality with red marked area of European ground squirrel population occurrence within monitoring period (2006–2008). Figure of development of the population size is included.

Obr. 6. Ortofoto mapa lokality Svatobořice-Mistřín, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2006–2008). Graf vývoje velikosti populace je vložen do obrázku.

abundance was very sparse. Population monitoring, started in 2013, and took place already in the period of population extinction. The estimated population size did not exceed 30 individuals in any year. Since 2016 no individuals have been observed.

**Svatobořice-Mistřín** (Hodonín district): fine mosaic of gardens, vineyards, orchards and crop fields north of the village Mistřín. This mosaic contiguously covers at least an area of approx. 70 ha, but ground squirrels were always observed only in the

northernmost part of 0.5 ha (Fig. 6). Population monitoring started in 2006 and took place during the period of population extinction. The estimated population size did not exceed 15 individuals in any year. Since 2009 no individual has been observed.

**Újezd u Brna** (Brno venkov district): fine mosaic of gardens, vineyards and orchards on the NE border of the village. This mosaic contiguously covers at least an area of approx. 80 ha, but ground squirrels were always observed only in the central part of 1.5 ha, northwest of the railway underpass (Fig. 7). Population moni-

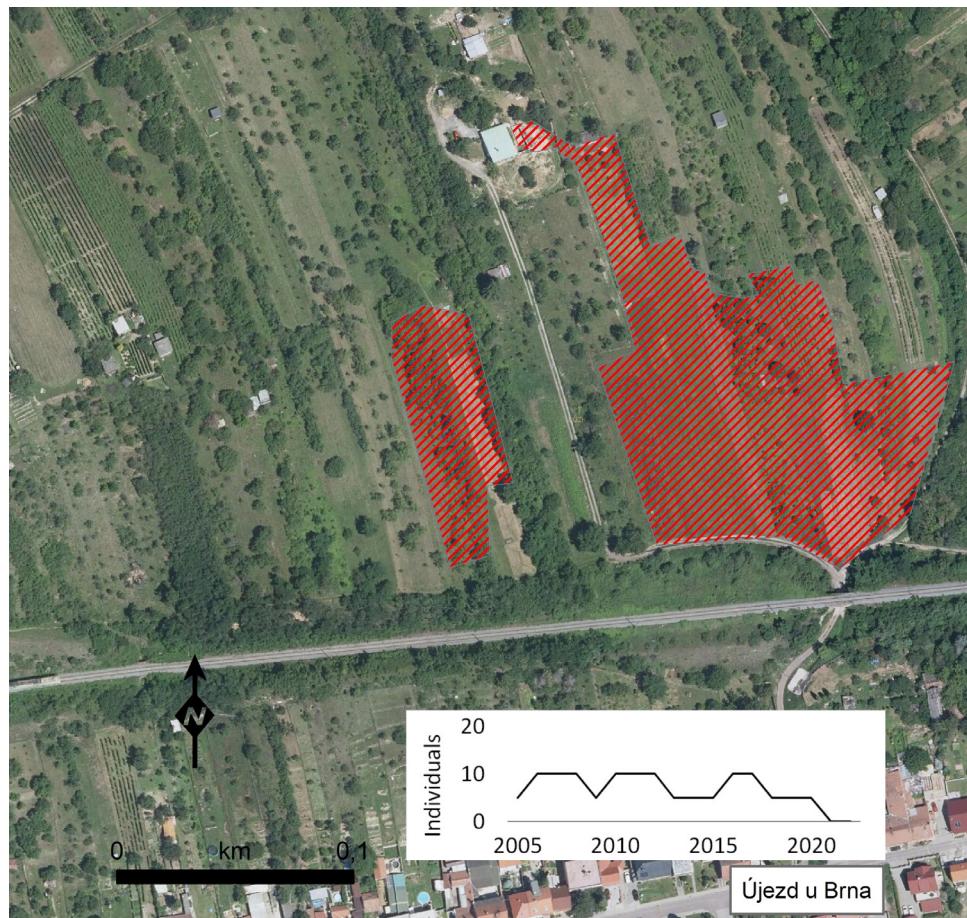


Fig. 7. Aerial map of Újezd u Brna locality with red marked area of European ground squirrel population occurrence within monitoring period (2005–2020). Figure of development of the population size is included.

Obr. 7. Ortofoto mapa lokality Újezd u Brna, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2005–2020). Graf vývoje velikosti populace je vložen do obrázku.

toring took place during the period of slow population extinction. Population was monitored since 2005 and the estimated abundance did not exceed 10 individuals in any year, however the survey there is very difficult due to the habitat. Since 2021 no animal has been observed.

**Valtice** (Břeclav district): Occurrence of ground squirrels in Valtice locality is known since 2015. The population is certainly based on individuals coming from neighbouring Austrian population (authors' observation, Enzinger & Walder 2006). Most of the habitat in the locality is made up of vineyards and an orchard supplemented by grass strips that serve as temporary paths and grass embankments. Until now, only a few individuals were recorded in the vineyards in the Czech Republic so it is obvious that the occurrence of ground squirrels is completely dependent on the situation at the Austrian side of the locality (Fig. 8). Reproduction of ground squirrels in the Czech part of the locality was observed in 2021.

### Ground squirrel populations in Hrušovany u Brna and Velké Pavlovice

These two populations have been studied in detail. Both ground squirrel populations in Hrušovany u Brna (Brno venkov district) and Velké Pavlovice (Břeclav district) occur in areas of fine mosaic of gardens, vineyards, orchards and crop fields.

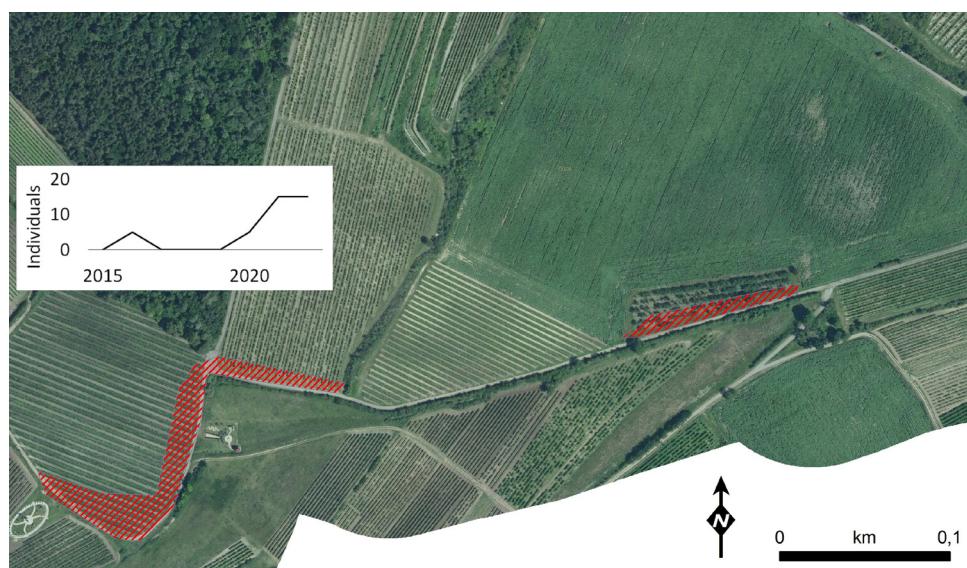


Fig. 8. Aerial map of Valtice locality with red marked area of European ground squirrel population occurrence within monitoring period (2015–2022). Figure of development of the population size is included.

Obr. 8. Ortofoto mapa lokality Valtice, červená plocha vyznačuje celkovou oblast výskytu populace sysla obecného v monitorovacím období (2015–2022). Graf vývoje velikosti populace je vložen do obrázku.

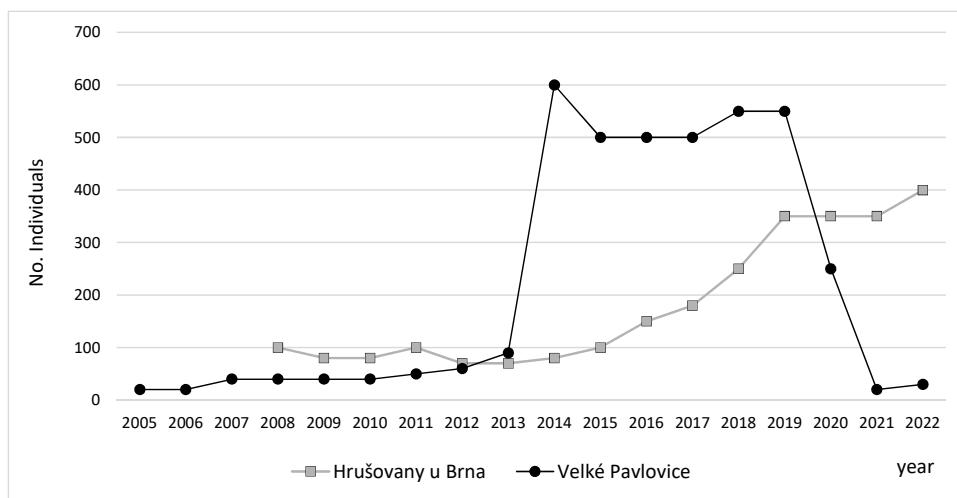


Fig. 9. Development of the ground squirrel populations in two example localities described in assessed size of the population (for an explanation of the sharp increase in the estimated number of individuals between 2013–2014 and decrease in 2019–2021 at Pavlovice locality, see the text).  
Obr. 9. Vývoj velikosti populací sysla obecného na dvou detailněji studovaných lokalitách (vysvětlení prudkého nárůstu a poklesu velikosti populace ve Velkých Pavlovicích v hlavním textu).

### Local ground squirrel populations

The population in Hrušovany u Brna (hereafter Hrušovany) has been known and monitored since 2008, however, according to local residents, ground squirrels have always been present here. Similarly, the population in Velké Pavlovice (hereafter Pavlovice) has been known and monitored since 2005 and has always been occurring there according to local residents.

Population in Hrušovany has been steadily increasing since the beginning of monitoring (Fig. 9) and currently completely occupies a clearly defined area of heterogeneous mosaic agricultural landscape southwest of the village which is surrounded by less suitable habitats (urban areas and extensive crop fields). The distribution of burrow openings is not uniform through the area of occurrence (Fig. 10). Hrušovany's area of population occurrence (APO) is 40.0 ha.

Development of the population in Pavlovice is slightly unclear because of the huge potential area of suitable habitat around the town. Monitoring data showed a big increase in 2014 (Fig. 9), the reason being that there was a reassessment of population size estimate based on the first detailed mapping of the whole area. More realistic is a slow increase of the population up to 2019, when the population size was assessed to be between 500–600, followed by dramatic decline in 2020–2021 to 20 individuals, most probably due to flooding caused by torrential rains and generally cold and rainy springs in these years (Fig. 9). Pavlovice area of population occurrence (APO) is 404.5 ha. The distribution of burrow openings is not uniform through the area of occurrence. Colony shows a central core surrounded by more or less

connected smaller groups or even solitary individuals (Fig. 11). Suitable habitats are also outside the area of population occurrence, so there is a space for spreading and growth of the population.

### Description of habitat in APO

In both localities environment is not monotonous, both areas are fragmented into small differently managed plots. In Pavlovice locality 909 plots of land were recognized, and 252 plots in Hrušovany (Figs. 12 and 13). Thirteen habitat types and six types of management of herbaceous vegetation were identified there (Tab. II).

All 13 habitats were identified in Pavlovice APO and 10 habitats in Hrušovany APO. The proportions of habitats and types of management vary between localities (Tab. III). Habitats with a high proportion of trees (tree stands, tree alleys, orchards) occupy 18% in Pavlovice and 28% in Hrušovany. Habitats where bush shaped plants predominate (scrublands, vineyards) occupy 55% in Pavlovice and 30% in Hrušovany. Diverse habitats of arable land (crop fields, gardens) occupy 18% in Pavlovice and 31% in Hrušovany. Only herbaceous vegetation patches (pastures, steppe

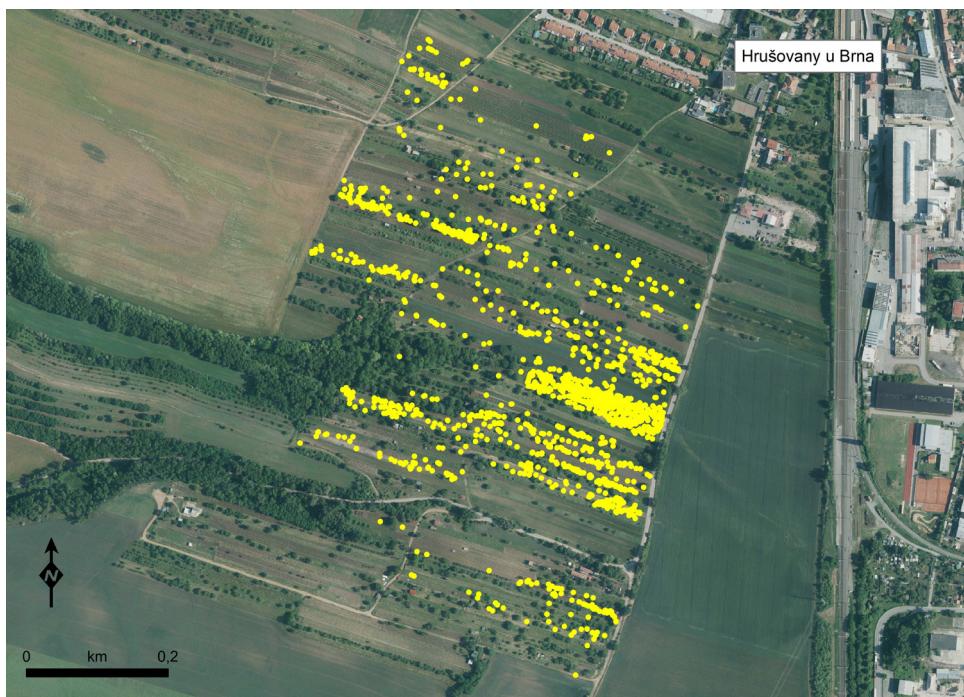


Fig. 10. Aerial map of Hrušovany u Brna locality with results of mapping of burrow openings of European ground squirrels (yellow dots) in 2019–2022.

Obr. 10. Ortofoto mapa Hrušovany u Brna s vyznačením identifikovaných nor sysla obecného (žluté body) v letech 2019–2022.

grassland, tall and short-cut grasslands, ruderal) occupy only 9% in Pavlovice and 6% of the area in Hrušovany.

The height of herbal vegetation varies greatly on individual plots in all habitats due to different land owners who have different farming methods and different machinery. Individual patches vary from ploughed, through to ones mulched at weekly intervals and to others mowed once or twice a year. Plots with no management of vegetation occur in the areas too. In the case of arable land, the height of vegetation depends on the kind of crop which, except vegetables, reaches heights over 20 cm (e.g., alfalfa up to 0.5 m, grain up to 0.5 m, corn up to 1.5 m). The proportion of basic categories of management of herbal vegetation in both areas is shown in Tab. IV.

#### **Distribution of ground squirrels within the area of occurrence (APO) based on mapping of burrows**

As part of a detailed study, 476 burrow openings were found in Pavlovice APO and 723 in Hrušovany APO. Within the study period the overall density of BOs was 21.4 BOs/ha in Hrušovany, respectively 1.37 BOs/ha in Pavlovice.

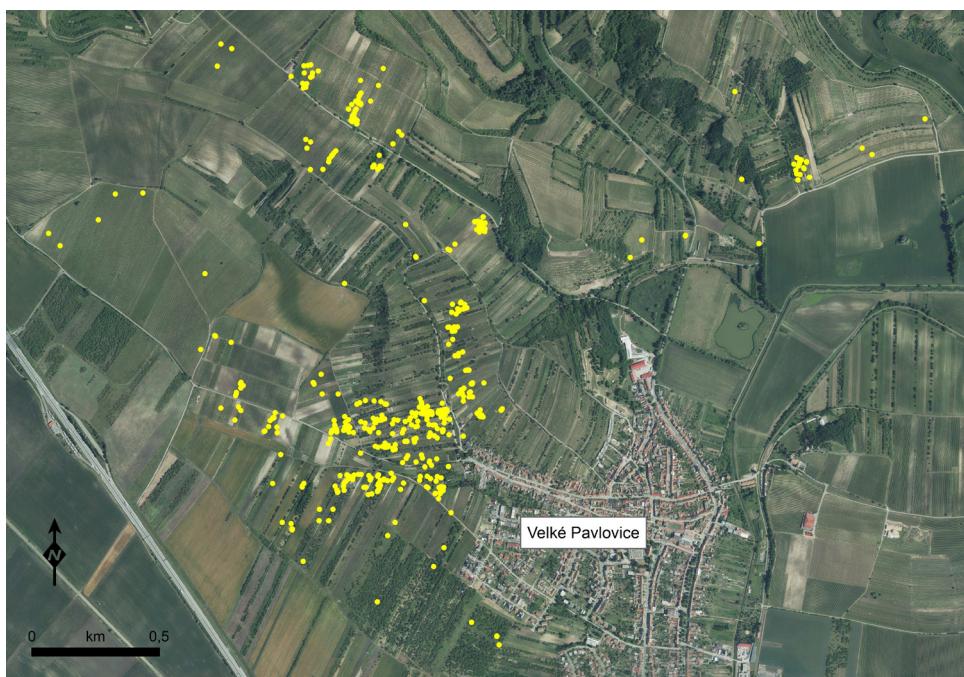


Fig. 11. Aerial map of Velké Pavlovice locality with results of mapping of burrow openings of European ground squirrels (yellow dots) in 2018.

Obr. 11. Ortofoto mapa Velkých Pavlovic s vyznačením identifikovaných nor sysla obecného (žluté body) v roce 2018.

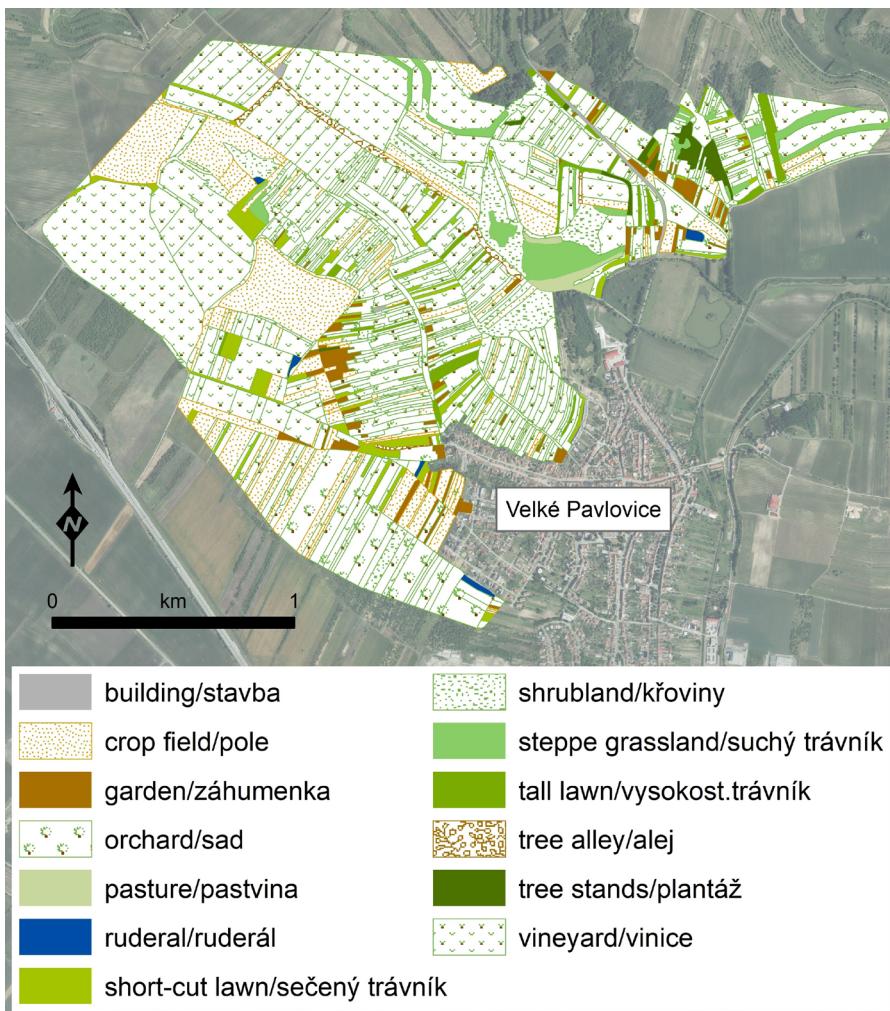


Fig 12. Map of habitat types in the area of occurrence of European ground squirrel in locality Velké Pavlovice.

Obr. 12. Mapa typů prostředí v oblasti výskytu populace sysla obecného u Velkých Pavlovic.

Within the areas of occurrence ground squirrels occur in different densities. There were single plots, or in Pavlovice even bigger parts of the area without any ground squirrels. Habitat types where there were no records of burrows at all are ruderal, tree stands, building and grazed pasture (Tabs. III and IV, Figs. 14 and 15).

In most habitat and management types, ground squirrel burrows were found. The potential of individual types of habitat / management for ground squirrels is shown

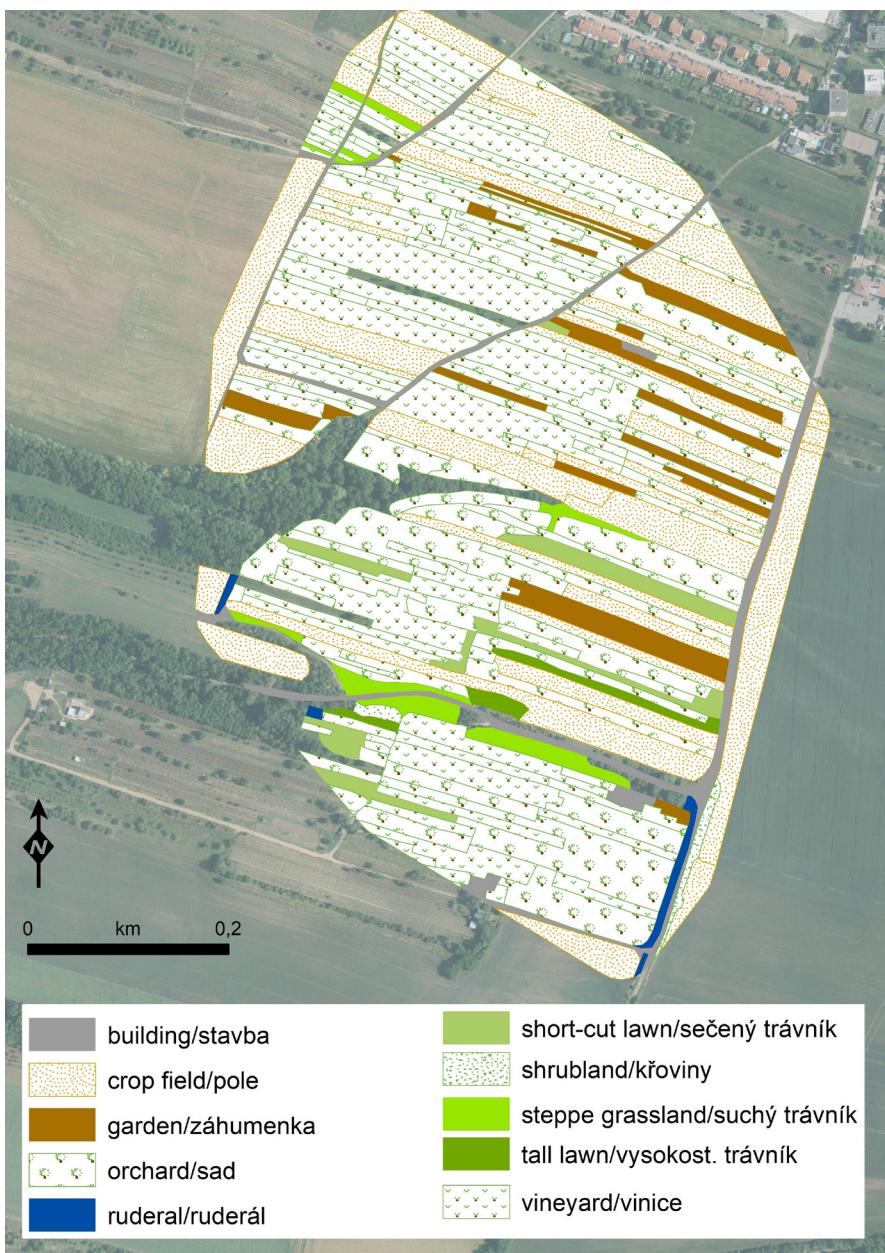


Fig. 13. Map of habitat types in the area of occurrence of European ground squirrel in locality Hrušovany u Brna.

Obr. 13. Mapa typů prostředí v oblasti výskytu populace sysla obecného u Hrušovan u Brna.

Tab. II. Overview of type of mapped habitats and recorded type of management in two evaluated localities (Hrušovany u Brna and Velké Pavlovice) of European ground squirrel  
 Tab. II. Přehled typů prostředí a způsobu hospodaření na dvou lokalitách (Hrušovany u Brna a Velké Pavlovice) s výskytem sysla obecného

type of habitat typ prostředí	type of management / typ hospodaření					
	ploughed oraný	mowed grass sečený	grazed pasený	ploug./mowed oraný/sečený	fallow ladem	no man. bez hosp.
vineyard vinice	×	×			×	×
orchard sad	×	×	×		×	×
garden záhumenka					×	
crop field pole	×					×
ruderal ruderál						×
pasture pastvina			×			
short-cut lawn kosený trávník		×				
tall lawn vysokost. trávník						×
steppe grassland suchý trávník	×		×			×
shrubland křovina						×
tree stands plantáz stromů						×
tree alley alej		×				×
building stavba						×

in Figs. 14–17 showing the range of BOs densities recorded on individual plots of the given type of habitat / management. In vineyards, orchards, gardens and crop fields, ground squirrels are able to occur in very high densities. The number of outliers shows that under certain conditions, ground squirrels burrows can reach extreme densities on a certain plot (this is not surprising, since the ground squirrels tend to live in colonies). 34 BOs (2.8 %) were found at plots with no management (abandoned orchards and vineyards, shrubland, steppe grassland, tall lawn), all of them at the edges of those plots.

The occurrence and distribution of burrows confirms that ground squirrels live in vineyards and orchards, even in parts of the area with only this habitat type (see detailed pictures of BOs distribution on Figs. 18, 19).

Tab. III. Proportion of different types of habitats in the area of population occurrence of European ground squirrel in localities Pavlovice and Hrušovany and mean densities of ground squirrel burrow openings (BOs) on plots of given habitat

Tab. III. Podíl jednotlivých typů prostředí v oblastech výskytu sysla obecného u Velkých Pavlovic a Hrušovan u Brna a průměrné hustoty nor syslů pro identifikované plochy daného prostředí

habitat prostředí	Pavlovice			Hrušovany		
	total area		mean density of BOs	total area		mean density of BOs
	celková plocha	průměrná hustota nor	ha	%	celková plocha	průměrná hustota nor
vineyard vinice	190.22	47.0	1.3	10.33	25.8	22.6
orchard sad	66.70	16.5	1.6	11.27	28.2	26.5
garden záhumenka	9.98	2.5	0.4	2.04	5.1	27.0
crop field pole	63.87	15.8	1.6	10.21	25.6	18.3
ruderal ruderál	1.00	0.2	no BOs	0.18	0.5	no BOs
pasture pastvina	2.11	0.5	no BOs	0	0	–
short-cut lawn sečený trávník	12.97	3.2	3.0	1.09	2.7	18.6
tall lawn vysokost. trávník	6.15	1.5	2.0	0.35	0.9	no BOs
steppe grassland suchý trávník	12.41	3.1	no BOs	0.79	2.0	11.2
shrubland křoviny	30.49	7.5	no BOs	1.50	3.8	3.4
tree stands plantáž	3.39	0.8	no BOs	0	0	no BOs
tree alley alej	3.65	0.9	0.7	0	0	–
building stavba	1.49	0.4	no BOs	0.16	0.4	no BOs

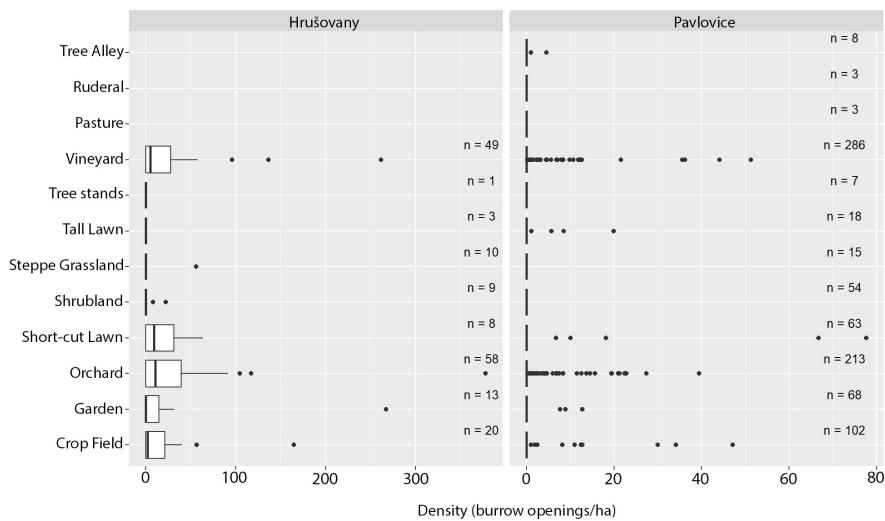


Fig. 14. Distribution of densities of ground squirrel burrow openings in different types of habitat in all mapped plots (because of different densities of ground squirrel in both localities, different scale at axis X is used).

Obr. 14. Distribuce hustot nor sysla obecného v daném prostředí ze všech mapovaných ploch (z důvodu různých hustot populace sysla obecného na dvou lokalitách byla použita odlišná škála osy X).

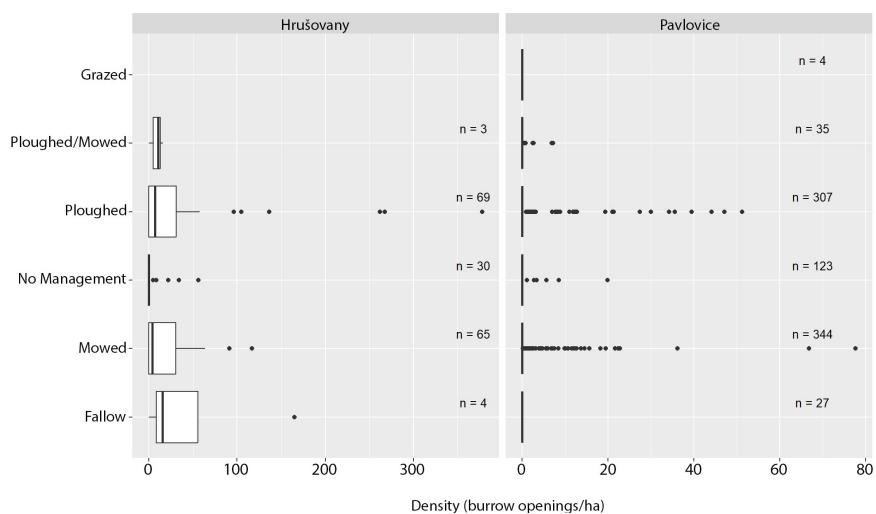


Fig. 15. Distribution of densities of ground squirrel burrow openings with different types of management in all mapped plots (because of different densities of ground squirrel in both localities, different scale at axis X is used).

Obr. 15. Distribuce hustot nor sysla obecného v daném typu hospodaření ze všech mapovaných ploch (z důvodu různých hustot populace sysla obecného na dvou lokalitách byla použita odlišná škála osy X).

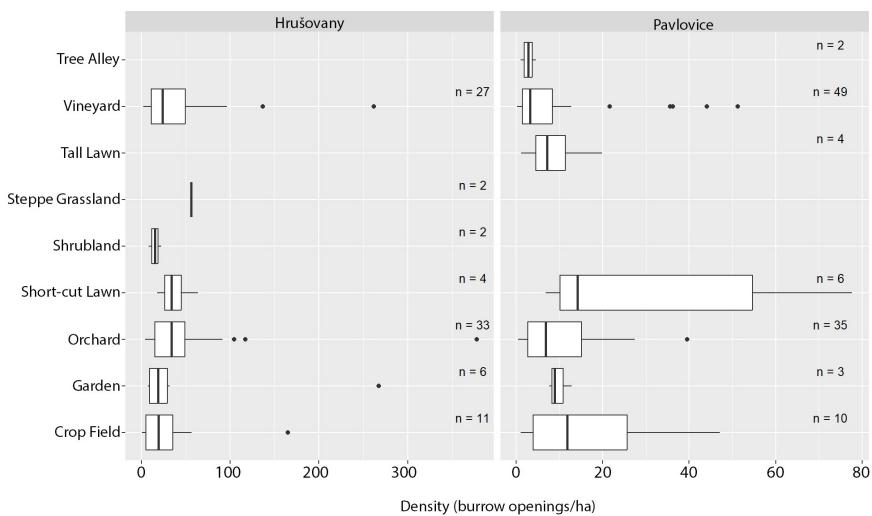


Fig. 16. Distribution of densities of ground squirrel burrow openings in different types of habitats in plots with ground squirrel occurrence (because of different densities of ground squirrel in both localities, different scale at axis X is used).

Obr. 16. Distribuce hustot nor sysla obecného v daném prostředí z mapovaných ploch s výskytem sysla obecného (z důvodu různých hustot populace sysla obecného na dvou lokalitách byla použita odlišná škála osy X).

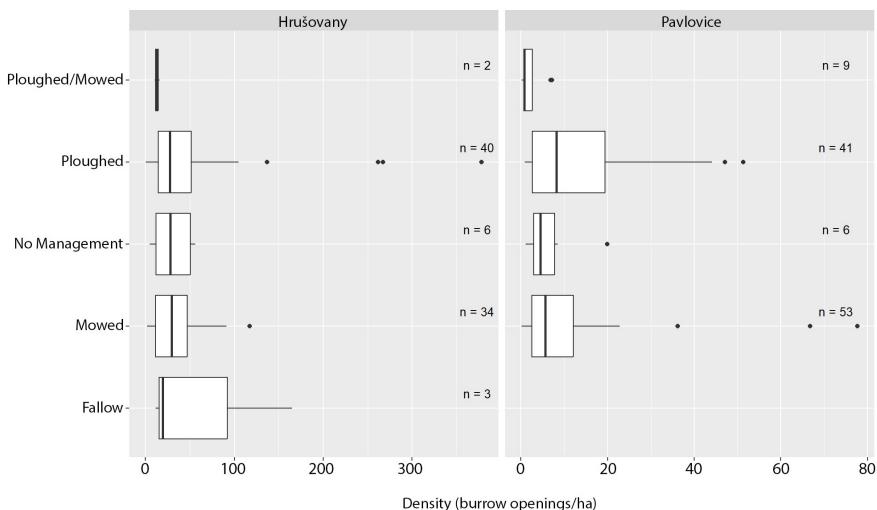


Fig. 17. Distribution of densities of ground squirrel burrow openings in different types of management in plots with ground squirrel occurrence (because of different densities of ground squirrel in both localities, different scale at axis X is used).

Obr. 17. Distribuce hustot nor sysla obecného v daném typu hospodaření z mapovaných ploch s výskytem sysla obecného (z důvodu různých hustot populace sysla obecného na dvou lokalitách byla použita odlišná škála osy X).

Tab. IV. Proportions of different types of management of herbaceous vegetation in the area of population occurrence of European ground squirrel in localities Pavlovice and Hrušovany and mean densities of ground squirrel burrow openings (BOs) on plots with given type of management  
 Tab. IV. Podíl jednotlivých typů hospodaření v oblastech výskytu sysla obecného u Velkých Pavlovic a Hrušovan u Brna a průměrné hustoty nor syslů pro identifikované plochy daného hospodaření

habitat prostředí	Pavlovice			Hrušovany		
	total area		mean density of BOs	total area		mean density of BOs
	celková plocha	průměrná hustota nor	ha	%	celková plocha	průměrná hustota nor
ploughed orané	128.15	31.7	1.8	19.45	48.6	30.9
mowed grass sečené	163.24	40.4	1.6	12.28	30.7	17.2
grazed pasené	6.74	1.7	No BOs	0	0	—
ploughed / mowed orané / sečené	38.98	9.6	0.6	1.05	2.6	8.7
fallow dočasně ladem	8.01	2.0	No BOs	0.42	1.1	48.9
no management bez hospodaření	57.66	14.3	0.3	4.60	11.5	6.1

Important characteristics of both localities is the heterogeneity of the habitats and management. Plot size in both studied localities are very small (Tab. V). See detailed picture of BOs distribution in the central part of Pavlovice locality (Fig. 20). Five photos of the environments visually illustrate the heterogeneity of the environment and the amount of view obscuring vegetation in both localities (Figs. 21–24).

## DISCUSSION

### General comments to populations in heterogeneous agricultural habitats

We identified 10 populations of the European ground squirrel in southern Moravia living in a highly heterogeneous landscape of orchards, vineyards and arable lands. The population's status and development vary amongst the populations. Most of them are rather small numbering only a few dozens of individuals but there are others with an estimated population of several hundreds. Some colonies died out recently, others are decreasing, fluctuating in size or increasing. Above-described populations trends are similar to other populations living in more typical habitats (e.g., MATĚJŮ et al. 2008, MATĚJŮ et al. 2010, MATĚJŮ & BRZOBOHATÁ 2022). Often and high fluctuations in numbers are typical for small and isolated populations, which is the situation of most of the European ground squirrel colonies in the Czech Republic. More detailed study would be necessary to discover all causative factors.

Tab. V. Size of identified habitat plot (in hectares) in the area of population occurrence of European ground squirrel in localities Pavlovice and Hrušovany

Tab. V. Velikost identifikovaných ploch určitého prostředí (v hektarech) v oblastech výskytu populací sysla obecného na lokalitách Hrušovany u Brna a Velké Pavlovice

locality lokalita	mean průměr	sd sd	median medián	minimum minimum	maximum maximum
Pavlovice	0.44	1.114	0.196	0.00100	24.66
Hrušovany	0.16	0.196	0.097	0.00002	1.18

However, the examples of some populations (e.g., Hrušovany and Pavlovice) show that, under certain conditions, agricultural heterogeneous landscapes with high proportion of view obscuring vegetation can provide viable habitat for the long-term survival of the European ground squirrel.

#### Populations in Hrušovany u Brna and Velké Pavlovice

The occurrence of ground squirrels in two detail-studied areas is not uniform. There are patches with high and low densities of BOs and parts with no occurrence of



Fig. 18. Example of occurrence of ground squirrel burrow openings (yellow dots) in part of only vineyard habitat (Velké Pavlovice 2018).

Obr. 18. Příklad výskytu nor sysla obecného (žluté body) v části, kde se vyskytuje pouze vinice (Velké Pavlovice 2018).

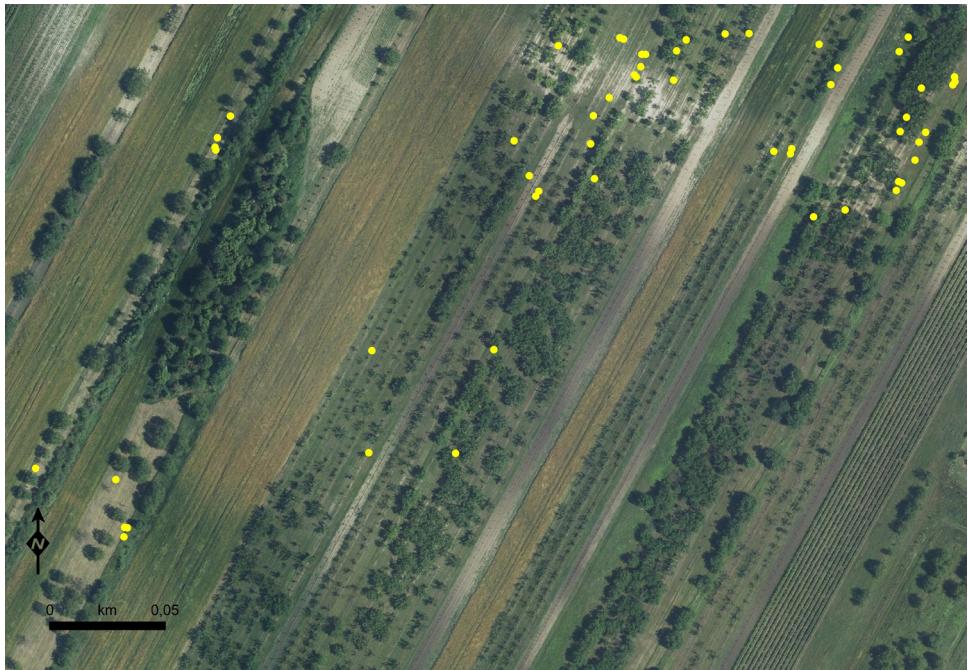


Fig 19. Example of occurrence of ground squirrel burrow openings (yellow dots) in part with prevailing orchard habitat (Velké Pavlovice 2018)  
 Obr. 19. Příklad výskytu nor sysla obecného (žluté body) v části, kde převažují sady (Velké Pavlovice 2018).

ground squirrels. Also, the environment at both localities is not uniform, it is highly diverse in proportion of bushes, proportion of trees, management of herbaceous vegetation. Measured median size of plots was 0.097 ha in Hrušovany, respectively 0.196 ha in Pavlovice, the values being rather smaller than expected home range of individual ground squirrel (between 0.1 – 0.6 ha, Matějů 2008, Turrini et al. 2008). This allows individuals to move amongst different plots on a daily basis as needed. The observed small sizes of agricultural plots (mean: 0.16 respective 0.44 ha) are even more striking when compared with the average size of agricultural plots in the Czech Republic: 5.6 ha (LPIS 2022). According to data from 1936, when the ground squirrel was a common species in the territory of the Czech and Slovak Republics, the average size of the fields of small and medium-sized farmers ranged from 0.25 to 0.33 ha (GRULICH 1955). It is very close to the situation in the locations we studied.

Ground squirrels live in orchards and vineyards, it is their main habitat in those localities. Despite the fact that orchards consist of plantations of fruit trees and vineyards are plantations of woody grape vine “bush”, the density of them allows the growth of grass and herbal vegetation which is usually managed by mowing or ploughing. Also, the lower parts of fruit trees and grapevines are trimmed. The-



Fig. 20. Example of occurrence of ground squirrel burrow openings (yellow dots) in central part of very fine mosaic of small plots of different habitats (Velké Pavlovice 2018).  
 Obr. 20. Příklad výskytu nor sysla obecného (žluté body) v centrální části s jemnou mozaikou různých typů prostředí (Velké Pavlovice 2018).

refore, under and between the trees and vine rows, there is a relatively open environment probably allowing a sufficient all-round view and with enough herbaceous vegetation as a source of food. Ground squirrels may benefit from burrows located under tree trunks respectively under their crowns, where the soil is dry and there is less risk of burrow flooding during torrential rains. Moreover, ground squirrels also benefit from fruit trees in the form of fallen nutritious fruit they consume (apricots, cherries, sour cherry, nuts). Only 15 BOs were found at abandoned orchards and vineyards with no management (1.6% from all BOs in these two habitats) and only at their edges. Olive groves mentioned by RAMMOU et al (2021) from Greece are probably similar in nature to the fruit orchards described in our study.

In both closely studied localities, gardens and crop fields are important components of the local environment. Ground squirrels live in them and can reach high densities in these habitats. Gardens and crop fields are a very diverse group of plots, which vary over time depending on the crop that is currently grown there. The height of vegetation could vary from zero up to 1.5 m. Similarly, to orchards, gardens and crop fields are an important source of nutritious food for ground squirrels, as they eat planted vegetables, legumes and cereals (GRULICH 1960, own unpublished data). However, it must be noted that the abundant occurrence of ground squirrels

in field cultures is mainly a matter of field edges and is probably only seasonal. Ground squirrel burrows were mapped here at a time when the fields could provide them with some food. Whether the burrows or the occurrence of ground squirrels persists outside the growing season, when ploughing is carried out, has not been checked. In view of the earlier study by GRULICH (1955, 1960), we do not consider this likely.

Occasionally ground squirrel burrows were found also in tall lawns and shrubland – habitats with tall and dense vegetation. However, all those burrows were located only at the edges of those plots and close to other more suitable habitats.

Small patches of open habitats such as pasture, steppe grassland and short-cut lawns are very rare and scattered in both localities. Ground squirrels occur there, but it is not their main habitat. No occurrence of ground squirrels on two pastures occurring in Pavlovice APO (habitat known as preferred by ground squirrels) can be explained by the fact that they originated in the period of the survey.

Fruit tree alleys are also rare, however they could play an important role as corridors with suitable habitat (mowed lawn) and nutrition food (fallen fruit).

Most plots with ground squirrel occurrence cannot be classified as open habitat, as they are dominated by higher vegetation. An environment with a high proportion of view-obscuring vegetation may mean a higher risk of predation for ground



Fig. 21. Central part of locality Velké Pavlovice, where the core of the local ground squirrel population occurs.

Obr. 21. Centrální oblast výskytu populace sysla obecného ve Velkých Pavlovicích.



Fig. 22. European ground squirrel in the described habitat  
Obr. 22. Sysel obecný v popisovaném typu prostředí.

squirrels and is not favourable for them in the long term. For example, Townsend's ground squirrel (*Urocitellus townsendii*) shows differences in vigilance depending on the occurrence of bushes (SHARPE & VAN HORNE 1998). At some localities from our survey, ground squirrel populations actually disappear, but in others they persist in large numbers and in some localities they even spread. Thus, the level of predation could indeed be too high in some localities, but in other places, it may not be a limiting factor. And of course, the environment of orchards and vineyards can also bring ground squirrels some benefits that can compensate for the negative effects of predation.

There are probably two main factors, which provide benefits for European ground squirrels in described habitat: rich food sources and heterogeneity of the environment. Nutritional food is especially important for ground squirrels as they are a hibernating species that have to build up fat reserves during a short period of the year (SHERMAN & RUNGE 2002, STRAUSS et al. 2007). Assuredly, the orchards, crop fields and gardens offer such food.

Heterogeneity could work in more ways. Firstly, small plots also create additional habitat – ecotones, with additional food sources. Second, it gives the possibility to avoid temporary disturbances like mowing or ploughing by moving to another not disturbed plot. The third is the possibility of utilisation of habitats, which do not meet all ground squirrel needs, but as a mixture of different habitats, they do. For example, a ploughed vineyard itself provides only relatively open habitat, but no



Fig. 23. Central part of locality Hrušovany u Brna.

Obr. 23. Centrální oblast výskytu populace sysla obecného v Hrušovanech u Brna.

food. On the other hand, tall grassland or grain fields provide nutritious seeds, but no view. In such a variety of different habitats, ground squirrels are able to use areas that are not suitable on their own. The same principle probably works for other species here, which means higher biodiversity in general. The preliminary survey suggested high invertebrate fauna diversity (EKRTOVÁ et al. 2021). Invertebrates are also important food components of ground squirrels (AROK et al. 2021).

According to HANNON et al. (2006) Uinta ground squirrel (*Urocitellus armatus*) seems to be capable of adapting to variation in the structure of vegetation and will likely thrive in areas of sagebrush occurrence as long as an abundance of grasses are available to provide fatty seeds to forage. KARELS et al. (2000) found in their long-term study that the population density of the Arctic ground squirrel (*Urocitellus parryii*) increased when supplemental food was provided or when predation was excluded. The changes occur primarily through changes in body condition and reproduction respectively. A study by HOFFMANN et al. (2008) showed that an anthropogenically modified environment can significantly influence – increase – the density of European ground squirrels and positively influence their reproductive abilities. In places with a source of nutritionally rich food (alfalfa field), a significantly higher representation of sexually active yearling males was recorded.

#### **Implications for protection of the species**

The European ground squirrel is endemic to south-eastern and central Europe. In the middle of the 20<sup>th</sup> century, European ground squirrels were widespread in the former Czechoslovakia and considered an agricultural pest (GRULICH 1960). With intensification of agriculture and mainly farmland consolidation, agricultural open

land in the Czech Republic dramatically changed, subsequently the ground squirrel population began to decrease in the 1960s and break into small and isolated colonies. Currently ground squirrels occur in about 40 small isolated populations of size between a few individuals up to several hundred (MATĚJŮ et al. 2008, 2010; MATĚJŮ & BRZOBOHATÁ 2022). The species is therefore considered critically endangered in the Czech Republic. Strong population decline has been observed also in other EU countries (JANÁK et al. 2013, HEGYELI 2020).

Usually, the Czech populations are located at airports, playgrounds and anthropogenic short-cut grassland. They are rather small, mutually isolated and surrounded by unsuitable habitats with no potential to spread, which leaves them susceptible to extinction risk due to stochastic fluctuations and genetic factors.

Localities described within the study could offer large potential space for the populations and due to their patchiness, the “metapopulation” system of occurrence of colonies could be established there. Moreover, those localities are used for agricultural (commercial) purposes. By their nature they are maintained by farmers, so they are not dependent on State nature conservation support. However as previously



Fig. 24. Ground squirrel in a young apricot orchard in the locality Hrušovany u Brna, where the highest density of ground squirrels was observed.

Obr. 24. Sysel obecný v meruňkovém sadu u Hrušovan u Brna, kde se nachází nejvyšší pozorovaná hustota syslů.

mentioned, there are still factors that remain unclear in influencing the development of ground squirrel populations. Future research is necessary to identify those factors and ensure that the preferred conditions can be provided for the species. An important issue for nature conservation is the potential conflict caused where ground squirrels could cause damage to cultivated crops. Potential conflict and the use of poisons as a common way of rodent reduction in agricultural lands must be addressed through informing and education.

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## SOUHRN

Sysel obecný je druhem typickým pro otevřené, bezlesé prostředí. Jeho životní strategie je založena na vytváření kolonií, jejichž členové se vzájemně varují před predátory, které vizuálně kontrolují. Úspěch takovéto strategie ovšem vyžaduje otevřené a přehledné prostředí. V České republice však existují případy výskytu kolonií v prostředí s významným podílem stromů a keřů.

Předložená studie popisuje 10 jihomoravských populací sysla obecného, které se v takovém prostředí vyskytují (tab. I). U osmi populací je stručně popsán charakter prostředí a vývoj kolonii. V případě dvou populací v Hrušovanech u Brna a u Velkých Pavlovic jejich velikost a příznivý stav umožnily detailnější analýzu využívání prostředí. Ve všech případech se jedná o heterogenní zemědělské lokality, kde se střídají vinice, sady, záhumenky a drobná pole. Vývoj populací na jednotlivých lokalitách výrazně fluktuuje a některé i zanikly. Na druhou stranu některé z nich existují izolovaně dlouhodobě (např. Hrušovany u Brna a Velké Pavlovice) a je tedy zřejmé, že tento typ prostředí poskytuje prostor pro životaschopné populace.

Na lokalitě Hrušovany u Brna bylo identifikováno 10 různých typů prostředí a velmi jemná krajinná mozaika ploch o průměrné velikosti 0,16 ha (medián 0,097 ha). Na lokalitě Velké Pavlovice bylo identifikováno 13 typů různého prostředí a také velmi jemná mozaika ploch o průměrné velikosti 0,44 ha (medián 0,196 ha). Na obou lokalitách bylo nejvíce nor systů nalezeno v době udržovaných sadech a viničích (celkem 73 % v Hrušovanech, 83 % v Pavlovicích). Nezanedbatelné množství nor bylo také nalezeno na oranžích polích, která jsou ale v závislosti na typu polní plodiny využívána převážně krátkodobě. Parametry popisující charakter prostředí v obou lokalitách jsou uvedeny v tab. II až V a obr. 12 až 17.

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