Expansion of the Striped field mouse (*Apodemus agrarius*) in the south-western Slovakia during 2010–2015

Filip Tulis[1*], Michal Ambros[2], Ivan Baláž[1], Dávid Žiak[3], Veronika Hulejová Sládkovičová[3], Peter Miklós[3], Alexander Dudich[4], Andrej Stollmann[5], Peter Klimant[1], Balazs Somogyi[6], Győző Horváth[6]

[1]Department of Environmental Sciences, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 949 74, Nitra, Slovak Republic
[2]ŠOP SR, Administration of CHKO Ponitrie, Samova 3, 949 01, Nitra, Slovak Republic
[3]Department of Zoology, Faculty of Natural Sciences, Comenius University, Mlynská dolina B-1, 842 15 Bratislava, Slovak Republic
[4]Nám. Sv. Trojice 15, 969 01 Banská Štiavnica, Slovak Republic
[5]Krivá 10, 947 01 Hurbanovo, Slovak Republic
[6]Department of Animal Ecology, Institute of Biology, Faculty of Sciences, University of Pécs, Ifjúság útja 6, 7624 Pécs, Hungary

Abstract

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Population of the Striped field mouse spread out into unoccupied territories leading to the rapid enlargement of their range of distribution is defined as an expansion. In 2010, the presence of the species in south-western Slovakia was recorded for the first time. During monitoring of this expansion (from 2010 to 2015) 59 new localities in south-western Slovakia were recorded, representing confirmation of the presence of *A. agrarius* in 18 new quadrates of Databank of Slovak fauna. Thus in 2015, marginal points of the distribution area were the Danube River in south-western Slovakia, the Šur National Nature Reserve in the west, the wetland near Tešmak in the east and the Jasová water reservoir in the north. The impact of this expansion on the quantitative composition of the small mammal's community has been evaluated for three sites (Čiližská mokraď wetland, Okoličianska mokraď wetland, Martovská mokraď wetland) and one larger area (south-western corner of Danubian lowland). In all the observed sites the expansion of *A. agrarius* was related to rapid increase of its abundance. However its representation in the small mammal's community was significantly growing only in the site Čiližská mokraď wetland and Martovská mokraď wetland. In general, the rapid increase of the abundance of *Apodemus agrarius* in the small mammal's community in the observed sites led to the significant decrease of the abundance of several species of small mammals, mainly *Apodemus sylvaticus*, *Clethrionomys glareolus* and *Sorex araneus*.

Keywords

small mammals' community, species expansion, Rodentia

*Corresponding author:
e-mail: ftulis@ukf.sk

Introduction

Populations of the Stripe field mouse, *Apodemus agrarius,* are characteristic for their changes in the range of distribution. Its expansion from the centre of origin (eastern Russia; Suzuki et al., 2008) westward represents the most dramatic expansion of small mammals species unassisted by man (Hildebrand et al., 2013). Skeletal findings confirm the presence of this species in some parts of Europe already in the Pleistocene epoch, and in other parts during the Holocene epoch (Kowalski, 2001; Toškan and Kryštufek, 2006). However, paleontological findings (Horáček and Ložek, 1993), as well as the analysis of owl subrecent diet (Obuch, 1992; Obuch and Dorica, 2011) also indicate that some of the colonized territories were later retreated by this species to recolonize them subsequently.

Recent spread of the species in other areas is documented in several parts within the range of its distribution such as Northern Hungary (Bihari, 2007; Gubányi, 2010), Moravia and north of the Czech Republic (Polechová and Graciasová, 2000; Bryja and Řehák, 2002; Flousek et al., 2004), western Austria (Spitzenberger, 2001; Spitzenberger and Engelberger, 2014), the European part of Russia and northern Kazakhstan (Karaseva et al., 1992), or southeast of Russia (Bazhenov et al., 2015). During the period of 1980's to 1990's, changes in the species distribution were reported also in central Slovakia and the distribution rate was estimated at 3 km per year (Dudich, 1997). Factors affecting the current expansion of the species are climate change with increasing average temperature, continuing fragmentation of forests, expanding urbanization (Spitzenberger and Engelberger, 2014), building of water units in the country (Dudich, 1997) or conversion of the steppes to agricultural land (Karaseva et al., 1992). Large migration ability (Babinska and Werka, 1981; Liro and Szaki, 1987) or large reproductive potential (Stein, 1955; Pelican, 1965) are also supportive in spreading of the species. Expansion of *A. agrarius* in the area of soutwestern Slovakia, location where this species wasn't reported in the past research (e.g. Balát, 1956; Folk, 1956; Pachinger et al., 1996, 1997; Veselovský et al., 1997; Krištofík, 1999), was first documented in 2010 (Ambros et al., 2010).

An important feature of the species is the gradual increase in dominance (Stanko, 2014) and its competitive pressure on the certain syntopic occurring species such as Yellow-necked mouse *Apodemus flavicollis* (Gliwicz, 1981; Simeonovski-Nikolova, 2007) or Bank vole *Clethrionomys glareolus* (Gliwicz, 1981; Kozakiewicz and Boniecki, 1994). Dissemination of the *A. agrarius* on a new territory brings competitor of other species of the genus *Apodemus* or the family Muridae (Dudich, 1997) to the original community of small mammals. This competitive pressure of *A. agrarius* together with its epidemiological signification as a reservoir for spreading hantavirus (Lee et al., 1981; Klempa et al., 2005; Jakab et al., 2007), mastadenovirus (Klempa, 2009), *Borrelia burgdorferi* s.s. (Štefaníčková et al., 2004) or tick-borne encephalitis (Achazi et al., 2011) highlight the need to monitor the expansion of this species. Its expansion could be liable to pose a potential threat to the native biota (Johnson et al., 2001; Arriaga et al., 2004).

The aim of this paper is: (*i*) to describe the sequence of *A. agrarius* expansion within the area of south-western Slovakia during the years 2010 to 2015 and (*ii*) to analyse its expansion impact on the quantitative composition of the small mammals' community in the observed area.

Material and methods

The research was conducted on small mammals in different types of habitats from waterlogged areas overgrown by *Carex* sp. to the edges of channels, dead branches and remnants of old arms intersecting large areas of agrocoenosis. These water features belong to the system of Carpathian rivers in south-western Slovakia: Danube (Dunaj), Váh, Nitra, Žitava, Hron and Ipeľ.

Small mammals were captured during the years 2010 to 2015 by using two methods. First quadrat method using 25, 36 and 50 live traps exposed within the range of 1 to 4 nights. Captured species were marked with ear tags. Second one was the line method using 50 snap traps and 36 live traps exposed during 2 to 3 nights. Live traps were checked twice a day, morning and evening. Snap traps were checked once a day. The captured species of small mammals were examined for gender and age. Due to the use of two capture methods, different type and number of traps and various range of their exposition in the sites, we evaluated the abundance of the captured species through corrections for 100 traps per nights per session – C100TN (Gillies, 2013) using the following formula: number of captured individuals of given species × 100/ number of traps used per session. Research design allowed us to observe the annual changes in the abundance of *A. agrarius* and other small mammal species only within three sites (Čiližská mokraď wetland, Okoličianska mokraď wetland, Martovská mokraď wetland) and one larger area (south-western corner of the Danubian Lowland (Fig. 1).

One way ANOVA was used to compare to year changes in the abundance of *A. agrarius* and other small mammal species within observed sites. Statistical analyzes were run in STATISTICA 8.0 software (StatSoft Inc., 2007). Acquired knowledge about expansion of the species were visualized by Databank of Slovak fauna (DSF) with quadrant size 12 km × 11 km in ArcMap 10.1 (Esri, 2011).

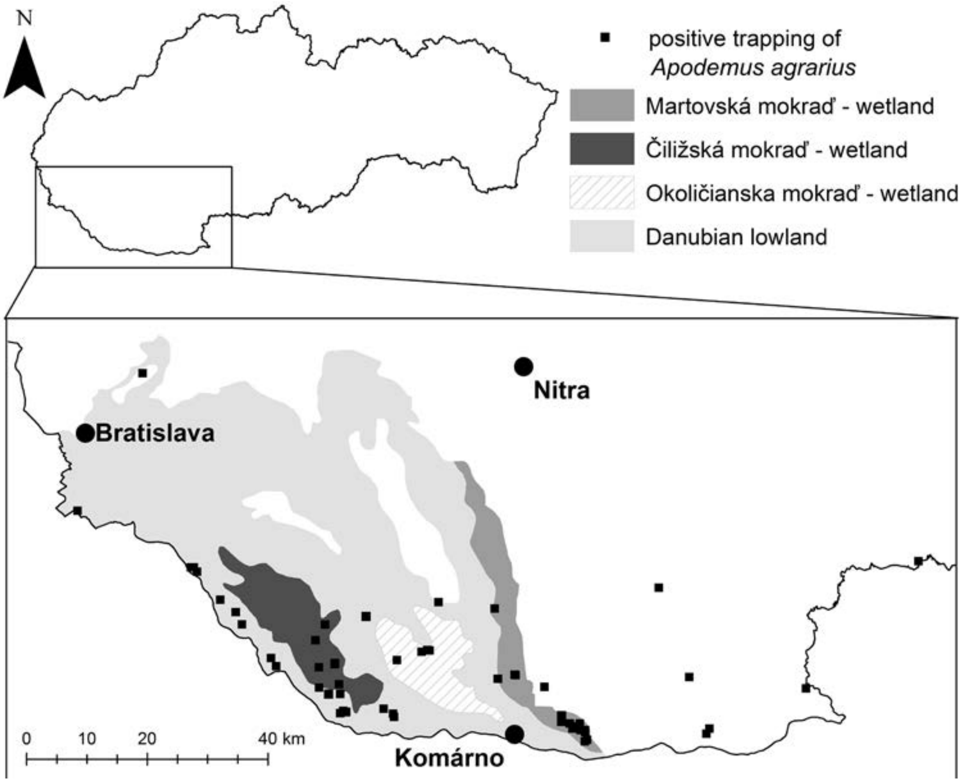

Fig. 1. Localization of *Apodemus agrarius* trapping plots in sites of southern Slovakia.

Results and discussion

During the years 2010 to 2015, we confirmed the presence of *A. agrarius* in 59 new localities of the south-western Slovakia that represents 18 quadrates of DSF (Fig. 2). Totally, 1,114 individuals of the species have been captured. In 2015, the marginal points of the distribution area of *A. agrarius* in the south-western Slovakia are: the Danube river in south-western Slovakia, the Šúr National Nature Reserve in the west, the wetland near Tešmak in the east and the Jasová water reservoir in the north. A complete list of the localities with confirmed presence in the particular years is in the Appendix 1.

Increasing of new quadrates to the northwest and to the northeast suggest that the expansion in the area of Slovakia arrived from the south – Hungary. It is just in Hungary where the spreading of the species to the northwest was recorded in the last years (Bihari, 2007) and the nearest confirmed locality with the species presence in the surroundings of the Lipót village (Gubányi, 2010) is only 4 km far from the locality of Bodíky. Even here, the species were recorded in the stationary trapping plot for the first time in 2010 after a long-term research. With this assumption it is necessary to take into consideration a natural barrier to spreading of the species which is the Danube river-basin, in large measure divided to the Gabčíkovo river barrage system and the river-basin of the Old Danube. Miklós et al. (2015) suppose that species spread just through the river-basin of the Old Danube where the stream with low water level is easier to overcome than the wide canal of the Gabčíkovo river barrage system with the massive and regularly mowed barrage. Nevertheless, Ambros et al. (2010) suggested also the possible human mediated dispersal origin of the population founding species in the south-western Slovakia which is connected with the cross-border transport of waste. Human mediated introduction of the species by industrial products in the south-eastern Russia is anticipated also by Bazhenov et al. (2015). In the years 2012 and 2014, broadest surroundings of Bratislava revealed localities with presence of *A. agrarius* (DSF 7769, 7968) (Fig. 2) that may be an after-effect of the recent species spreading in the east Austria (Herzig-Straschil et al., 2003; Spitzenberger and Engelberger, 2014). Spitzenberger and Engelberger (2014) state that the current expansion of *A. agrarius* in the south-western Slovakia is a part of the major range expansions in the western border of the range of distribution of its spreading in the Central Europe (the east of Russia, the north of Hungary, the southwest of Slovakia, the west and the centre of the Czech Republic). A possibility of existence of an isolated, long-overlooked population of *A. agrarius* in the southwest of Slovakia was excluded in the context of fossil and sub-fossil knowledge and intensive research carried out in the south-western Slovakia in the recent past (Balát, 1956; Folk, 1956; Pachinger et al., 1996, 1997; Krištofík, 1999; Ambros, 2010).

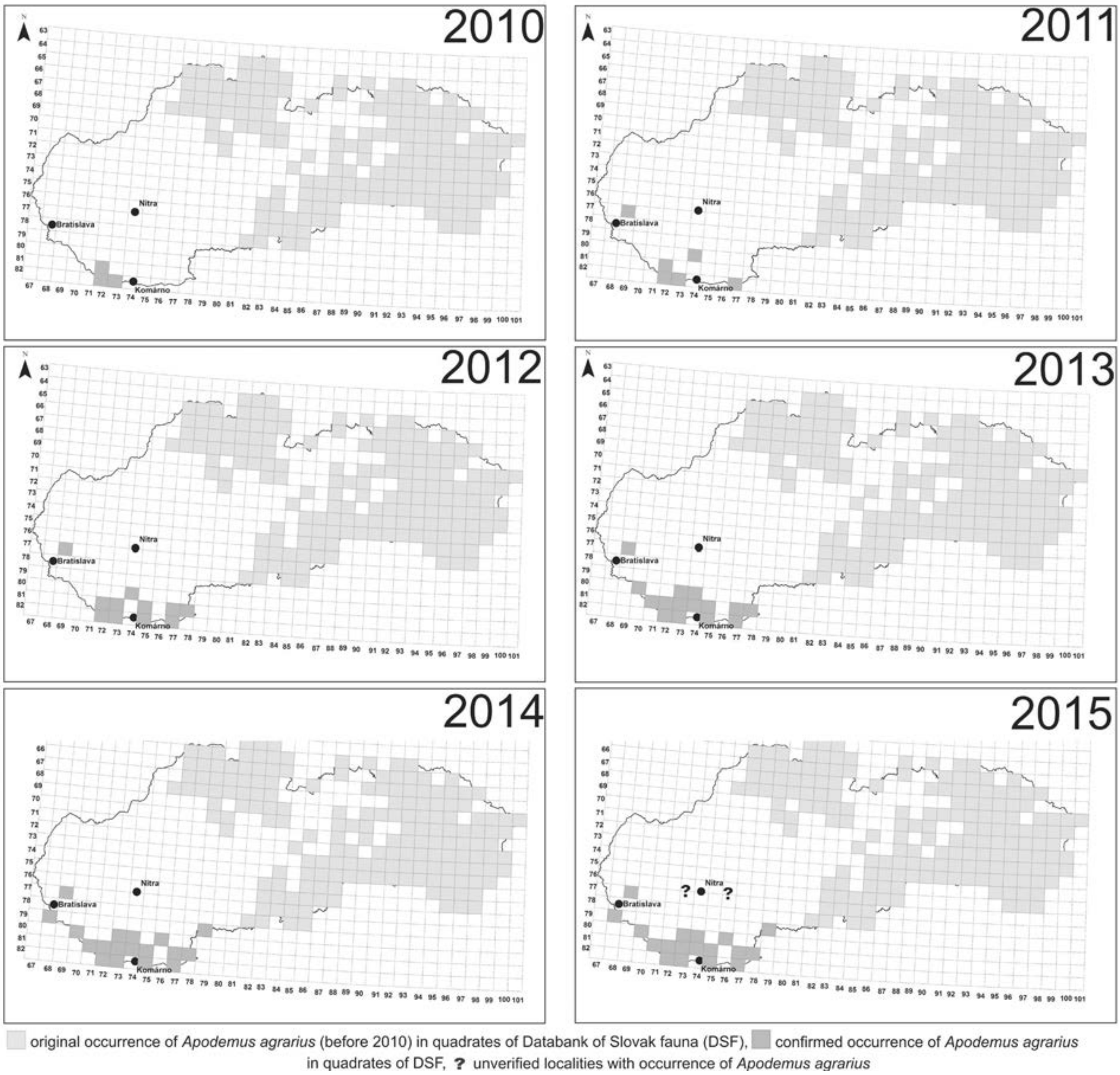

Fig. 2. Progress of *Apodemus agrarius* expansion in south-western Slovakia during the years 2010–2015.

Building of hydraulic engineering units like channels (Dudich, 1997) or the change of steppe into agrocenosis (Karaseva et al., 1992) is described as a factor contributing to the species spreading. Spitzenberger and Engelberger (2014) consider the climate change with growing average temperature and the continuing fragmentation of forests together with the increasing urbanization to be the main factors of the current species expansion. Paleontological findings and analyses of the subrecent owl food indicate that in some cases deal only recolonizes the same territory which was colonized by it in the past (Obuch, 1992; Horáček and Ložek, 1993; Obuch and Dorica, 2011). This fact indicates also the comparison of the west range of distribution of *A. agrarius* with its preferred ectoparasite flea *Hystrichopsylla orientalis.* While the host species from the occupied territory withdrawn in the past, the parasite in this territory persists till today in another guild of host species (Dudich, 1997).

During the expansion the abundance of *A. agrarius* in small mammals' community changed annually in all sites (Fig. 3). Significant differences has been found only in Čiližská mokraď wetland (F = 2.98, n = 21, P = 0.046) and Martovská mokraď wetland (F = 2.82, n = 61, P = 0.033). Growing abundance of *A. agrarius* manifests itself naturally in the quantitative composition of the original community species (Fig. 3). In the three observed sites, we have recorded changes in the abundance of the species such as Wood mouse *Apodemus sylvaticus*, Yellow-necked mouse *Apodemus flavicollis*, Herb field mouse *Micromys minutus*, Bank vole *Clethrionomys glareolus* and surprisingly also Common shrew *Sorex araneus* (Tab. 1). In any case, the species penetration to new areas has to be shown also in the structure of the original community or ecosystem (Townsend and Crowl, 1991; McIntosh and Townsend, 1996). Similarly with our results, Stanko (2014) has recorded progressive increasing of the dominance of *A. agrarius* in the small mammals' community.

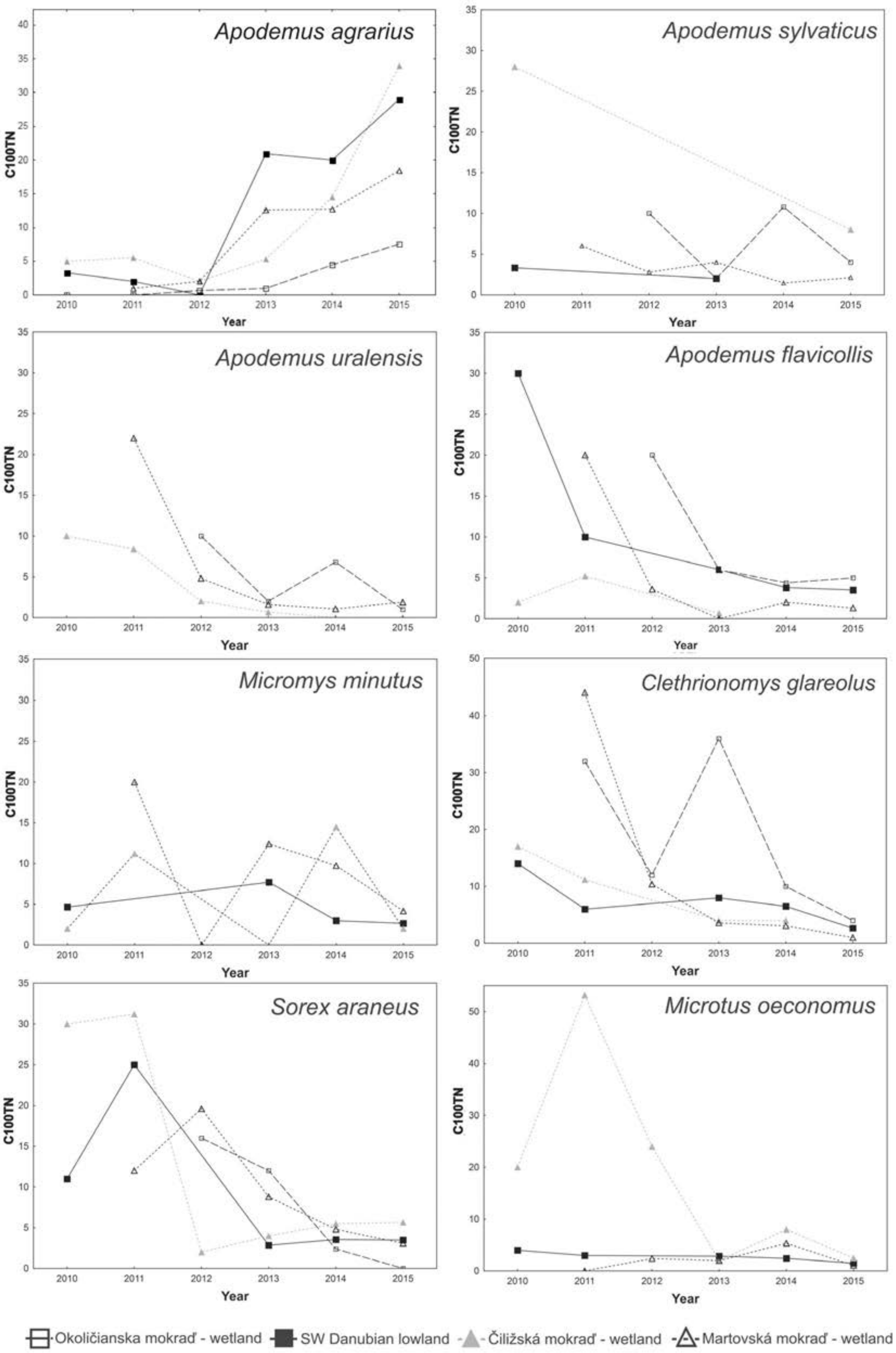

Fig. 3. Annual changes in abundance (mean) of *Apodemus agrarius* and other species of small mammals' community expressed by the proportion of the corrected number of trap-nights (C100TN) in studied sites.

Table. 1. ANOVA results for species with significant decrease of abundance in study sites

Sites	Species	F	n	*P*
South-west of Danubian lowland	*A. sylvaticus*	4.40	27	<0.01
	S. araneus	11.71	27	<0.001
Čiližská mokraď wetland	*A. sylvaticus*	18.40	21	<0.001
Martovská mokraď wetland	*A. flavicollis*	13.20	61	<0.001
	A. uralensis	3.87	61	<0.01
	C. glareolus	34.17	61	<0.001
	S. araneus	5.05	61	<0.01

n – number of sites.

Avoidance of *A. agrarius* to Yellow-necked mouse is a response to its aggressive behaviour during a breeding period (Simeonovska-Nikolova, 2007). However, Gliwicz (1981) suggested that in the time of lower accessibility to food, Yellow-necked mouse is becoming more dominant. Aggressive interactions have been also described between *A. agrarius* and Wood mouse. In sympatry populations, these two species may occur even in the same communities (Frynta et al., 1995). In places of absence of the *A. agrarius*, the space is occupied by Wood mouse (Dickman and Doncaster, 1986; Frynta, 1992). Aggressiveness as a consequence of competition for available burrows has been observed also between *A. agrarius* and Bank vole (Gliwicz, 1981). Kozakiewicz and Boniecki (1994) termed their mutual relation as a non-tolerant mutual interaction. However, the competitive pressure between the *A. agrarius* and Bank vole is lower in comparison with *A. agrarius* and Yellow-necked mouse (Gliwicz, 1981).

Zub et al. (2012) indicated a possible competitive relation between *A. agrarius* and Common shrew *Sorex araneus.* Their competition is also a consequence of overlapping of their diet niche, where up to 40% of the food of *A. agrarius* can be formed by an animal diet (Holišová, 1974). According to Zub et al. (2012), the increasing abundance of voles and mice causes increased consumption of vegetable food that points itself on the decreasing number of plant-eating vertebrates which represent an important food of Common shrews (Churchfield and Rychlik, 2006). Adverse conditions during winters may also cause a decrease in the abundance of Common shrew when its surviving is lower comparing to the *A. agrarius* (Hayes and O'Connor, 1999; Ochocińska and Taylor, 2005).

A strong competitive pressure of *A. agrarius* on the other species of small mammals is a consequence of the species characteristics which support also its successful expansion such as great migration capability (Babinska-Werka et al., 1981; Liro and Szaki, 1987), high fertility (Stein, 1955; Pelikán, 1965), capability to occupy a wide spectrum of habitats (Stanko, 2014), but also a capability to colonize or recolonize habitats affected by floods (Balčiauskas et al., 2012). Miklós et al. (2015) thus suggested that in the south-western Slovakia, the intricate river branch system of Danube presents not only suitable living conditions but also ideal conditions for rapid spreading of this species. Gliwicz (1981) described the rapid reactions of *A. agrarius* on the increased capacity of the environment caused by experimental disposing of other species as a typical feature of the expansive species. The results indicate that the expansion of *Apodemus agrarius* and its increasing abundance may have a negative impact on the abundance of native species in small mammals' communities. The decrease of these species of small mammals, however, may be influenced by several-year fluctuations of populations of voles (Lambin et al., 2000; Tkadlec and Stenseth, 2001), shrews (Sheftel, 1989; Zub et al., 2012), Bank voles (Christiansen, 1983; Marcstrom et al., 1990) or Yellow-necked mice (Marcstrom et al., 1990; Fernandez et al., 1996).

Conclusions

In the course of six years, *A. agrarius* inhabited a substantial part of the south-western Slovakia, where it found a persisting population which is, at present independent from immigration. In the context of current knowledge, the species expansion in the south-western Slovakia is a part of the major expansion in the western border of its spreading within the Central Europe. In the period of our investigation, the expansive, less abundant species became a dominant element of the community and it might be influenced by largeness of populations of sympatric species such as *Apodemus flavicollis*, *Apodemus sylvaticus*, *Apodemus uralensis*, *Clethrionomys glareolus* and *Sorex araneus*. Another monitoring of the species expansion is needed because *A. agrarius*: (*i*) represent epidemiologically significant species; (*ii*) influence the changing of the composition of the original community of small mammals; (*iii*) could have potential impact on the syntopically glacial relict subspecies *Microtus oeconomus mehélyi* and its survival in the refuges of the south-western Slovakia is still unclear.

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Appendix 1. Year: site – coordinates (WGS84 format)

2010: Dunajské tŕstie 1 – 47.779997E,17.835476N; Dunajské tŕstie 2 – 47.773944 E, 17.857257N; Hamske tŕstie 1 – 47.769932N, 17.753508E; Hamske tŕstie 2 – 47.771344N, 17.746639E; Kľúčovec. Čobánsky chrbát – 47.802691N,17.688727E; Čiližska Radvaň. Hansky kanál – 47.839478N, 17.717974E;
2011: Mužla. Čenkovská niva. A – 47.7927N, 18.557499E; Mužla. Čenkovská niva. B – 47.7847N, 18.551901E; Čiližská Radvaň A – 47.840392N, 17.719425E; Čiližská Radvaň. Kanál pri obci – 47.833N, 17.684097E; Čiližská Radvaň – 47.840392N, 17.719425E; Kľúčovec – 47.79611111N, 17.73666667E; NPR Šúr – 48.24472222N, 17.23055556E; Kolárovo. Vrbové – 47.944049N 18.060239E;
2012: Lela. Barina – 47.864109N, 18.763636E; NPR Parížsky močiar. – 47.866861N, 18.503567E; CHA Dropie. topoľový lesík – 47.873025N, 17.925220E; CHA Dropie. rameno Dudváhu – 47.873269N, 17.920103E; Chotín. Fialkový kanál 1 – 47.794046N, 18.228470E; Krátke Kesy. močiar – 47.774230N, 18.273772E; Krátke Kesy. Želiarske pole 1 – 47.779089N, 18.257926E; Krátke Kesy. Želiarske pole 2 – 47.782672N, 18.248708E; Iža. Patinský kanál – 47.775440N, 18.255464E; Hurbanovo. Konkoly – 47.833875N, 18.186008E; Pataš. A – 47.8725N, 17.67111111E; Žitavský luh. B – 48.17716667N, 18.29652778E;
2013: Pod Kamenným. Studiensky kanál – 47.946134N, 17.935209E; CHA Dropie. rameno Dudváhu – 47.872758N, 17.918611E; Hliník. Hlinický kanál – 47.840097N, 18.081739E; Bodíky. A – 47.919466N, 17.45216E; Boheľov. A – 47.89722222N, 17.68916667E; Číčov. A – 47.767608N, 17.740673E; Číčov. B – 47.770393N, 17.753588E; Erčéd. A – 47.828535N, 17.589722E; Chotín. Fialkový potok – 47.793862N, 18.229755E; Išpánoš. A – 47.840006N, 17.576885E; Kľúčovec. A. Vára – 47.81055556N, 17.73222222E; Kráľovská lúka. B – 47.90317N, 17.489167E; Marcelová. Pohrebisko – 47.77517N, 18.283306E; Marcelová. Šerke – 47.757837N, 18.284883E; Martovce. Hliník – 47.839973N, 18.08103E; Pataš. A – 47.8725N, 17.67111111E; Vojka. A – 47.96361111N, 17.38666667E; Vojka. D. Žofín – 47.957533N, 17.394728E;
2014: Tešmak. močiar – 48.066670N, 18.990861E; CHA Dropie. topoľový lesík – 47.873025N, 17.925220E; Bodzianske lúky – 47.870016N, 17.907829E; Sokolce. Lák – 47.854353N, 17.854872E; Marcelová 1 – 47.760788N, 18.289746E; Pohrebisko 1 – 47.773999N,18.283697E; Iža. Patinský kanál – 47.775440N, 18.255464E; Chotín. Fialkový kanál 1 – 47.794046N, 18.228470E; Chotín. Fialkový kanál 2 – 47.789606N, 18.229105E; Marcelová 3 – 47.784035N, 18.270747E; Krátke Kesy. Želiarske pole 2 – 47.782672N, 18.248708E; Sysľovské polia 1 – 48.030752N, 17.117165E; Jasová. VN – 47.996081N, 18.419655E; Bakanské rameno – 47.885767N, 17.505616E; Boheľov. A – 47.89722222N, 17.68916667E; Číčov – 47.767608N, 17.740673E; Erčéd. A – 47.828535N, 17.589722E; Chotín. Fialkový potok – 47.793862N, 18.229755E; Kľúčovec. A. Vára – 47.81055556N, 17.7322222E; Bodíky. Kráľovská lúka. B – 47.903170N,17.489167E; Marcelová. Pohrebisko – 47.77517N, 18.283306E; Marcelová. Šerke – 47.757837N, 18.284883E; Martovce. C. Gamota – 47.84763N, 18.119854E; Martovce. Hliník – 47.839973N, 18.08103E; Pataš. A – 47.8725N, 17.6711111E; Vojka. A – 47.9636111N, 17.3866666E; Vojka. B/C – 47.96318N, 17.380706E; Vojka. D. Žofín – 47.957533N, 17.394728E;
2015: CHA Dropie. topoľový lesík – 47.873025N, 17.925220E; CHA Dropie. rameno Dudváhu – 47.873269N, 17.920103E; Marcelová 1 – 47.760788N, 18.289746E; Pohrebisko 1 – 47.773999N, 18.283697E; Marcelová 3 – 47.784035N, 18.270747E; Krátke Kesy. Želiarske pole 2 – 47.782672N, 18.248708E; Iža. Patinský kanál – 47.775440N, 18.255464E; Chotín. Fialkový kanál 1 – 47.794046N, 18.228470E; Chotín. Fialkový kanál 2 – 47.789606N, 18.229105E; Pohrebisko 10 – 47.771948N, 18.283965E; Chotín 8 – 47.784309N, 18.229651E; Pohrebisko 11 – 47.776490N, 18.271927E; Číčov. A – 47.767608N, 17.740673E; Chotín. Fialkový potok – 47.793862N, 18.229755E; Kľúčovec. A. Vára – 47.81055556N, 17.73222222E; Martovce. C. Gamota – 47.84763N, 18.119854E; Vojka. A – 47.96361111N, 17.38666667E; Vojka. D – 47.957533N, 17.394728E; Martovce. C. Gamota – 47.84763N, 18.119854E; Martovce. línia 1 – 47.848426N, 18.117697E; Čiližská Radvaň. KL1 – 47.84158N, 17.718818E; Veľké Kosihy. KL1 – 47.769274N, 17.859935E; Čiližská Radvaň. KL3 – 47.84158N, 17.718818E; Veľké Kosihy. KL1 – 47.769274N 17.859935E; Bodíky. Kráľovská lúka. B – 47.90317N, 17.489167E; Marcelová. Šérke – 47.757837N 18.284883; Martovce. Hliník – 47.839973N, 18.08103E; Marcelová. Pohrebisko – 47.77517N, 18.283306E; Išpánoš – 47.840006N, 17.576885E; Erčed – 47.828535N, 17.589722E.