



## Patterns of vole gnawing on saplings in managed clearings in Central European forests



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### ABSTRACT

Sustainable management of European forests aims to ensure economic targets (timber production) as well as ecological aims of the forest (maintenance of biodiversity). Smaller-sized clear-cutting followed by artificial planting creates a mosaic of small forest patches suitable for many small mammals including three possible pest species – the bank vole (*Clethrionomys glareolus*), the field vole (*Microtus agrestis*) and the common vole (*Microtus arvalis*). The vole gnawing pattern was studied on a number of small-sized clearings (up to 2 hectares) situated in managed forests in the Czech Republic (Central Europe). Damage by voles gnawing occurred almost in all study areas; mostly damaged were saplings on clearings at the age up to 5 years after planting, with herb layer dominated by grasses and situated above 700 m a.s.l. The field vole was identified as the main pest species and its density was identified as the most important predictor of gnawing occurrence even though its density on clearings was usually lower than that of the bank vole. Gnawing by voles caused direct mortality of saplings to a greater degree than other biotic factors including deer fraying and browsing; however, saplings were able to repress the effect of gnawing by natural re-grow of bark and the majority of damaged saplings survived, even though with significant stem deformations. While strong inter-annual variation in damage rate is reported in northern Europe, damage rates in Central European managed forests are lower (at about 3.5% per annum) but more consistent with only moderate inter-annual variation. As a result, despite the relatively low rate of damage which may occur in any given year, damage levels can accumulate over several years after planting with significant economic implications for forestry management.

### 1. Introduction

Small rodents represent an important part of forest ecosystems. They provide a crucial food resource for a variety of predators (Dawson and Bortolotti, 2000; Kouba et al., 2017) and the herbivorous rodents significantly influence the diversity and structure of plant communities through selective grazing or seed predation (Giller, 1984; Ostfeld and Canham, 1993; Grellmann, 2002; Hipkiss et al., 2008; Henden et al., 2009). Moreover, voles, especially, are considered to be serious pests in silviculture in many regions of the world (Hansson and Zejda, 1977; Gill, 1992a; Baxter and Hansson, 2001; Huitu et al., 2009). Voles may frequently cause direct damage during the earliest phases of forest regeneration by removing bark from young seedlings or severing them

entirely (Gill, 1992a; Baxter and Hansson, 2001; Niemeyer and Haase, 2002; Borowski, 2007; Sullivan and Sullivan, 2008). In addition to a direct negative effect in the form of increased mortality, the effects of bark gnawing may also be indirect. Removal of part of the bark can 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 Löytyniemi, 1992).

Even though rodent damage in forestry is known from both hemispheres (Baxter and Hansson, 2001), the most extensive damage is

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reported from the northern areas (Kaneko et al., 1998; Feldhamer et al., 2003; Huitu et al., 2009). Generally, the damage rate decreases within the Holarctic from north to south, even though the intensity of damage seems to be highly variable in space and time (Baxter and Hansson, 2001; Borowski, 2007; Gill, 1992a; Jacob and Tkadlec, 2010). Gnawing is more frequent in plantations versus naturally regenerating stands (Niemeyer and Haase, 2002; Baxter and Hansson, 2001; Heroldová et al., 2007, 2012) and seedlings in monoculture stands seem to be damaged more than those in mixed forests (Gilbert et al., 2013a). The preference for particular species highly varies geographically and the native species are usually more severely damaged than exotic ones (Baxter and Hansson, 2001; Jacob and Tkadlec, 2010).

This issue is mostly studied in northern Europe due to important economic consequences of vole damage (e.g. Hansson and Henttonen, 1985; Hansson, 1986, 2002; Huitu et al., 2009; Gilbert et al., 2013a, 2013b; Huitu et al., 2013; Lylly et al., 2014). Vole-induced damage reported in the northern Europe seems to be related to some extent to the multiannual fluctuations in vole population number (population cycles; Hansson and Henttonen, 1985; Hansson, 1986; Norrdahl, 1995; Stenseth, 1999). However, the environmental conditions in Central Europe significantly differ from those in Northern Europe. Central European forest ecosystems are more fertile than Scandinavian forests (Borowski, 2007) and, in contrast to northern European rodent populations, those in Central Europe appear to be less strongly cyclic and/or non-cyclic (Tkadlec and Stenseth, 2001; Jacob and Tkadlec, 2010; Gouveia et al., 2015). Multiannual fluctuations have primarily been detected among open-habitat species in agricultural landscape, especially in common vole (*Microtus arvalis*) populations (Tkadlec and Stenseth, 2001; Heroldová, 2002; Lambin et al., 2006; Borowski, 2007) but only a little is known about rodent fluctuations in forest habitats. Based on our own previous results (Krojerová-Prokešová et al., 2016), populations of voles in Central European managed forests seems to be non-cyclic (*Microtus* sp.) or only moderately cyclic (bank vole *Clethrionomys glareolus*). Such differences in vole population dynamics and habitat carrying-capacity might influence the pattern of vole gnawing in Central European in comparison to that experienced in more northern European forests. However, only a few studies have thus far been conducted in Central or Southern Europe (Niemeyer and Haase, 2002; Borowski, 2007; Heroldová et al., 2012; Suchomel et al., 2012a, 2016; Imholt et al., 2017).

Over the last century, forestry management in many European countries has favoured the planting of predominantly coniferous monocultures. As part of the general process of attempting to maximise biodiversity within forest systems, a major goal of current management is to increase the proportion of deciduous trees in these forest habitats and restructure existing, predominantly coniferous, plantations into mixed, semi-natural forests with higher biodiversity, regeneration capacity and sustainability (A new EU Forest Strategy 9944/14; Jactel et al., 2009; Gamfeldt et al., 2013). This transformation of forest stands is a formidable challenge in many areas due to extensive damage caused by deer browsing and vole gnawing (Kamler et al., 2010; Suchomel et al., 2012a). Contrary to deer browsing impacts on seedlings and saplings, the damage caused by voles is not so evident and could be easily overlooked by foresters. The subsequent increased mortality of saplings might simply be attributed to other, especially abiotic, factors (drought, freeze, etc.). Currently, only a few mitigation measures are effected to protect tree plantations against vole gnawing.

Clear cutting of entire coupes of timber still represents the most widespread management practice in the primarily state-owned forests in several Central and Eastern European countries due to the much larger costs attached to other practices of, for example, selective cutting or shelter-wood cutting and it represents the mostly used practice how to transform monocultures to more sustainable mixed forest stands there. Re-forestation using small-sized clear-cuts (up to 2 ha) subsequently artificially re-planted by saplings from nurseries (with only one tree species planted as monoculture), offers a compromise between

economic and ecological approaches to forest management, protecting a higher biodiversity of forest ecosystems (Lešo et al., 2014; Krojerová-Prokešová et al., 2016). The environmental conditions on the clearings are suitable for wide spectrum of small mammals including both forest as well as open-habitat species (Suchomel et al., 2012a, 2016; Krojerová-Prokešová et al., 2016). All three vole species, field vole (*Microtus agrestis*), common vole (*Microtus arvalis*), and bank vole, are usually present on Central European clearings adjacent to open habitats (Krojerová-Prokešová et al., 2016) and all can contribute to damage resulting from bark gnawing.

Damage by voles are reported annually in the Czech Republic and even though higher fluctuations in damage rate were detected during last decade of 20th century, after 2000 extent of reported damage showed little fluctuation between years (Supplementary Fig. 1). Damage from voles is reported almost from all regional districts of the Czech Republic, from lowlands to mountain forest habitats (Supplementary Fig. 2). Currently existing data are not suitable for the identification of the most critical areas/forest stands. The aim of this study was a more detailed analysis of factors influencing the bark gnawing and description of general pattern of vole gnawing on clearings in managed forests within the Czech Republic with the intention that results would likely be applicable to similar forest areas elsewhere within Central Europe. We aimed to answer following questions: (1) which tree species are preferred by voles in Central European conditions; (2) what is the relative contribution of each of the three main species of vole to gnawing damage; (3) what is the effect of bark removal on sapling survival; (4) is vole abundance the most important factor influencing the damage rate as in northern Europe; (5) is the damage rate influenced by the clearing type (age, size, woodland type, altitude); and (6) does damage vary seasonally and/or geographically?

## 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 10 study areas within the Czech Republic in different types of managed forests (Fig. 1). With the exception of one location at Bohemian-Moravian Highlands, all study areas were included in our previous study focused on the structure of small mammal communities in Central European clearings (Krojerová-Prokešová et al., 2016).

### 2.2. Data collection

A number of rectangular clearings, each with a developed herb layer, was selected at random in each study area (Fig. 1). All clearings were artificially re-planted by saplings transplanted from nurseries and at each clearing only one tree species was planted as a monoculture (this is a common forestry practice in several Central European countries). The number of monitored clearings slightly varied between consecutive winter seasons 2007/08, 2008/09, 2009/10, and 2010/11 mostly due to early snowing before snap-trapping or due to constraints on finances and human resources (Table 1). At each clearing, the abundance of voles was assessed during autumn before snowing and the gnawing damage on saplings was measured following snow melt in spring.

The abundance of voles was assessed using snap-trapping during September – October in 2007, 2008, 2009, and 2010. Snap traps were laid in lines of 34 traps each, approximately 3 m apart, so the total length of each line at one clearing was about 100 m. Traps were baited with peanut butter and exposed for three successive nights (considered to have only a minor effect on the overall small mammal community - Christensen and Hörnfeldt, 2003). Traps 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 or destroyed by

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