Contribution to the knowledge of *Apodemus sylvaticus* populations in forests of the managed landscape of southern Moravia (Czech Republic)

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ABSTRACT: The population dynamics of wood mouse (*Apodemus sylvaticus*) was studied in three forest complexes differing in food supply in the intensively managed landscape of southern Moravia. They included an old semi-natural floodplain forest dominated by oak (HL), production broadleaved forest with the predominance of oak and robinia (HA) and a pheasantry with various forest stands consisting of diverse species and age categories of trees with a quantity of additional food for additional feeding of pheasants and roe deer (RB). The population fluctuation within six-year monitoring was affected by seed years (acorn crops in 2003 and 2006), which resulted in an increase in the species population density in the next year. Statistically significant effects of the crop of acorns on the body weight of monitored species were also detected ($P < 0.01$, $F = 1.44$). Relative abundance differed significantly between the floodplain forest (HL) and RB and HA ($P < 0.01$). The two last-mentioned sites did not differ and only a trend of greater preference to the most variable biotope in RB was noted. It evidences the unsuitability of floodplain forest for the species. In spite of the food specialization in small seeds significant effects of the excess crop of acorns can result in a rapid increase in the *Apodemus sylvaticus* population which can then cause damage to the natural regeneration of oak or artificial regeneration by seeding although to a substantially smaller extent than the more harmful *A. flavicollis.*

Keywords: wood mouse; forests in managed landscape; population dynamics; food supply

The wood mouse (*Apodemus sylvaticus* [L.]) – hereinafter *As,* ranks among the most common small mammals of the Central-European cultural landscape. It is a typical ubiquitous species the ecological niche of which covers the broad spectrum of biotopes from fields through groves and small forests to edges and open sites of larger forest complexes of various species composition and age structure (Niethammer, Krapp 1978; Zejda 1981; Gurnell 1985; Suchomel, Heroldová 2004) in the wide range of altitudes from lowlands to mountains (Zejda 1976, 1991; Suchomel et al. 2007). In forest stands, it is more dominant than *A. flavicollis* in ecotone zones (groves, tree belts, fragments of woody vegetation, edges of forest complexes) (Pelikán 1986, 1989) where it finds the sufficiency of food in field crops, in stands of small-seed trees (poplar, alder) and in stands of conifers (spruce, pine) (Holišová 1960; Zejda 1981; Heroldová 1994).

In the past decades, the species was studied under conditions of the CR within integrated studies on communities of small mammals (e.g. Zejda 1973, 1976, 1981, 1991; Pelikán 1986, 1989; Suchomel, Heroldová 2004; Suchomel et al. 2007) and in several more detailed papers concerning food (Holišová 1960; Heroldová 1994) or reproduc-

tion and population dynamics (Pelikán 1964, 1976). At present, the problem of the ecology of *As* research in forest ecosystems is in the background by reason of rather difficult differentiation from the more abundant *A. flavicollis* (Niethammer, Krapp 1978) and substantially lower importance with respect to damage to forest stands. In the present paper, the population dynamics of *As* is described in larger forest complexes of southern Moravia depending on the biotope and food supply including the response of the population to the crop of acorns and small-seed trees.

MATERIAL AND METHODS

The material was obtained at three study sites in 2002 and 2007. They included larger forest complexes isolated within the intensively managed landscape of southern Moravia (Czech Republic). The sites are characterized by different intensities of anthropic exploitation and by defined groups of forest types (Randuška et al. 1986).

The Horní les locality (HL) (120 ha) is a semi-natural forest characterized by the forest type group *Ulmeto-Fraxinetum carpineum*. It is situated near Lednice na Moravě. The dominant species are common ash (*Fraxinus excelsior*), pedunculate oak (*Quercus robur*), black poplar (*Populus nigra*), large-leaved lime (*Tilia platyphyllos*) and common maple (*Acer campestre*).

The Hájek locality (HA) (60 ha) is a typical production forest characterized by the forest type group *Carpineto-Quercetum acerosum*. It is situated near Vranovice. The dominant woody species are pedunculate oak (*Quercus robur*), sessile oak (*Q. petraea*), black locust (*Robinia pseudoacacia*) and hornbeam (*Carpinus betulus*). The shrub stratum was little developed, forming patches of vegetation. It consisted of *Crataegus oxyacantha* and *Eonymus europaea* besides scattered bushes of *Carpinus betulus*.

The Rumunská locality (RB) (280 ha) situated near the town of Židlochovice is used as an intensive pheasantry. With regard to microhabitats, the Rumunská locality is the most variable area. It includes a number of miscellaneous woody species of various age categories as well as small open areas, such as meadows, small fields, and wetlands. Pedunculate oak (*Quercus robur*), durmast oak (*Q. petraea*), Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and black poplar (*Populus nigra*) are the most prevalent woody species in this location. The following groups of forest types were identified there: *Ulmeto-Fraxinetum carpineum, Saliceto-Alnetum* and *Carpineto-Quercetum acerosum*.

The annual mean air temperature in the study area was 9.5°C; the total annual precipitation was 545 mm. In each locality under study, immediate mast supply was evaluated on ten plots each of 0.5 m² and the average amount of mast was determined. The plots were selected randomly in the oak stand and the number of acorns was determined on each of the plots. The acorns were then hulled and the net weight of kernels without peel was determined in grams. These weights were then averaged for each of the localities and converted to m². In all trial plots, the methodology of traditional line trapping was applied (Pelikán 1975). Snap traps were used and baited with a wick fried in pork fat or spread with peanut butter. The animals were trapped at even intervals five times a year in 2002–2007. Each catch lasted for three trap-nights. All trapping was carried out at the same places within the study plots throughout the research.

The trapped individuals were dissected in a laboratory. They were classified according to the species, body size, sex, and sex condition. In this material the population of *As* was evaluated.

The relative abundance (rA) of *As* was expressed as the number of individuals trapped per number of trap-nights. The differences between body size and rA were compared by the analysis of variance, *t*-test and Scheffe post-hoc test. All statistical tests were computed using the Statistica program for Windows 7.0.

RESULTS

During 30 trapping periods (30,725 trap nights) 3,545 individuals of small mammals were recorded. As to the individual species, *Apodemus flavicollis* (55.7%) *A. sylvaticus, A. microps* (0.1%), *Myodes glareolus* (22.4%), *Microtus arvalis* (4.6%), *M. subterraneus* (0.1%), *Mus musculus* (0.1%), *Sorex araneus* (0.3%), *S. minutus* (0.03%), *Crocidura leucodon* (0.1%) and *C. suaveolens* (0.1%) were trapped. Out of these 584 (16.5%) were *As* individuals.

The population fluctuation of *As* during the six-year period of study varied and a strong influence was exerted by the seed years (2003 and 2006, oak mast; Fig. 1). In the HL forest, the amount of oak mast food supply was highest (208 g/m²) in contrast to RB (69 g/m²) in 2003, but in RB supplemental food was given to pheasants and roe deer all the year round. In 2006, the crop of acorns was even higher, which became also evident in the higher number of caught small mammals in the next year (Fig. 1). The highest mast was in RB (480 g/m²) and *vice versa* the lowest one in HL (191 g/m²). *Apodemus sylvaticus*
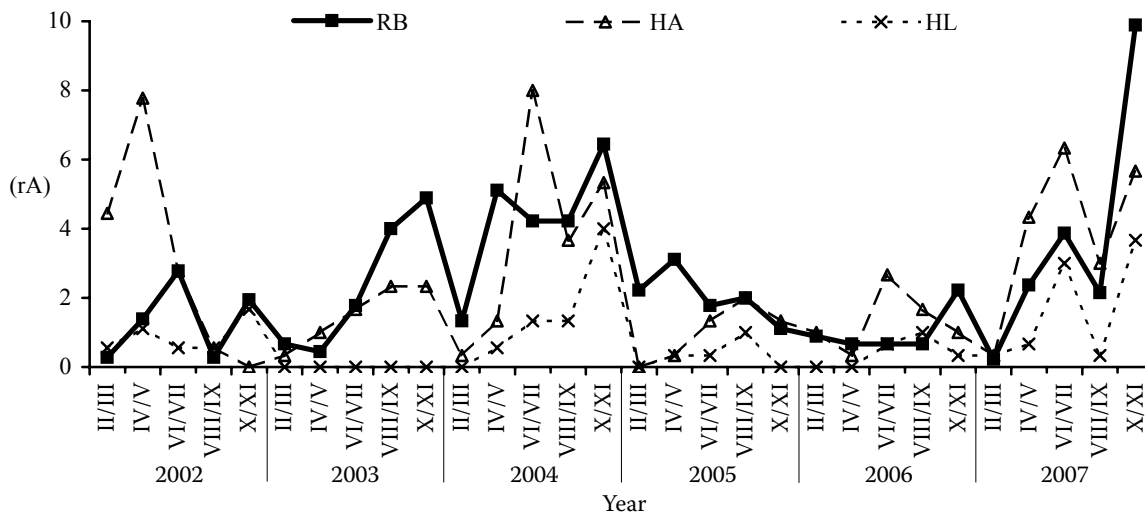
Fig. 1. Six-year monitoring the relative abundance (rA) of *Apodemus sylvaticus* in three forest complexes under various environmental conditions in the rural landscape

responded by an increase in relative abundance in the next years 2004 and 2007. The peak of the population abundance was reached at the HA locality in 2002, which can be explained by the crop of seeds of small-seed species (linden, hornbeam, ash) in 2001, because the crop of acorns was missing in this period. Small-seed species occur substantially less at the other two localities and, thus, at localities HL and RB, the populations remained markedly lower. There were significant differences in abundance between the localities. Relative abundance in HL was significantly lower than in HA and RB (F = 7.59, P < 0.005, ANOVA, Scheffe test), these two being virtually the same. There was only a tendency to prefer the most variable biotope in RB (rA = 2.42), which was influenced by food supply. Lower abundance was found in HA (2.39) and the lowest in HL (0.81).

The weight of animals in the following year after the crop of acorns was higher (2003 – mean weight 24.78 g vs. 2004 – 27.43 g; 2006 – 26.75 g vs. 2007 – 28 g) because of increased food supply but differences in the body weight of *As* were statistically significant only if the years 2003 and 2004 were compared (F = 1.44, P < 0.001, t-test) but not if 2006 and 2007 were compared (both influenced by the seed crop).

The crop of acorns caused the extension of a reproduction stage in the *As* population until November (2003, 2006) when both pregnant females and fully sexually active males were found. On the other hand, in the period of gradation, the population stopped to reproduce as early as in July 2007 and probably in August 2004 because in July pregnant females were still found rather abundantly (in 38.2%).

Comparing the sexual activity at particular localities the highest one was at HL (51.1% of active females) and

the lowest at HA (48.6%) and only slightly higher at RB (49.1%). The sex ratio was markedly in favour of females at all three localities. The highest difference was at HA locality (77%), very marked also at HL (71.1%) and it was nearly balanced at RB locality (54%).

The body weight and length were compared and the tendency to be the highest was in HA (weight: max. 38.9 g, min. 6 g, mean 25.64 g; length 94.7 mm) and the lowest in RB (weight: max. 36.9 g, min. 6 g, mean 22.81 g; length 90.7 mm). Differences in the body length (F = 12.33, P < 0.001, ANOVA, Scheffe test) and weight (F = 14.23, P < 0.001, ANOVA, Scheffe test) were significant comparing RB and HA but insignificant comparing HA and HL. Comparing only adult individuals, statistical significance was found between HA and RB individuals in weight (F = 5.75, P < 0.005, ANOVA, Scheffe test) and between HL and RB in the body length (F = 5.56, P < 0.005, ANOVA, Scheffe test), the values of individuals from RB being always lower.

With respect to the significant effect of seed crop on the population dynamics and body condition of *As* this species can locally quite markedly affect the natural regeneration of trees, namely not only small-seed species (hornbeam, ash, linden etc.) but also oak, which is an important and preferred commercial species.

DISCUSSION

During the study of small mammal populations in three large forest complexes in southern Moravia *As* was one of the most dominant species at RB and HA localities (both 19.8%), which correspond to ecological requirements of the species as the typical

representative of a cultural steppe and ecotone zones (Niethammer, Krapp 1978; Dudich, Štollmann 1983; Májsky 1985; Pelikán 1986, 1989; Ouin et al. 2000; Tumur et al. 2007) with an optimum food supply (Holišová 1960; Heroldová 1994). The most optimal site was HA, a production forest with the normal hydric regime, sufficient proportion of oak and a high proportion of small-seed species (linden, ash, robinia, maple, hornbeam), which are the main food of *As* (Heroldová 1994). Thus, the population created there three peaks in the course of monitored years depending on the crop of small-seed species in 2001 and of acorns in 2003 and 2006. The preference of small seeds of tree species can influence its abundance there (Flowerdew 1985) in the time of the species progradation phase. The RB locality, which is characterized by the mosaic of various types of open and forest microbiotopes showed similar relative abundance, however, the population created there peaks only twice after the crop of acorns in the years mentioned above. Moreover, the food supply was increased there by supplementary food for roe deer and pheasants. In spite of the supplementary food, however, the populations of *As* are not more stable there than in the qualitatively comparable HA due to the competition of more numerous *A. flavicollis* (52.1% to 19.8%) or *M. glareolus* (22.7% to 19.8%), the biotope and food niches of which can partly overlap (Holišová 1960; Zejda 1973; Heroldová 1994; Suchomel, Heroldová 2004). High populations of predators, which concentrate there by reason of the food surplus, can play their role.

We presume that the variety of biotopes provided more space and lower competition also for other species than the most dominant *Af* (Suchomel, Heroldová 2006). The lowest relative abundance was shown by the *As* population at HL locality (floodplain forest) (8.1%), which is the least suitable biotope for the species (Zejda 1976, 1991) due to the high proportion of oak in the stand and thus also the high abundance of larger and more aggressive *A. flavicollis* (Gurnell 1985; Montgomery, Gurnell 1985).

Populations of small mammal species were studied in various types of forests, such as lowlands of Moravia and Slovakia (e.g. Zejda 1976; Dudich, Štollmann 1983; Májsky 1985; Zejda 1985, 1991; Krištofík 1999) and also other types of low-altitude forests (e.g. Zejda 1973). In all biotopes, *As* was one of the three dominant species. In our study, we concentrated on the study of the species population similarly like some other authors (Montgomery 1979; Ouin et al. 2000; Tumur et al. 2007). As to the dynamics of abundance during the six years

of our study the years 2002, 2004 and 2007 seem to be similar. As the crop of seeds in the forests varied in the particular years, it was noted that 2001, 2003 and 2006 were medium and high seed crops. In the period under study, the synchronization of fluctuation occurred also with other species of rodents, such as *A. flavicollis* and *M. glareolus* (Suchomel, Heroldová 2006; Suchomel et al. 2007; Suchomel unpublished) due to the crop of acorns at studied localities. It shows that trophic requirements of all three species overlap. In 2001, a good crop of hornbeam and lime seeds occurred and this fact positively affected the abundance and litter of *As* populations in 2002 especially in HA as the proportion of hornbeam and lime was high there. In 2007, abundance and litter were the highest in RB where food was supplied for pheasants and roe deer. In 2003 and 2006, good crops of oak mast occurred. The abundance of *As* increased at all localities during the following years 2004 and 2007. According to Watts (1969), Flowerdew (1973), Zejda (1976), Flowerdew and Gardner (1978), Jensen (1982), Zejda (1985), Pucek et al. (1993), Jedrzejewska et al. (2004) and some other authors, a large crop of tree seeds in forests positively affects the dynamics of seed feeding of small mammals in the year after "seed year".

In RB, the population of *As* was permanently fed by food for pheasants and deer. Under this effect it reached the higher winter population abundance than in the other two forests (Fig. 1). It also showed higher litter sizes in spring and summer. However, populations in all forests declined during the late summer and autumn. According to Watts (1969; 1970) and Flowerdew (1972, 1985), food quality appears to influence the amplitude of the fluctuation in numbers but not the species decline. Thus, both food and behaviour are limiting factors at the same time.

Our data are comparable with the findings of Pelikán (1964), who reported the mean litter size being about 5.6 in southern Moravia. The reproduction period of *As* ends mostly in October (Pelikán 1964; Zejda 1981). In our study, the reproduction was prolonged until the beginning of November only in one case in RB and HA localities. *Apodemus sylvaticus* reproduced until August even in the years of abundance culmination. The gradual decline of the population of more competitive *A. flavicollis*, which ceased to reproduce already in June (Suchomel, Heroldová 2006), was probably one of the causes of active reproduction in this period as well as the lower dependence of *As* on the crop of acorns as a food specialist in small seeds (Niethammer, Krapp 1978; Heroldová 1994).

In our case, the sex ratio was markedly in favour of females in HA and HL and balanced in RB. It is a characteristic feature of stable populations living in optimum habitats (Niethammer, Krapp 1978).

The number of sexually active females indicates also the quality of a habitat (Zejda 1976; Mazurkiewicz, Rajska-Jurgiel 1989). According to the dominance of this species the most suitable forest types were RB and HA (19.8%). Considerable differences were found between localities HL and RB with HA. The highest number of females with embryos and placental scars were found in HL. However, the higher mean litter size occurred in RB, which confirms the influence of supplementary food (Flowerdew 1972, 1985, 1987).

The body weight also provides information about the habitat quality (Suchomel, Heroldová 2006). In our case, the animals of both sexes were not significantly heavier at any of the localities. But the higher mean body weight and the maximum body weight were found in HA and the lowest mean body weight in RB. The significantly lower size in the *As* population at RB locality was probably caused by a high proportion of individuals of lower weight categories, which shows evidence of the more intensive reproduction of the species than at the other two localities. Increased reproduction could be enabled by the lower abundance of competitive *A. flavicollis* in RB in consequence of the lower pressure on food sources.

The fluctuation of population dynamics of *As* can also be affected by predators, namely potentially mostly at RB locality, where rather high amounts of birds of prey concentrate unlike other plots due to the high food supply (pheasants, rodents). At studied localities, the predator-prey relationships in *As* were not investigated being, however, known from literature. It refers mainly to the study of predators, particularly weasels (*Mustela* spp.) and owls (Goszczyński 1977; Southern, Lowe 1982; King 1985). Effects of predators are considerably dependent on the environment heterogeneity, amount of the species of predators at the locality and availability of an alternative prey (Southern, Lowe 1982; Erlinge et al. 1983; King 1985). Generally, the response of changes in the *As* population abundance is based on the combination of functional and numerical response of all occurring species of predators (King 1985). Nevertheless, under conditions with the diverse and stable community of predators-generalists and the amount of alternative prey a functional response predominates (Erlinge et al. 1983). Thus, we can expect it also on monitored plots (HA, RB). The predation pressure on *As*

populations is lower in this environment than at sites where alternative prey occurs rarely, which results in the low diversity of generalists and predominance of predators-specialists (weasel, barn owl) the effect of which leads to an increase in predator effects on the population dynamics of *As* (Southern, Lowe 1982).

Thanks to its trophic and site requirements, *As* is not as important pest in forest management as other species of rodents (*A. flavicollis, Myodes glareolus*). Nevertheless, it can cause damage under certain conditions even to commercial tree species (e.g. oak) due to seed consumption.

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Příspěvek k poznání populací myšice křovinné (*Apodemus sylvaticus*) z lesů kulturní krajiny jižní Moravy

ABSTRAKT: Byla studována populační dynamika myšice křovinné (*Apodemus sylvaticus – As*) ve třech lesních komplexech, lišících se potravní nabídkou, v intenzivně obhospodařované krajině jižní Moravy. Šlo jednak o starý polopřirozený lužní les s dominancí dubu (HL), dále o produkční listnatý les s převahou dubu a trnovníku akátu (HA) a bažantnici s rozmanitostí lesních porostů, tvořených rozličnými druhy a věkovými kategoriemi dřevin, s množstvím doplňkové potravy pro přikrmování bažantů a srnčí zvěře (RB). Kolísání populace v průběhu šestiletého sledování bylo ovlivněno semennými roky (2003 a 2006 úroda žaludů), což mělo za následek zvýšení populační hustoty vždy v roce následujícím. Byl zjištěn i statisticky průkazný vliv úrody žaludů na tělesnou hmotnost sledovaných zvířat ($P < 0,01$, $F = 1,44$). Relativní abundance se průkazně lišila mezi lužním lesem (HL) a RB i HA ($P < 0,01$), přičemž dvě poslední stanoviště se nelišila, byla pouze zaznamenána tendence více preferovat nejvariabilnější biotop v RB. To svědčí o nevhodnosti lužního lesa pro tento druh. I přes potravní specializaci na drobná semena může signifikantní vliv nadúrody žaludů vést k prudkému nárůstu populace *As*, jenž pak může způsobit škody na přirozené obnově dubu či umělé obnově síjí, byť v podstatně menší míře než více škodící myšice lesní (*A. flavicollis*).

Klíčová slova: myšice křovinná; lesy v kulturní krajině; populační dynamika; potravní nabídka

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