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Structure of small mammal communities on clearings in managed Central European forests

Jarmila Krojerová-Prokešová [a,*], Miloslav Homolka [a], Miroslava Barančeková [a], Marta Heroldová [a,c], Petr Baňař [b], Jiří Kamler [a,c], Luboš Purchart [c], Josef Suchomel [d], Jan Zejda [a]

[a] Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, v.v.i., Květná 8, 603 65 Brno, Czech Republic
[b] Moravian Museum, Department of Entomology, Hviezdoslavova 29a, 627 00 Brno, Czech Republic
[c] Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic
[d] Faculty of Agronomy, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

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ABSTRACT

Clear-cutting followed by direct planting currently remains the predominant forest management practice in managed forests in Central Europe. However, this practice may have a pronounced negative effect on the biodiversity of forest ecosystems including small mammals. In this study we investigated the effect of a range of environmental variables on diversity and structure of the small mammal community in relatively small-sized clear-cuts. During 2007–2010 the structure of small mammal communities was assessed at 198 small-sized clearings (up to 2 ha) in 11 areas of managed forest in the Czech Republic. The complete trapping effort was 75,072 trap-nights. Overall 8,542 small mammals belonging to 17 species were caught, including forest species as well as species of open habitats. The diversity and relative abundance of small mammal communities in these small clearings was comparable to that described in the literature for old mature forests. Differences in structure of small mammal communities in our study clearings were mostly influenced by habitat structure, primarily the structure of the herb layer, and partially by altitude (climatic conditions) and size of the clearing. No effect of geographic location (latitudinal and/or longitudinal effect) on small mammal community structure or diversity was detected. Our results indicate that the practice of felling within relatively small-sized clearings may help preserve the diversity of small mammal community in managed forests and might assist in maintaining forest biodiversity by comparison to the more widespread current practice of larger clear-cuts. Re-forestation using small-sized clearings would thus offer a compromise between economic and ecological approaches to forest management, protecting a higher biodiversity of forest ecosystems.

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1. Introduction

Small rodents (Rodentia) and insectivores (Eulipotyphla) are important parts of forest ecosystems. They serve as prey for various amphibian, reptile, bird and larger mammal species (Parker et al., 1983; Chubbs and Trimper, 1998; Dawson and Bortolotti, 2000); insectivores and generalist rodents in turn are predators of many invertebrate species (Lovejoy, 1975; Carey and Harrington, 2001) while herbivorous species such as voles and mice, can significantly influence the diversity and structure of plant communities through selective grazing or seed predation (Giller, 1984). On the other hand they may also be important dispersal agents of various seeds (Ostfeld et al., 1997; Bermejo et al., 1998) and fungal spores (Maser et al., 1978; Kirkland, 1990).

In addition to these roles within the natural dynamics of forest systems, some herbivorous species (chiefly voles) may also become significant pests in economic forestry blocks (Gill, 1992a; Hansson and Zejda, 1977; Maxson and Oring, 1978; Baxter and Hansson, 2001). Voles may frequently cause damage during the earliest phases of forest regeneration by gnawing bark and severing entire young seedlings (Gill, 1992a; Baxter and Hansson, 2001; Borowski, 2007). This direct damage can also facilitate entry of wound-infecting pathogens which may then further affect seedling condition and subsequent timber quality (Bazzigher, 1973; Roll-Hansen and Roll-Hansen, 1980; Gill, 1992b). Resulting infections can increase mortality at later stages of tree development, and may also reduce the economic value of timber, e.g., through stem deformations or 'staining' of the timber (Heikkilä and Löyttyniemi, 1992).

Forest management based on a system of clear-cutting (clear-felling) and subsequent direct replanting is a relatively widespread approach in the majority of temperate managed forests. This type

* Corresponding author.
E-mail address: krojerova@ivb.cz (J. Krojerová-Prokešová).

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of forest management markedly changes the vegetation structure and affects the biodiversity of forest ecosystems (Bengtsson et al., 2000; Decocq et al., 2005; Durak, 2012; Scheller and Mladenoff, 2002). The effect of clear-cutting on small mammal abundance appears to be species- and area-specific (Fuller et al., 2004). Some species show significant decline following clear-felling; by contrast, many species successfully exploit the altered environments created by clear-cutting. This should come as no surprise since north temperate forest small mammals have largely evolved in an environment characterized by natural periodic disturbances (e.g. fires, windstorms, and floods), and were influenced by serious climatic and vegetation changes during Pleistocene glaciations (Kirkland, 1990). Generally, forest management based on a series of large clear-cuts (>10 ha) alters species abundance and community structure by favouring open-habitat species such as *Microtus* spp. (Hansson, 1978) or forest–field mosaic species such as *Apodemus* spp. (Kozakiewicz et al., 1999) at the expense of the forest-dwelling *Clethrionomys* spp. (Hansson, 1999; Rosenberg et al., 1994; Sullivan and Sullivan, 2001; Pearce and Venier, 2005) within those clear-cut areas.

For truly sustainable management of forests within Europe it is necessary to maintain all functions of the forest ecosystem, including biodiversity. In the primarily state-owned forests of Central and Eastern Europe, clear-cutting still represents the most widespread management practice due to the much larger costs attached to other practices e.g. selective cutting or shelter-wood cutting. However, it seems likely that adopting a cutting system which creates rather smaller-sized clear-cuts (in some cases called strip-cuts or patch cuts) represents a possible way to retain and maintain the biodiversity within managed areas.

Several Central European countries including the Czech Republic have imposed maximum sizes for clear-cuts (e.g. Slovakia 3 ha; Romania 3 ha; Austria without special permission 0.5 ha, Czech Republic 2 ha). In other countries the clear-cut size is controlled by national forestry management plans. Smaller clear-cut size is also facilitated by a more general shift in management objectives. As part of the general process of attempting to maximise biodiversity within forest ecosystems, a major goal of current management, in many countries in Europe, is to increase the proportion of deciduous trees in these forest habitats and restructure existing, predominantly secondary coniferous stands into mixed, semi-natural forests with higher biodiversity, regeneration capacity and sustainability. Within such a process of restructuring, the size of the clear-cuts created is usually small.

The smaller-sized clear-cuts (<3 ha) thus being created under current management regimes in many European countries are in contrast to much larger clear-cuts (>10 ha) formed (naturally after storms and fires, or artificially due to timber production) in numerous areas in Scandinavia or in North America (Payette et al., 1989; Hansson, 1992). A number of studies have addressed the habitat associations of small mammals (e.g., Aubry et al., 1991; Carey and Johnson, 1995) and compared population abundances and community structure in these larger clear-cuts (e.g. Gashwiler, 1970; Hooven and Black, 1976; Sullivan, 1980; Morrison and Anthony, 1989; Cole et al., 1998). By comparison, similar studies are very rare in the Central European state-owned forests now increasingly comprised of a mosaic of small-sized stands of different age and vegetation structure (Supplementary Fig. S1), where different habitat and climatic conditions could result in different ecological response of small mammal community occupying this habitat.

Because of their economic significance and ecological importance, understanding the factors affecting the density and distribution of small mammal communities at forest clearings is essential to delivery of sustainable management of Central European forests and maintenance of natural level of biodiversity. The aim of this study was to analyse (1) the structure and diversity of small mammal communities and (2) the relationships between small mammal community structure and habitat variables at small-sized clear-cuts in different types of managed forests. We predicted that environmental conditions and vegetation structure at small-sized clearings allow for the presence of various small mammal species resulting in higher diversity of small mammal communities at these sites.

2. Material and methods

2.1. Study areas

The structure of small mammal communities at small-sized clearings was monitored during four successive years (2007–2010) at 11 study areas in different types of Central European managed forests within the Czech Republic (Fig. 1). Particular study areas were not homogenous in vegetation structure. Basic characteristics of the study areas are given in Tables 1 and S1.

2.2. Data collection

A number of rectangle-shaped clearings with a developed herb layer was selected at random in each study area (Fig. 1, Table S1). The average distance between monitored clearings within a study area was 7.25 ± 6.57 km and varied from 300 m to 51 km. We measured several abiotic factors in each clearing including the clearing age, altitude, temperature, slope, and size. We also recorded information about vegetation structure in and adjacent to the clearing, including height and cover of the ground vegetation in terms of grasses, forbs, and weeds (especially *Rubus* sp., *Urtica dioica*, *Senecio* sp., *Epilobium angustifolium*); cover of seedlings of deciduous and coniferous tree species and amount of grassy litter labelled in three level scale (0 – no grassy litter, 1 – discrete layer of grassy litter in patches, 2 – continuous layer on the whole clearing). The proportion of the perimeter of the clearing adjacent to forest stands or other clearings was recorded and the nature of neighbouring forest stands recorded as to whether these were coniferous or deciduous forests. Maturity of forest stands was also scored in relation to potential seed/mast production (important for granivorous species). Extent of grazing and browsing by large ungulates at the clearings was also recorded. However, contrary to findings of some other studies (e.g. Putman, 1986; Petty and Avery, 1990) this factor was not significant and was excluded from further analyses. All measures were repeated annually.

Trapping was carried out annually during autumn (September–October) in order from higher to lower altitudes to allow data comparison between study areas. Snap traps were laid in lines of 34 traps each, approximately 3 m apart so the total length of each line was about 100 m. Traps were baited with peanut butter and exposed for three successive nights. They were checked once per day in the morning and the bait was replaced if necessary (when eaten away or washed away by precipitation). Traps removed by predators were replaced. The complete trapping effort was 75,072 trap-nights across 198 clearings. Animals trapped were identified to species, sexed, weighed, measured (body length, tail length, hind foot length), and assessed for reproductive condition.

Snap–trapping as a destructive method can significantly bias the estimated abundance and diversity of small mammals in dependence on the length of the removal period (Sullivan et al., 2003; Sullivan and Sullivan, 2013). However, Christensen and Hornfeldt (2003) detected that the removal of small numbers of animals once or twice a year has only a little effect on the overall small mammal community. Therefore, we supposed that the trapping design of 3-nights period once a year would not affect the

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