Inventory of rodent damage to forests

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ABSTRACT: Conversion of coniferous monocultures to more stable mixed stands is one of the crucial tasks of present forestry in the Czech Republic. One of the factors hampering this process is the activity of small rodents that can cause severe damage to young plantations in winter. Little knowledge is still available of the ecology of small mammals in the forest environment and of the factors influencing their distribution and extent of damage. In order to acquire relevant information on rodent impacts on forest regeneration, we mapped the cumulated damage to forest plantations in 13 regions within the Czech Republic in 2007 and 2008. We checked 19,650 trees of eight species on 393 plots. Broadleaves were affected by browsing much more than conifers (20% and 4%, respectively). Of the monitored species, beech was damaged the most frequently (26% individuals). Browsing intensity differed among the regions (6–60% browsed individuals). The least damaged were the plantations at the altitudes below 400 m a.s.l.; on higher located plots the browsing intensity showed no trend. The proportion of damaged trees increased with plantation age up to 6 years, then it did not vary significantly. This study has confirmed that rodents are an important factor with a negative influence on the regeneration of broadleaves. Bark browsing in young trees is affected by several factors and the prediction of damage is complicated. Further research should improve the prediction of the bark browsing threat to young plantations and at the same time the efficiency of protection against rodent-caused damage.

Keywords: bank vole; field vole; bark damage; forest protection

Rodents are a natural component of forest ecosystems where they play an important role, mainly in food chains. Their typical feature is a high reproduction rate and related fluctuation in their abundance within seasons of the year and within several-year periods (Sharpe, Millar 1991; Eccard, Ylönen 2001). Fluctuations in the size of rodent populations are affected by external factors such as weather, predators, diseases and structure of vegetation, as well as by intra- and interspecies relations (competition for food resources, social behaviour, stress). From the forestry aspect, the most significant problem is the ability of rodents to reach high population densities at localities with favourable conditions such as open areas (Ecke et al. 2002; Sullivan et al. 2008; Klenner, Sullivan 2009). Abundant rodent populations are then able to cause damage to vegetation, especially to artificial regeneration of forest stands (Schneider 1996). Rodent species preferring seeds in their diet, such as the Yellow-necked Mouse (*Apodemus flavicollis*) and the Wood Mouse (*Apodemus sylvaticus*), may negatively influence natural regeneration by consuming a large proportion of seed crop and also spoil the newly sown areas (Birkedal et al. 2009, 2010). However, the biggest problem-makers from the aspect of forestry are the species that consume mainly the vegetative parts of plants, i.e.

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the Field Vole (*Microtus agrestis*), the Common Vole (*Microtus arvalis*) and the Bank Vole (*Myodes glareolus*) (Castien, Gosalbez 1996; Baxter, Hansson 2001; Hansson 2002; Wheeler 2005). In the periods of food shortage, these species feed on bark and under certain conditions they are able to destroy all young trees at clearings (Sullivan et al. 1993; Niemeyer, Haase 2002). Factors influencing the reproduction of rodents in the forest environment, and thus also the degree of damage to trees, have not been sufficiently explained so far (Niemeyer, Haase 2003). The extent of damage is probably influenced mostly by (1) abundance of rodents at the specific locality in the winter season, (2) attractiveness of the planted tree species compared to other accessible food sources at the locality and (3) depth and duration of snow cover limiting accessibility of food to rodents (Sullivan et al. 1993; Hansson 2002; Sullivan, Sullivan 2008). This implies that the danger of damage to trees due to small mammals should be lower in areas with low winter abundance of pests, with sufficient supply of attractive food in the herbal layer and where snow cover is shallow and the rodents are usually able to find a sufficient amount of quality feed.

In spite of the damage that small mammals cause to woody plants, only minimal attention is paid to research of their ecology in the forest environment. Methods for the estimation of a risk of rodent damage do not exist and preventive modifications of forest regeneration technology are mostly omitted (Klenner, Sullivan 2009; Sullivan et al. 2009). Rodenticides are used on a small scale in forests and often without information on the population density of small mammals, which, in addition to wastage, also leads to pointless burdening of the environment with chemicals and killing of non-target organism species. Generally, protection of stands against rodent-caused damage is underestimated and many foresters anxiously await the end of winter when the extent of damage to plantations becomes apparent, being unable to defend against this harmful factor effectively.

One of the reasons for this passive approach to damage caused by small mammals is certain underestimation of the seriousness of this phenomenon which was not so severe in the past. At open areas that had been planted mainly with conifers, small mammals really caused only minor damage as they find conifers (especially spruce) only little attractive. In recent years, however, the share of broadleaved tree species in plantations has increased and one of the outcomes of this management is serious rodent-caused damage at many localities. It is therefore an important task of this time to find some reliable measures that will allow successful protection of broadleaved species, not only from the aspect of forest management economics, but also in order to ensure a sufficient proportion of broadleaves in stands, which is the basic prerequisite for sustainable development of our forests in future.

The seriousness of damage to forests caused by small mammals and the incomplete knowledge of their ecology and feeding behaviour have made us initiate extensive research focused on monitoring the population dynamics of rodents in the forest environment, their feeding behaviour and damage they cause to forest regeneration. The objective of the present study is to survey the extent of damage caused by rodents to the regeneration of forest tree species in the Czech Republic and to demonstrate possible solutions of rodent damage.

MATERIAL AND METHODS

Study area

In the Czech Republic, we selected 11 regions representing forests at various altitudes a.s.l. from the region of South Moravia to the Beskids Mts. (Fig. 1; Table 1). In each of these regions, we assessed the extent of rodent-caused bark browsing on 15–40 plots. The monitored plantations were at the age of 3 to 15 years and had different tree species composition. The plots were chosen with respect to the prevailing group of forest types in the specific region and in such a way so as to characterize one type of biotope only (one tree species and homogeneous structure of vegetation).

Extent of bark browsing

We examined 50 individuals of the selected tree species on each study plot. In each tree, we took record of its height, stem diameter at the ground surface and extent of bark damage over the last 4–5 years identifiable as rodent-caused browsing. The injury of individual trees was estimated from the size of the debarked area, distance of the lower margin of the browsed area from the ground surface and percentage of the damaged circumference of the trunk. The intensity of damage to individual study plots was expressed as the proportion of affected individuals in the total number of checked trees. Overall assessment comprised all acquired

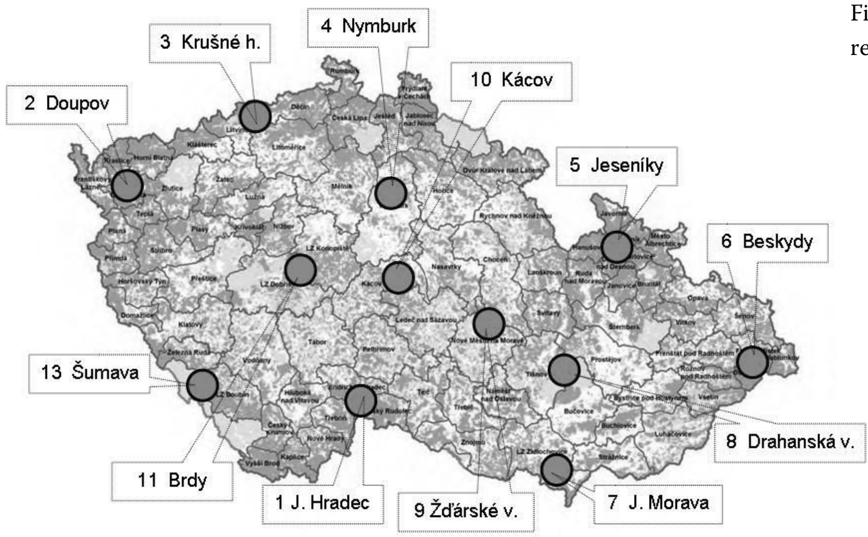

Fig. 1. Distribution of the monitored regions in the Czech Republic

data; for evaluation of selected factors we used only the data from plots with "attractive" tree species (beech, sycamore, ash and rowan). In some cases we evaluated only the significantly damaged individuals (50% and more of the trunk circumference debarked). We calculated the proportion of damaged trees according to study regions and tree species (mean ± standard deviation). Differences between groups were tested using *t*-test (SPSS 11 software). We used values of *t*-test (*t*), degrees of freedom (df) and significance (*P*).

RESULTS AND DISCUSSION

Overall extent of bark browsing

Study plots were chosen so as to reflect the representation of the main tree species grown in that region. Therefore, the observed damage reliably characterizes the degree of damage to forests in the particular regions. In total, we examined 18,900 trees of 13 species, of which 3,064 individuals (16%) were injured. The results confirmed significant differences in the attractiveness of monitored species

Table 1. A list of regions included in the monitoring of rodent impacts on the regeneration of forest tree species in the Czech Republic and their main characteristics

Region (number-name)	No. of plots	Average altitude (m a.s.l.)	Forest vegetation zones*	Average coverage of conifers in shrub layer	Average coverage of deciduous trees in shrub layer	Average area of clearcuts (ha)
1-J. Hradec	30	624	5	8.2	25.8	0.31
2-Doupov	39	712	5, 6	4.5	15.8	0.24
3-Krušné hory	30	750	5, 6, 7	15.8	21.4	0.53
4-Nymburk	30	247	1, 2	2.5	24.4	0.44
5-Jeseníky	39	878	5, 6, 7	4.2	4.7	0.42
6-Beskydy	34	886	5, 6, 7	9.8	13.7	0.28
7-J. Morava	30	178	1	0.5	2.5	1.22
8-Drahany	41	445	3, 4	7.6	34.9	0.33
9-Žďár	30	692	5, 6	25.8	24.6	0.35
10-Kácov	30	446	3, 4	30.1	34.9	0.21
11-Brdy	30	624	5	8.2	25.9	0.31

* 1 – oak, 2 – oak with beech, 3 – beech with oak, 4 – beech, 5 – beech with fir, 6 – beech with spruce 7 – spruce with beech

to rodents. In broadleaved species, the intensity of bark browsing was 5 times higher than in conifers (20% and 4% of individuals with signs of bark browsing, respectively). Rodents browsed the most frequently on bark of beech (26.3% of individuals), while in larch, spruce and pine there were less than 5% of the individuals injured. Not only were the broadleaves browsed more frequently, but also the debarked area on individual trees was larger than in conifers. The proportion of the strongly affected individuals (50% and more of the trunk circumference debarked) was 8.9% in broadleaved trees, while in conifers it was 1% only. The average debarked area was larger in broadleaves (185.2 ± 383.4 cm^2) than in conifers (76.7 ± 219.4 cm^2) (t = 3.698; df = 3062; P < 0.000). These differences can be explained in general by different attractiveness of the individual tree species, caused mainly by the content of available nutrients. That is why rodents begin to consume the more attractive tree species sooner than the less attractive ones and they consume a larger volume of bark.

As regards the damage caused by small rodents to trees in the Czech Republic, beech has an exceptional position as it is an important and widespread forest species; moreover, it is very attractive to rodents. The average area of damaged bark in one beech tree was 207.2 cm^2 ± 403.6; N = 2,449. In most of the other species the debarked area was smaller than 100 cm^2 (13–99 cm^2), only in rowan it was larger (184.3 ± 424.0; N= 86).

Similar results were found out in other studies monitoring the same or some other tree species. Hjältén and Palo (1992) reported the average area of injured bark around 6.5 cm^2 in rowan, 4.5 cm^2 in birch and 2.8 cm^2 in alder. Similarly, the highest attractiveness was documented in ash, beech, rowan, maple and larch, while birch, spruce, pine and alder were the least preferred species.

Variability in bark browsing

The intensity of bark damage was unevenly distributed in the studied regions, with the number of affected individuals ranging from 2.7 to 44.0%. Such differences could have been partially caused by different spectrum of tree species at individual localities. For this reason we evaluated the influence of the basic factors affecting the bark browsing intensity only in a group of attractive species (beech, rowan, ash, maple). When we compared the damage suffered by these attractive species only, the range of the affected individuals was from 6 to 60% (Fig. 2).

The attractiveness of the particular tree species (Fig. 3) indicates the threat from rodent-caused bark browsing to their young plantations. However, such attractiveness is not the only indicator of the potential risk to the newly planted areas. Significant is also the role of the specific conditions at the site (food supply, accessibility of food, population density) and within the region (Fig. 2).

Altitude

One of the key factors that could affect bark browsing is the altitude of a locality. Different climatic conditions at different altitudes determine the spectrum of the grown tree species, overall structure of the herb layer vegetation as well as the depth and duration of snow cover.

Damage suffered by the attractive species depended on the altitude (test of fit χ^2 = 343.4; df = 6; P < 0.000). At the lowest locations (180 to 400 m a.s.l.), only 5% of the individuals were injured (N = 400), while the most intensive bark browsing occurred at altitudes of 401– 600 m a.s.l. (Fig. 4). The low intensity of bark browsing in lowlands may be due to irregular snow cover and better food supply of green herbs in the

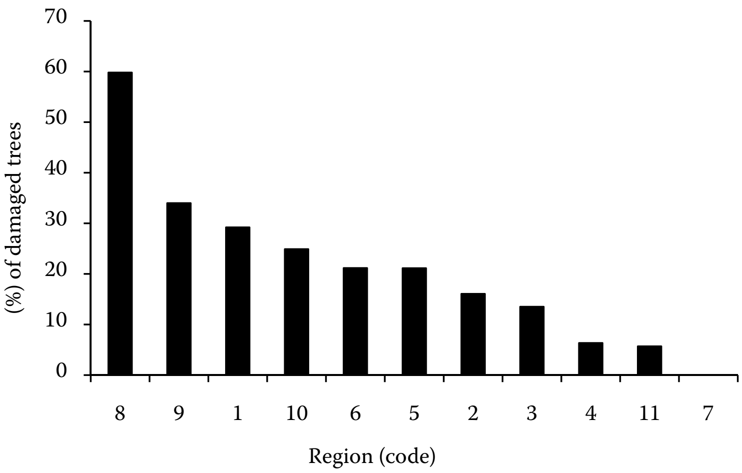

Fig. 2. Proportions of damaged individuals of attractive tree species in particular regions (N= 10,550)

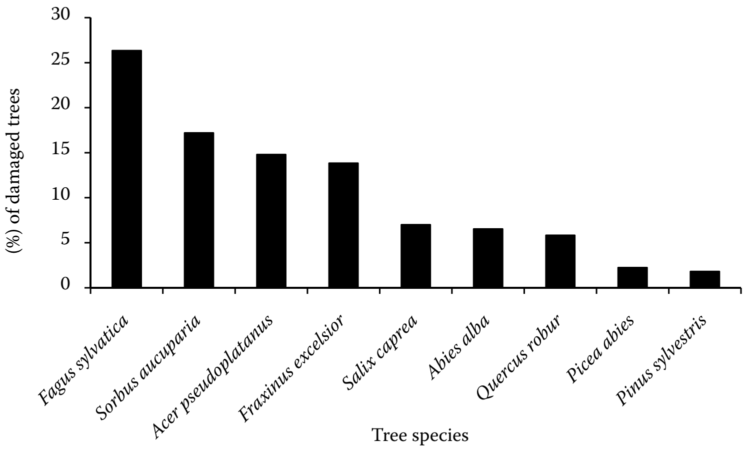

Fig. 3. Proportions of individuals affected by bark browsing according to tree species

winter season. It is not quite possible to explain differences in the intensity of bark injury at higher locations on the basis of our current data. They will most probably depend on a combination of several factors (rodent density, duration of snow cover, food supply). Although snow cover increases with altitude, conversely, the abundance of small mammals decreases (Blaustein et al. 1996).

Age of clearing

The structure of vegetation at clearings changes with time; simultaneously the living conditions of small mammals inhabiting them are also changing (amount of food, shelter). The proportion of damaged trees (of the attractive species) increased with the age of clearing up to 6 years and then it stagnated (Fig. 5). A gradual increase in the proportion of browsed trees may be due to the accumulation of browsing in the first five years after planting and to growing population density of small mammals in the initial phases of succession. Stagnation of bark browsing in the next years may be a result of decreasing abundance of voles with the age of clearing. As soon as the trees begin to suppress herbal vegetation, the living conditions become less favourable for small mammals and their numbers gradually decrease, together with the intensity of damage to trees. Besides, at some clearings the less attractive plants begin to dominate after a few years. For example, Ferguson et al. (2003) reported a stand where there was so little grassy vegetation nine years after planting of pines that the survival of voles was impossible in such environment. Another cause of the lower proportion of damaged trees found in older stands is that the young trees, dead due to bark browsing, disintegrate after several years and therefore they are not included in the inventory.

Bark injury was located just above the root neck in most cases, bark was often damaged also under the ground level. On the other hand, in France, Baubet et al. (2005) found most of the browsing marks on roots of trees, less frequently on stems and only rarely on branches, buds or leaves. According to our experiences, browsing damage to stems is easy to overlook during spring check-up, because the stem base, which is damaged the most frequently, is usually hidden in dry vegetation. Many trees are able to survive for several years even with severe browsing damage before they gradually die back. Information from forestry practice on the extent of damage in individual years may therefore be misrepresented due to the fact that foresters sometimes notice the damage with the delay of one or two years.

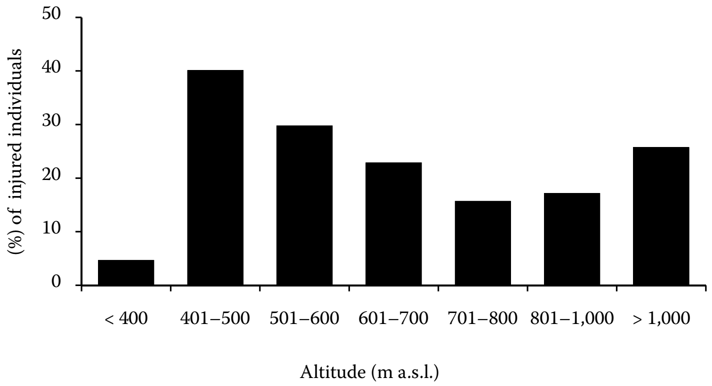

Fig. 4. Proportions of browsed individuals of attractive tree species in relation to altitude a.s.l.

Fig. 5. Proportions of attractive tree species with browsed bark according to the plantation age

From the aspect of tree survival, the most significant is the percentage of the trunk circumference that was debarked. Our data indicate that the injury of as little as one quarter of the circumference slows down the tree growth markedly. Out of the dying individuals, 80% suffered bark browsing on less than 50% of the trunk circumference. Significance of the size of the debarked area for tree survival was evaluated for example by Sullivan et al. (1993). They found that in a pine stand, 31% of trunks were browsed by hare on more than 50% of the trunk circumference and after 10 years, 20% of the trees died back; height and width increment decreased significantly with the increasing percentage of the trunk circumference debarked.

CONCLUSIONS

The results have shown that rodents are one of the serious factors hampering successful regeneration of broadleaved stands in the Czech Republic. In particular regions they destroy from 6 to 60% (26% on average) of the planted trees. It has been proved at the same time that the intensity of damage to plantations is uneven and its prediction is complicated as the extent of bark browsing depends on a complex of factors. This implies the need of further research that will help us better understand the mechanism of the occurrence of damage to young plantations and predict the threat to plantations more precisely; as a consequence, it will allow a considerable reduction of costs necessary for their protection and regeneration.

References

Baubet O., Ducourtieux C., Royer P. (2005): And if we talked about rodent damage. RenDez-Vous-Techniques, *7*: 46–50.

Baxter R., Hansson L. (2001): Bark consumption by small rodents in the northern and southern hemispheres. Mammal Review, ***31***: 47–59.

Birkedal M., Fischer A., Karlsson M., Lof M., Madsen P. (2009): Rodent impact on establishment of direct-seeded *Fagus sylvatica*, *Quercus robur* and *Quercus petraea* on forest land. Scandinavian Journal of Forest Research, ***24***: 298–307.

Birkedal M., Lof M., Olsson G.E., Bergsten U. (2010): Effects of granivorous rodents on direct seeding of oak and beech in relation to site preparation and sowing date. Forest Ecology and Management, ***259***: 2382–2389.

Blaustein L., Kotler B.P., Nevo E. (1996): Rodent species diversity and microhabitat use along opposing slopes of Lower Nahal Oren, Mount Carmel, Israel. Israel Journal of Zoology, ***42***: 327–333.

Castien E., Gosalbez J. (1996): Diet of Clethrionomys glareolus in the western Pyrenees (north Iberian Peninsula). Folia Zoologica, ***45***: 137–144.

Eccard J.A., Ylönen H. (2001): Initiation of breeding after winter in bank voles: effects of food and population density. Canadian Journal of Zoology, ***79***: 1743–1753.

Ecke F., Lofgren O., Sorlin D. (2002): Population dynamics of small mammals in relation to forest age and structural habitat factors in northern Sweden. Journal of Apllied Ecology, ***39***: 781–792.

Ferguson J.W.H., Van Jaarsveld A.S., Johnson R., Bredenkamp G.J., Foord S.H., Britz M. (2003): Rodent-induced damage to pine plantations: a South African case study. Agriculture Ecosystems & Environment, ***951***: 379–386.

Hansson L. (2002): Consumption of bark and seeds by voles in relation to habitat and landscape structure. Scandinavian Journal of Forest Research, ***17***: 28–34.

Hjältén J., Palo T. (1992): Selection of deciduous trees by free ranging voles and hares in relation to plant chemistry. Oikos, ***63***: 477–484.

Klenner W., Sullivan T.P. (2009): Partial and clearcut harvesting of dry Douglas-fir forests: Implications for small mammal communities. Forest Ecology and Management, ***257***: 1078–1086.

Niemeyer H., Haase R. (2002): The fate of young beech with their stem girth completely debarked by common vole in a afforstation in eastern Holstein. Forst-und-Holz, ***57***: 342–346.

Niemeyer H., Haase R. (2003): The importance of voles in afforestation of farmland. Forst und Holz, ***58***: 26–31.

Harpe S.T., Millar J.S. (1991): Influence on the variation in initiation of breeding in *Peromyscus-maniculatus*. Canadian Journal of Zoology, ***69***: 698–705.

Sullivan T.P., Coates H., Jozsa L.A., Diggle P.K. (1993): Influence of feeding by small mammals on tree growth and wood quality in young lodgepole pine. Canadian Journal of Forest Research, ***23***: 799–809.

Sullivan T.P., Sullivan D.S. (2008): Vole-feeding damage and forest plantation protection: Large-scale application of diversionary food to reduce damage to newly planted trees. Crop Protection, 2*7*: 775–784.

Sullivan T.P., Sullivan D.S., Lindgren P.M.F. (2008): Influence of variable retention harvests on forest ecosystems: Plant and mammal responses up to 8 years post-harvest. Forest Ecology and Management, ***254***: 239–254.

Sullivan T.P., Sullivan D.S., Lindgren P.M.F., Ransome D.B. (2009): Stand structure and the abundance and diversity of plants and small mammals in natural and intensively managed forests. Forest Ecology and Management, ***258***: S127–S141.

Wheeler P. (2005): The diet of field voles *Microtus agrestis* at low population density in upland Britain. Acta Theriologica, ***50***: 483–492.

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