Damage caused by rodents in Polish forests*

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Abstract

The impact of small rodents on Polish forest trees was examined at both the national and regional levels. Detailed information based on a questionnaire was collected at the national level in 1993. Field studies at the regional level were carried out from 1994 through to 1997. The damage due to rodents constituting a significant economic problem occurred in only 4% of the Forest Districts in Poland. The tree species that small rodents preferred most were larch, ash, beech and maple, whereas birch, Norway spruce, Scots pine and black alder were the least preferred. Regional field studies were conducted in localities with the highest levels of damage situated in the Sudety Mountains (southern Poland). In this region, the most common rodent species was the field vole. Levels of tree-seedling damage were correlated with vole population density in the Autumn. I conclude that: (1) at the national level, the damage caused by small rodents has limited impact on Polish forestry; (2) at the regional level small rodents may exert considerable pressure on the over-wintering survival of tree seedlings.

Keywords: Tree damage, small rodents, population dynamics, short-tailed vole, Microtus agrestis, forest damage, tree preferences, vole pressure, tree survival

1. Introduction

The structure and persistence of forest ecosystems is influenced by primary factors such as climate and human activity, and by secondary ones which in Europe include fungi, insects and herbivorous mammals (mainly deer and small rodents).

In forestry, the damage inflicted by small rodents mainly entails the chewing, nibbling or complete severing of the trunks, roots and stems of forest trees, as well as the consumption of seeds. In a review of the literature concerning damage of this kind inflicted in boreal-zone forests, Gill (1992) concluded that the squirrels and voles (Sciuridae and Microtinae) could be held primarily responsible. While the damage done by squirrels was due to the chewing of tree bark, that inflicted by voles was due to the chewing and at times the severing of tree seedlings, saplings and roots, as well as the consumption of seeds. There are also geographical differences in the damage caused by these two rodent families: in North America (the USA and Canada) most damage is caused by squirrel, whereas in Europe most damage is done by voles.

The voles in question, primarily of the genera Clethrionomys and Microtus, are renowned for their characteristic temporal fluctuations in population numbers. In some cases, these attain sufficient constancy of amplitude to merit consideration as population cycles (Taitt and Krebs 1985; Hansson and Hettonen 1988; Stenseth and Ims 1993). In the face of such dynamics, it is expected that the impact vole populations have on forest ecosystems should vary accordingly. During the peak phase of the population cycles (high-density populations) the negative pressure should be the highest, while during the low phase of the population cycles the negative pressure should become almost imperceptible (Ostfeld and Canham 1993). Indeed, fieldwork in Sweden involving parallel monitoring of numbers of the field vole (Microtus agrestis) and bank vole (Clethrionomys glareolus) and the damage done to forests, has confirmed a close link between population densities and levels of damage (Hansson and Larsson 1980). Years of high rodent densities have also been associated with significant damage to forestry in the growing season. Since the regularity and amplitude of the cycling of vole populations is shown to increase with latitude, the pressure the rodents are able to inflict upon forest plantations also related to this geographical factor (Hansson and Hettonen 1985). However, a further factor upon which the level of damage to trees also depends is the availability of resources in the environment. Simple ecosystems of an impoverished character can be expected to experience greater pressure by rodents on their woody vegetation, than will fertile and more complex ones. The discovered North–South gradient in the intensity of damage caused by small rodents reported from
Scandinavia coincides with changes in both environmental quality and the amplitude and regularity of vole population cycling. That is why it is very difficult to separate the impact of these two factors (habitat quality and population cycles) on the level of damage. Furthermore, we do not know whether a relationship between habitat quality and population cycles exists also in Central Europe’s forest ecosystems (which are more fertile than Scandinavian forest ecosystems).

It needs to be borne in mind that the diet of *Microtus* species consists primarily of the foliage of monocotyledonous and dicotyledonous herbaceous plants (Stenseth et al. 1977; Hansson 1985a). Trees and shrubs are in fact ‘iron rations’ for them, only eaten in the face of a lack of alternative sources – most often therefore in winter (Lindroth and Batzli 1984; Bucyanayandi et al. 1992). In this connection, it is quite possible for marked differences in population dynamics to produce no change in the pressure that animals exert on woody vegetation, so long as the aforementioned main component of the diet continues to be present.

As was implied above, the literature on the linkage between the dynamics of small-rodent populations and the scale and intensity of damage to trees is limited where more complex forest ecosystems are concerned. Indeed, there has been a general lack of work on the dietary preferences of small rodents in connection with the trees that form ecosystems in Central Europe, or on the influence these might exert on forestry in the region. It was thus decided to plan and under take research across the whole of Poland, with a view to determining:

1. whether the impact of small rodents on Poland’s forest ecosystems constitutes a problem across the country, or just locally;
2. the species of tree preferred by small rodents, and the periods during which these preferences are demonstrated;
3. the ages of stands most vulnerable to small rodent damage; and
4. the species of rodent responsible for damage in forests, and any possible link between the dynamics displayed by their populations and damage dynamics.

2. Study area and methods

The level of damage small rodents inflict upon trees in Poland’s forests was estimated as follows, via a two-stage procedure:

1. The first stage (1993) involved the sending out of questionnaires to all 440 Forest Districts (FD) making up the 12 Regional Directorates of Poland’s State Forests National Forest Holding, the aim being to generate data for each District on:
   - the total forest area, including areas of renewal and new afforestation;
   - the area (ha) and intensity of damage caused by rodents, as assessed using a four-point scale in which 0 equals no damage, 1 denotes limited damage to up to 20% of trees, 2 a moderate level of damage to between 21 and 50% of trees, and 3 a large amount of damage to more than half of all trees;
   - the species of tree being damaged by rodents, and species composition of plantations, as well as the periods in which damage is seen to arise; and
   - the places in which damage occurs, be these younger or older plantations, forest nurseries, young stands, older stands (of 30+ years), sapling stores or seed stores.
2. The second stage (1994) entailed the selection from among all Poland’s Forest Districts of one FD shown by the survey to manifest the greatest area and intensity of damage inflicted by rodents. This was then the subject of detailed field-based research to determine the culprit species, as well as the relationship between densities of species’ populations and the levels of damage they cause.

2.1. Fieldwork

Trapping methods were used to establish the size and species compositions of the populations of rodents present in Szklarska Poręba Forest District. A total of 122 Polish wooden live traps were laid out on each of two 1-ha permanent plots (100 × 100 m), the standard CMR (Catch Mark Release) technique being applied over five nights. Traps were baited with oats, spaced at 10-m intervals and checked twice a day in the morning (ca. 09:00 h) and in the evening (ca. 18:00 h). All captured voles were individually marked by toe-clipping. The data recorded were: species, identification of individual, trap station, body mass, sex and reproductive condition. Trapping was carried out in autumn (October) over the four successive years 1994–1997 inclusive. Vole population density was calculated as the number of voles per hectare.

The damage caused by small rodents in the young plantations of Szklarska Poręba FD was monitored in three of the aforementioned 4 years (1994, 1995 and 1996), checks being carried out in 35 such plantations at altitudes between 600 and 1000 m a.s.l. Randomly selected saplings were subject to damage assessment following the disappearance of snow cover (in March/April). The analysis encompassed four species: beech (*Fagus sylvatica*), larch (*Larix decidua*), Scots pine (*Pinus sylvestris*) and Norway Spruce (*Picea abies*). Noted in the course of the checks were the tree species involved, the number, and the absence or presence of damage due to rodents (with no account being taken of sapling damage caused by other vertebrates).
2.2. Statistical analyses

Statistical tests were performed with STATISTICA software (from StatSoft Inc. 1995). The relationships between the sizes of areas damaged and altitude, as well as between intensity of damage and altitude were analysed using Spearman rank correlations (Sokal and Rohlf 1995; Zar 1999). Differences in the damage caused by field voles to different forest tree species were analysed using the G-test.

3. Results

Out of the 411 Forest Districts into which the whole of Polish territory is divided, only 54 (or 13%) reported damage due to rodents. Furthermore, in only 13 (3% of the total) was there a high intensity of damage. This left 19 Districts (4%) with moderate levels of damage, and 23 (6%) with limited damage. The sizes of the areas damaged by small mammals varied across the range 1.63 – 400.3 ha, the mean figure for all FDs reporting damage being \( X = 47.6 \pm 83.2 \text{ ha (mean \pm SD)} \).

The Spearman rank correlation was then used to determine if the area and intensity of rodent-induced damage was related to the share of a Forest District taken by open areas, but no significant correlation with damage was obtained for either area afflicted \( (R = 0.05, P = 0.608, n = 99) \) or intensity \( (R = 0.057, P = 0.5731, n = 99) \).

To compare the levels of damage present over a larger area, the intensity and dimensions thereto were averaged at the level of the different State Forests Regional Directorates in which such damage had been reported (in 11 RDSFs out of 12). For each Directorate, a mean was calculated for the results obtained from 20 of its Forest Districts, the 11 Directorates and 20 FDs in each giving a total of 220 data items (Table I). Mapping to ensure fuller spatial depiction of the distribution to damage reported from the different FDs noted those places (RDSFs) with a total area of damage greater than 100 ha and an intensity of damage involving more than 50% of an area’s trees. This method allowed for the identification of just four locations, i.e. the Regional Directorates of Wrocław (773 ha so damaged), Lublin (200 ha), Poznań (160 ha) and Krosno (105 ha).

The damage done by rodents mainly occurred in winter, from which season some 70% of the reports of damage from Forest Districts derived. The 15% of reports each concerning summer and autumn damage referred to much more limited incidents. Spring was nevertheless the only season from which there were no reports of damage caused by small rodents.

As expected, the rodents were much more likely to damage broadleaved trees (mentioned in 78% of cases) than coniferous ones (the remaining 22%). Analysis of the dietary preferences using Ivlev’s electivity index (Krebs 1989) revealed the following order of preference for forest trees: larch, ash \((Fraxinus excelsior)\), beech, maple \((Acer spp.\)\), fir \((Abies alba)\) and pedunculate oak \((Quercus robur)\) (Figure 1). Among the tree species least preferred, and only sporadically damaged, by rodents – in spite of them being proportionally well-represented in stands – were (in rank order from the least preferred): birch \((Betula spp.\)\), Norway spruce, Scots pine, black alder \((Alnus glutinosa)\) and red oak \((Q. rubra)\) (Figure 1).

Among all the registered instances of damage to trees, the overwhelming majority (ca. 90%) were associated with saplings (in young plantations, at storage depots) or seedlings (at nurseries). Only 10% of cases related to damage in older stands, i.e. those aged 5–20 years or older. The average age of trees damaged – mainly through the chewing of saplings or seedlings – was 4 ± 1.7 years (mean ± SD), with the overall range being 1–10. The damage done as the bark of older trees was chewed or the seeds consumed would have to be described as marginal.

Once differences in the area and intensity of damage done by rodents had been analysed, Szklarska Poręba Forest District was chosen as the area in which to determine precisely the identity of the culprits, and the intensity with which damage was being inflicted. It was there that the damage had been depicted as particularly severe, with more than 50% of trees in areas in excess of 100 ha suffering. The period of trapping of rodents on permanent plots allowed for determinations of population sizes and species composition (Figures 2 and 3). The clearly dominant species was the short-tailed vole.

<table>
<thead>
<tr>
<th>State forests</th>
<th>Mean (± SD) area of damages (m²)</th>
<th>Mean (± SD) intensity of damages (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrocław</td>
<td>62.85 ± 97.8</td>
<td>1.22 ± 1.16</td>
</tr>
<tr>
<td>Lublin</td>
<td>27.0 ± 95.2</td>
<td>0.39 ± 0.61</td>
</tr>
<tr>
<td>Poznań</td>
<td>10.98 ± 23.72</td>
<td>0.7 ± 1.1</td>
</tr>
<tr>
<td>Zielona Góra</td>
<td>9.17 ± 38.89</td>
<td>0.17 ± 0.7</td>
</tr>
<tr>
<td>Krosno</td>
<td>6.21 ± 23.0</td>
<td>0.44 ± 0.98</td>
</tr>
<tr>
<td>Katowice</td>
<td>5.87 ± 17.28</td>
<td>0.55 ± 0.7</td>
</tr>
<tr>
<td>Szczeciniec</td>
<td>4.03 ± 16.47</td>
<td>0.28 ± 0.67</td>
</tr>
<tr>
<td>Olsztyn</td>
<td>1.22 ± 4.71</td>
<td>0.11 ± 0.32</td>
</tr>
<tr>
<td>Warszawa</td>
<td>0.85 ± 3.56</td>
<td>0.33 ± 0.97</td>
</tr>
<tr>
<td>Łódź</td>
<td>0.77 ± 2.84</td>
<td>0.22 ± 0.73</td>
</tr>
<tr>
<td>Pila</td>
<td>0.3 ± 1.18</td>
<td>0.11 ± 0.32</td>
</tr>
</tbody>
</table>

The intensity and area were averaged at the level of the different State Forests Regional Directorates in which such damage had been reported. In each Directorate, a mean was calculated for the results obtained from 20 of its Forest Districts. The intensity of damages done by rodents, as assessed using a four-point scale in which 0 equals no damage, 1 – up to 20% of damaged trees, 2 – from 21 to 50% of damaged trees, and 3 above 50% of damaged trees.
M. agrestis, which always accounted for more than 50% of specimens. Furthermore, the overlaps within the assemblage of this species plus the common vole (M. arvalis) always exceeded 80% of the total. The remaining rodent species, i.e. the bank vole, yellow-necked mouse (Apodemus flavicollis) and harvest mouse (Micromys minutus) were present in the young forest plantation when densities of short-tailed vole populations were both lower and higher. This suggests a weak relationship between the population densities of the dominant and subdominant rodent species. The densities of the short-tailed vole (and of voles in general) varied markedly from year to year, a value of 90 individuals ha$^{-1}$ obtained in 1994.
comparing with the situation in 1995, in which it did not prove possible to capture a single vole on the plot.

The level of small-mammal-induced damage to different species of tree in young plantations also varied greatly, reflecting well both the known dietary preferences of the rodents and a relationship between the aforementioned wide variations in number and levels of overall damage (Table II). Irrespective of the year of study, the tree species damaged most frequently was beech, followed (with a markedly lesser degree of damage) by larch and Scots pine. It was not possible to report any damage whatsoever to spruce trees. Not surprisingly, the highest level of damage was noted in the springs of 1994 and 1995 following the autumns of 1993 and 1994 with their high-density vole populations. In these years, respectively, 50 and 28% of beeches, 45 and 18% of larches and 9 and 5% of Scots pine trees were found to have experienced damage. In contrast, in the spring following the reporting of the lowest vole numbers (note that no voles whatsoever were captured in autumn 1995), not a single case of rodent-induced damage to trees was noted (Table II).

While no statistically significant relationship between the sizes of areas of damage and altitude (a.s.l.) was noted, there was a weak inverse correlation between altitude and intensity of damage, \( r_s = \)

Table II. Damage caused by field voles (Microtus agrestis) on different forest tree species in the years (1994 – 1996) in the Sudety Mountains.

<table>
<thead>
<tr>
<th>Tree species</th>
<th>No. examined seedlings</th>
<th>No. damaged seedlings</th>
<th>Differences between tree species (G-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>( G )</td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larch</td>
<td>1100</td>
<td>198</td>
<td>( g = 449.91 )</td>
</tr>
<tr>
<td>Beech</td>
<td>1000</td>
<td>252</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Scotch pine</td>
<td>700</td>
<td>42</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Norway spruce</td>
<td>1400</td>
<td>1</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larch</td>
<td>1000</td>
<td>107</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Beech</td>
<td>1100</td>
<td>156</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Scotch pine</td>
<td>850</td>
<td>14</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Norway spruce</td>
<td>1300</td>
<td>0</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larch</td>
<td>1200</td>
<td>0</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Beech</td>
<td>1300</td>
<td>0</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Scotch pine</td>
<td>840</td>
<td>0</td>
<td>( g = 100.66 )</td>
</tr>
<tr>
<td>Norway spruce</td>
<td>1550</td>
<td>0</td>
<td>( g = 100.66 )</td>
</tr>
</tbody>
</table>

In 1995 no damage was observed on Norway spruce species – therefore it was excluded from the statistical analysis.

\(-20\%, \ P = 0.00256\) (Spearman rank correlation). Thus, successively greater altitudes are associated with slightly, if significantly, lower intensities of damage.
4. Discussion

Analysis of results from the nationwide survey suggests that the problem of damage to Poland’s forests by small rodents is at most a marginal one. Only 13% of Forest Districts even reported it, and it took on more significant dimensions in terms of area and intensity of damage in just 3% of districts. More intensive damage over much greater areas is only present locally (within Wroclaw RDSF) and is almost entirely confined to the Sudety Mountains. Indeed, a high level of damage caused by small rodents has been characteristic of that region since around 1980 (Szukiel et al. 1990), being most likely linked with the environmental disaster (air pollutants, acid rains) and forest death taking place there from the late 1970s onwards. The latter resulted in a marked increase in the open area available for colonisation by herb-layer vegetation, above all grasses and sedges. This was linked to a change in the species composition of the small-rodent assemblage. Prior to the aforementioned eco-disaster (when forest ecosystems were still stable), the small rodent community was dominated by the yellow-necked mouse, bank vole and pine vole (Pitymys subterraneus). In contrast, the share of the assemblage accounted for by the current dominant – the short-tailed vole – was much lower then – even lower than that of the common vole (Andera et al. 1974). Only as work was done in the aftermath of the forest dieback did it emerge that the short-tailed vole had become the clear dominant within the assemblage of small mammals (Szukiel et al. 1990; Flousek 1992; Grossmann 1992; Adamczewska-Andrzejewska 1995). Like other Microtus voles, this species is a typical inhabitant of open areas, which exerts a marked pressure upon tree seedlings and saplings, especially in winter. The cause of the strong pressure small rodents exerted in this region would thus seem to be the massive change in the proportion of small mammals present there. This points to a change in the environment from a typically forest one (with small-mammal assemblages dominated by such typically forest-dwelling species as the yellow-necked mouse and bank vole) to one of open areas subject to successional processes (in which the short-tailed vole prevails).

Analysis of the seasonal dynamics to the appearance of damage resembles work done in other countries in making clear that the greatest damage to stands is done in winter (70% of all reported incidents). Damage is done only much more rarely in autumn (15% of reports) or summer (also 15%). Spring was the one season of the year in which no damage whatsoever could be attributed to small rodents. The fact that most damage to saplings was done in winter was due to two factors. First, populations of rodents peak in late autumn, and second, winter is characterised by a lack of voles’ favourite food (herbs), and hence by the need to seek out the woody vegetation which is all that remains available at that time of the year (Buacyanayandi et al. 1992).

Contrary to the results from Scandinavia (Hansson and Larsson 1980; Hansson 1985b), no preference on the part of small rodents for Scots pine and birch was demonstrated in Polish forests. This difference may reflect differences in the species composition of the respective forest types, as well as in the abundance of the food base in the form of herb vegetation. In more-impovertised forest ecosystems (as opposed to richer ones), much greater pressure on woody vegetation will be exerted by small rodents. However, the results of this study accord with the work of others in regard to dietary preferences among Central Europe’s rodents (Szukiel et al. 1990; Grossmann 1992; Kolakowski 1992) and game animals (Szukiel 1993; Szukiel and Borowski 2000). The species shown to be most favoured were larch, ash, beech, maple, fir and pedunculate oak. Those damaged most rarely were spruce, birch, Scots pine and black alder.

As small rodents most often damage tree saplings and seedlings, the negative effects of their activities tend to be concentrated in nurseries and young plantations, as well as at depots where young trees are stored. These biotopes or artificial places feature both appropriate food and shelter for the animals in question. As a stand matures, the living conditions for rodents deteriorate, there being a resultant change in the species composition and decline in overall abundance of the small mammal assemblage (Wolk and Wolk 1985). Additionally, trees, as they age, become less and less vulnerable to the damage rodents are capable of inflicting, making it increasingly unlikely that real reportable damage will arise. Furthermore, the dominant rodent species in older stands is the bank vole, which differs from Microtus voles in its more varied diet and presence in an area at lower densities (Hansson and Larsson 1978; Borowski 2001).

The lowered intensity of damage at successively higher altitudes is most probably linked to changes in the species composition of small-rodent assemblages, as well as ever-lower densities of their component populations (Adamczewska-Andrzejewska 1995). This is, of course, dependent on changing abiotic conditions (i.e. an ever-harder climate and more and more limited availabilities of both food and shelter), as well as on the high risk of predation. The weakness of the dependent relationship may point to the non-linearity of these mechanisms, which may come into effect in abruptly above some threshold, as well as differently in different environments.

Field-based analysis of rodent dietary preferences within the forests of Szklarska Poreba FD registered levels of damage somewhat below those cited by the District’s foresters. The likely reason for these low mean values for the three aforementioned tree species is that rodents do damage that concentrates...
in particular areas. Meanwhile, forestry personnel tend to overestimate levels of damage to saplings (they automatically included in the report areas in which damage does not occur). Despite this, the degree of damage to the different tree species offers a good reflection of known differences in the small rodents’ dietary preferences (Borowski 1998). It was also in large measure linked to the population dynamics of voles, above all the short-tailed vole. The damage assessment of 1994 was done as the peak 1993 population entered its over-wintering period (Borowski 1998). Rodent population densities declined steadily in subsequent years, with the proportions of saplings damaged going down accordingly. The results of the field experiments make it clear that the level of damage being done by voles to the beech and larch of the western Sudety Mountains had fallen back within the moderate category (21–50% of trees damaged) almost immediately following the peaking of numbers (1994 had the highest densities noted across the 1994–1997 period). At this time, Scots pines were only damaged to a limited degree.

The proportions of the small-rodent assemblage accounted for by the different species varied, and were dependent on the study period. The year 1996 brought the maximum species diversity, with the dominant short-tailed vole (58% of all captures) being joined among species caught by the yellow-necked mouse and bank vole (the latter not having been noted previously in the study area). It appeared initially that the composition of such an assemblage (featuring two typically forest-dwelling species in the shape of the yellow-necked mouse and bank vole) was a response to habitat changes in the direction of forest over large deforested areas of the western Sudety Mountains. However, the following year (1997) saw a return to just a single species of small mammal on the study plot (i.e. the short-tailed vole). It appeared that the composition of such an assemblage (featuring two typically forest-dwelling species in the shape of the yellow-necked mouse and bank vole) was a response to habitat changes in the direction of forest over large deforested areas of the western Sudety Mountains. However, the following year (1997) saw a return to just a single species of small mammal on the study plot (i.e. the short-tailed vole). It would thus seem that 1996 stood out for its good reflection of known differences in the small rodents’ dietary preferences (Borowski 1998).

Comparison of the data obtained with the results of other authors would seem to suggest decided dominance of the small-mammal assemblages of degraded areas by the short-tailed vole. This species is less clearly prevalent at non-degraded sites (accounting for ca. 30% of an assemblage), and is also subject to differences in population density that reflect altitude. The species accounts for only 20% of the assemblage in the subalpine zone (Adamczewska-Andrzejewska 1998).

In summary, the pressure exerted by small rodents on Poland’s forest ecosystems is a limited preclude of effective forestry practice. Nevertheless, the kind of interaction between rodent population densities and the level of damage they cause that has proved demonstrable in Scandinavia, is also seen to hold in the more fertile forest ecosystems of Central Europe.

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