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Occurrence of the marbled rose-chafer (*Protaetia lugubris* Herbst, Coleoptera, Cetoniidae) in rural avenues in northern Poland

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Abstract

The occurrence of *Protaetia lugubris*, an endangered species developing in hollow trees, was studied in a network of rural avenues in northern Poland. We detected 1002 trees from nine species with hollows suitable for beetle development (25% of all trees inspected). Among them, 74 trees (7.4%) from seven species were occupied by *P. lugubris*. The distribution of *P. lugubris* was random with respect to tree species identity. The beetle preferred trees above 200 cm in circumference with a tendency towards higher occupancies of the bigger trees having circumferences above 300 cm. *P. lugubris* did not show any significant preferences according to hollow entrance area, exposition and road surface type. Our results indicate that *P. lugubris* is a generalist species colonizing all suitable hollows. Its occurrence indicates suitable conditions for many other species associated with tree cavities and decaying wood.

Introduction

Species dependent on old-growth deciduous forests have declined due to habitat loss and intensive forest management (Speight 1989). A conspicuous group of arthropod species naturally associated with tree cavities in old-growth deciduous forests are the saproxylic beetles of the family Cetoniidae. One of them is the marbled rose-chafer *Protaetia lugubris* Herbst, which develops inside tree hollows (Ranius and Nilsson 1997; Ranius and Jansson 2000). Most authors assume the beetle develops in a number of tree species with a preference for oak and is connected mainly with clearings and forest edges Bussler and Schmidl 2000). However, critical studies of beetle occurrences in relation to host tree frequencies, habitat type, and tree health status are still missing. There is an urgent need to recognize its requirements for assessing vulnerability and to prepare conservation schemes (Bussler and Schmidl 2000; Oleksa et al. 2005) in Europe.

Protaetia lugubris is regarded as being endangered over its whole distributional range, i.e., it is vulnerably endangered (stark gefährdet) in Germany (Geiser et al. 1984) and endangered (gefährdet) in Austria (Jäch et al. 1994). In Sweden its range contracted during the last century and the species completely disappeared from the south-western part of the country (Nilsson et al. 2002). The conservation status of *Protaetia lugubris* in Poland has not been evaluated. So far it is not protected despite its assumed status of being vulnerably endangered. Published data about its distribution (Burakowski et al. 1983) are already out of date.

This lack of knowledge about habitat preferences and vulnerability makes any conservation schemes for *P. lugubris* premature and might lead to inappropriate choices of prime areas for conservation. In this study we focus therefore on the habitat preferences of the marbled rose-chafer and aim to identify host tree characteristics and habitat structure to explain regional distribution patterns of *P. lugubris*.

We present data from a network of tree-lined country roads in Northern Poland. This was based on a previous study (Oleksa et al. 2005) where we found that the most important refuges of the beetle in northern Poland are old trees planted along roads in open rural landscapes. Such a regional occurrence pattern of *P. lugubris* has not been reported previously.

Materials and methods

The Iława Lakeland Landscape Park (NE Poland, (Figure 1)) is a rural landscape rich in old avenues dating back to the early 18th century. For this study we chose 71 avenue fragments with a total length of 55.5 km making up over 20% of all old avenues in that area and examined 3932 trees in July 2003. The avenues examined were dominated by the small-leaved lime (*Tilia cordata*), which made up 52.2% of all trees examined. Ash (*Fraxinus excelsior*) accounted for 11.3%, Norway maple (*Acer platanoides*) for 10.4%, and the

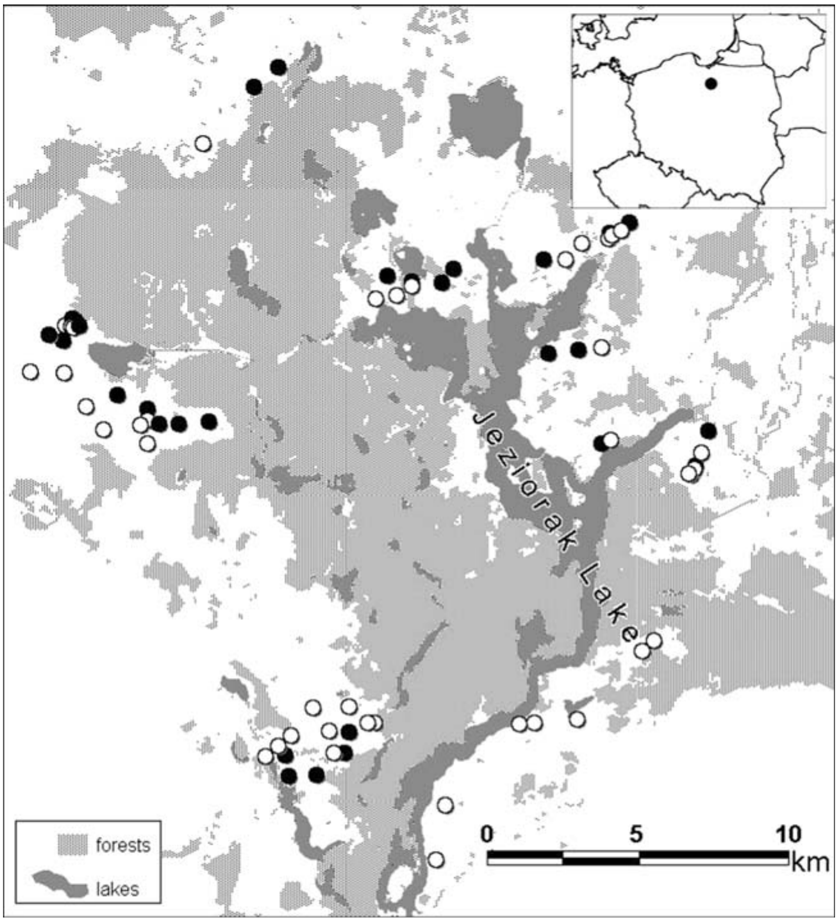

Figure 1. The study area. Black (occupied sites) and white (not occupied sites) denote the roads studied.

pedunculate oak (*Quercus robur*) for 9.4%. All other species accounted for only 16.7% of the total.

We took samples from all trees with hollows and looked for *P. lugubris* or its remnants. We took about 10 l of wood mould from each tree. In cases where less than 10 l was available we took as much mould as possible. The minimum mould volume per tree was 0.5 l as proposed by Ranius (2002). The wood mould was carefully examined and returned to the hollow. Larval frass was distinguished from the frass of other saproxylic beetles (especially the hermit beetle *Osmoderma eremita*) according to Pawłowski (1961). We regarded trees as occupied by *P. lugubris* if living individuals or remnants were found.

We used the 5 point scale of Pacyniak (1992) to assess tree health (lower levels denote healthier trees) (Table 1). Trunk circumference was measured at a height of 1.3 m. Avenues were classified according to tree species composition, road surface type, average number of potential host trees (trees with appropriate hollows), average tree health, and the number of trees occupied by *P. lugubris*.

We used multiple logistic regression with log-transformed predicator variables (stepwise backward elimination of non-significant variables at $p = 0.05$) and a general linear MANCOVA model (linear weight function, Akaike model choice criterion, Wald test) to infer differences in occupancy due to circumference, health class, and road surface. The models were computed with Statistica 6 (Statsoft 2001). Preferences of *P. lugubris* with respect to tree species, circumference and health status were compared with a random sample model of the number of beetles found within the total number of trees examined. Expected frequencies, standard deviations, and the normalized *Z*-scores ($Z = [x - \mu]/\sigma$) were generated from 5000 random samples each using the program *Sample* (Ulrich 2003; Ulrich and Ollik 2005). *Z*-scores above 2 or below -2 point to significant ($p < 0.05$) deviations of the observed value x from expectation μ.

To visualize the frequencies of unoccupied and occupied trees in relation to trunk width and to make these frequencies less dependent on width class choice we used kernel density estimates h of the frequencies and plotted h against trunk width. Kernel density estimates were computed with EasyReg (Bierens 2004) using a normal density function and a bandwidth of one sample standard deviation around the sample mean (Bierens 2004).

Results

We detected 1002 trees (25%) with hollows suitable for beetle development (Table 2). Of those trees, 74 (7.4%) were occupied by *P. lugubris*. Of these records 75.7% concern *Tilia cordata*, 12.2% *Acer platanoides*, and 5.4% *Salix alba*. Among the trees with suitable hollows 25.0% of *A. glutinosa*, 19.5% of *S. alba*, 7.9% of *T. cordata*, 6.3% of *A. platanoides*, 5.6 of *C. betulus*, 4.8% of *Q. robur*, and 2.9% of *F. excelsior* were occupied by *P. lugubris*.

The distribution of *P. lugubris* was random with respect to tree species identity (Tables 2 and 3). The number of occupied trees did not differ from the values expected from a random sample model. Further, we analysed the spatial distribution of *P. lugubris*. Of the 71 avenues sampled 66 had mixed stands with at least two tree species present

Table 1. Measurement of physical characteristics of trees.

Name	Description
Healthy state	The health state of trees according to Pacyniak (1992): 1 – trunk and crown healthy; 2 – hollows present, up to 25% of crown damaged (loss); 3 – 25–50% damaged (loss); 4 – 50–75% damaged (loss); 5 – above 75% damaged (loss) or a dead tree
Circumference	Trunk circumference at chest height with accuracy to the nearest 10 cm (cm)
Direction	The direction of the entrance – 8 compass directions: N, NE, E, SE, S, SW, W, NW (value with increased nearness to the most sun exposed compass direction: NE = 1, N or E = 2, NW or SE = 3, W or S = 4, SW = 5; according to Ranius and Jansson 2000)
Area of entrance	π* Height of the entrance * width of the entrance (m^2)
Road surface	Asphalted, dirt, brick paving, concrete slabs

Table 2. Frequency of tree species in the avenues studied and occupancy of hollow trees by *P. lugubris*.

Tree species	Number of trees examined	Number of trees with hollows	Number of trees with *P. lugubris*
Tilia cordata	2052 (52.19)	706 (70.46)	56 (75.7%)
Fraxinus excelsior	445 (11.32)	34 (3.39)	1 (1.4%)
Acer platanoides	410 (11.32)	143 (14.27)	9 (12.2%)
Quercus robur	369 (9.38)	21 (2.10)	1 (1.4%)
Betula pendula	105 (2.67)	6 (0.60)	0 (0%)
Carpinus betulus	78 (1.98)	36 (3.59)	2 (2.7%)
Salix alba	77 (1.96)	21 (2.10)	4 (5.4%)
Alnus glutinosa	56 (1.42)	4 (0.40)	1 (1.4%)
Aesculus hippocastanum	51 (1.30)	17 (1.70)	0 (0%)
Total	3932	1002	74

Table 3. Differences between observed and expected occupancies of trees. Expected occupancies were obtained by a random sampling of 74 trees (the actual number of trees *P. lugubris* was found in) out of the total of 1002 hollow trees.

Tree species	Number of hollow trees	Trees with *P. lugubris*	Expected number of occupied trees	SD of expected value	*Z*	*p*
Tilia cordata	706	56	52.17	3.74	1.03	0.24
Fraxinus excelsior	34	1	2.49	1.57	−0.95	0.25
Acer platanoides	143	9	10.76	2.92	−0.60	0.33
Quercus robur	21	1	1.48	1.22	−0.40	0.37
Betula pendula	6	0	< 1	–	–	–
Carpinus betulus	36	2	2.41	1.47	−0.28	0.38
Salix alba	21	4	1.56	1.27	1.93	0.06
Alnus glutinosa	4	1	< 1	–	–	–
Aesculus hippocastanum	17	0	1.28	1.15	−1.11	0.21
Total	1002	74				

Means and standard deviations of the expectation were estimated from 5000 replicates.

and all of the 29 road fragments in which the beetle was found had mixed stands. In six of these *P. lugubris* occurred in more than one tree species. We again compared this number with the expectation from a random sample (20 replicates) of 74 occurrences out of 1002 trees. This expectation was 5 ± 1 avenues. The number of 29 colonized road fragments also did not deviate from expectation (33 ± 6).

P. lugubris colonized only trees thicker than 200 cm circumference (Table 4, Figure 2) and preferred those above 300 cm circumference. We detected 116 trees below 200 cm circumference. Of the 436 trees between 200 and 300 cm circumference 20 were occupied (4.6%) and of the 450 trees above 300 cm 55 were occupied (12.2%). We found the greatest difference between the frequencies of occupied and unoccupied trees with suitable hollows for circumferences between 350 and 400 cm (Figure 2). Colonized trees were generally larger than potentially suitable trees (those with hollows) ($p(t) < 0.001$) (Figure 2, Table 4). Very large trees with a circumference over 600 cm seemed to be avoided but this effect was statistically not significant (Table 4).

Trees of health class 1 (by definition) lack hollows and were therefore not colonized by *P. lugubris*. Colonized trees had a slightly but significantly ($p(t) < 0.01$) worse health state (mean 2.9) than the potentially suitable (mean 2.4) (Table 3). Trees above health class 3 were more often colonized than expected from the random sample model (Table 5). However, *P. lugubris* did not show any significant preferences according to hollow entrance area (CHI^2 (observed–expected frequencies of *P. lugubris* in nine classes of entrance area) 7.37; $p = 0.44$) and exposition (CHI^2 (observed–expected frequencies of *P. lugubris* in eight directions) 5.39; $p = 0.61$). A logistic regression analysis with health state and exposition and log-transformed values of circumference and entrance area did not point to entrance area

Table 4. Differences in mean circumference and health between occupied and unoccupied trees.

Species	Variable	Unoccupied trees		Occupied trees		*T*
		Mean	SD	Mean	SD	
Acer platanoides	Circumference	223.8	57.5	312.2	46.8	−4.51***
	Health	2.4	0.7	3.0	1.1	−2.30*
Alnus glutinosa	Circumference	306.7	11.5	340.0	0.0	−2.50
	Health	2.3	0.6	2.0	0.0	0.50
Carpinus betulus	Circumference	201.8	37.5	260.0	14.1	−2.16*
	Health	2.2	0.5	3.0	0.0	−2.06*
Fraxinus excelsior	Circumference	259.4	50.2	250.0	0.0	0.18
	Health	2.3	0.5	2.0	0.0	0.64
Quercus robur	Circumference	335.8	109.0	450.0	0.0	−1.02
	Health	2.2	0.4	3.0	0.0	−1.84
Salix alba	Circumference	307.6	93.8	392.5	92.9	−1.63
	Health	3.0	0.9	4.0	0.8	−1.96
Tilia cordata	Circumference	305.2	85.5	338.8	71.7	−2.85**
	Health	2.4	0.8	2.8	1.0	−3.80**
All trees	Circumference	286.2	87.2	336.6	71.8	−4.85***
	Health	2.4	0.8	2.9	1.0	−5.16***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

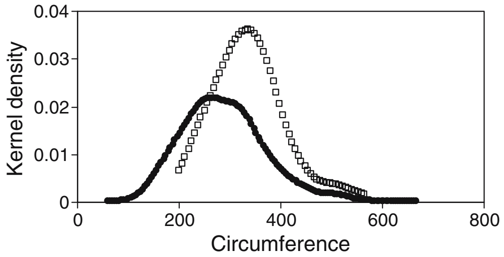

Figure 2. Colonization of trees (kernel density estimates) by *P. lugubris* dependent on tree circumference (cm). (White squares: trees with the beetle; black circles: unoccupied trees.)

and exposition as significant predicator variables (p(entrance area) = 0.49; p(exposition) = 0.65).

A comparison with occurrences from the random sample model showed that the marbled rose-chafer slightly preferred trees planted along dirt roads ($Z = 2.21$, $p = 0.03$) while it was less frequent in trees near asphalted roads ($Z = -2.23$, $p = 0.03$). The trees along the dirt roads were slightly thicker (mean 215 cm circumference) and therefore older than those along the asphalted roads (mean 207 cm). To test for this we used a general linear MANCOVA model (Table 6). The model again identified circumference and health status as being highly significant. Road surface appeared to be not significant.

Lastly, *P lugubris* preferred trees in the vicinity of forests. This can be seen in Figure 1, where the black dots (the occupied trees) are on average slightly nearer to the nearest forests than the white dots. Indeed, a *U*-test confirmed that occupied trees were on average nearer to the nearest forest margin than unoccupied trees ($p(U) = 0.03$).

Discussion

Previous studies reported *P. lugubris* to inhabit a series of deciduous trees: *Quercus, Fagus, Tilia, Acer, Ulmus, Aesculus, Fraxinus, Alnus, Malus, Populus* (Dajoz 2000; Nilsson et al. 2002). Exceptionally, the beetle even colonized compost heaps partly composed of wood (D. Telnovs, pers. comm.). However, contrary to common belief (Bussler and Schmidl 2000; Dajoz 2000; Schmidl 2003), we found no distinct host tree preferences of *P. lugubris*. At least in our study area the species seems to be a generalist, which is able to colonize different trees if appropriate wood moulds are present. Therefore, conservation schemes for *P. lugubris* have to consider a variety of possible host trees. An exclusive concentration on old oak stands, as suggested by some authors (Nilsson et al. 2002) seems to be unnecessary, or might even be risky while neglecting other suitable host trees. However, the results of Nilsson et al. (2002) imply that in other countries with different climatic

Table 5. Differences between observed and expected occupancies of trees according to tree health class. Computation of expectations as in Table 4.

Tree health class	Number of trees	Trees with *P. lugubris*	Expected number of occupied trees	SD of expected value	Z
1	1323	0	25.31	4.01	−6.31***
2	2057	33	38.82	4.26	−1.37
3	365	25	6.83	2.58	7.05***
4	72	6	1.47	1.25	3.63***
5	87	10	1.57	1.30	6.47***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 6. A MANCOVA model with the number of *Protaetia* as dependent and tree circumference (metrically scaled variable) and health status and road surface (categorized variables) as predicator variables.

Variable	Wald statistics	p
Constant	15.76	< 0.001
Circumference	10.50	< 0.01
Health status	19.68	< 0.001
Road surface	1.50	0.22

conditions the species might prefer certain tree species, for instance oak.

Many saproxylic beetles are associated with warmer stands (Ranius and Nilsson 1997; Ranius and Jansson 2000). We expected therefore that trees planted along asphalted roads should be preferred because the black surface warms up more. We did not find such a pattern even after controlling for tree health and circumference (Table 6). It seems that the temperature effect of the asphalt was too small to influence colonization patterns.

It is often assumed that big trees are best suited for the conservation of saproxylic insects (Grove 2002). Contrary to this assumption we found that *P. lugubris* prefers intermediate sized trees with a circumference of about 400 cm Figure 2). It might be that the cavities of very thick trees with circumferences above 600 cm are too wide to allow for a stable microclimate necessary for larval development.

The colonization of tree-lined country roads showed that *P. lugubris* is not closely connected with forest landscapes as reported by Bussler and Schmidl (2000) and Schmidl (2003). For *P. lugubris* being a generalist species, a diversity of host trees and environments can support its populations. The species might even survive in an agricultural landscape if only appropriate hollow trees are sufficiently abundant. These findings suggest that avenues with old trees might play a crucial role in the preservation of this and probably of many other saproxylic species. However, further studies need to investigate the occurrence of *P. lugubris* in different types of habitats. Without comparative inventories in semi-natural habitats and natural forests we are not able to judge whether the species can survive in anthropogenic habitats or whether such environments play only a role as refuges that do not allow for long-term survival.

At present *P. lugubris* seems to be a relatively rare species in country roads. In an earlier study (Oleksa et al. 2005) we found that the frequency of the more specialized hermit beetle *Osmoderma eremita* in the same set of trees was 11.4%, while the frequency of *Protaetia lugubris* was only 7.4%. This finding indicates that there are other factors than tree availability that limit the abundance of *P. lugubris*.

The marbled rose-chafer should be included in conservation schemes as an important element for the regional establishment of prime areas for conservation. Any such preservation strategy must take long-term processes of cavity creation and disappearance into account and needs series of tree generations that coexist to ensure the continuity of suitable habitats in space and time. The maximum generation gap must be less than the mean tree age when the first hollows appear. Thus, the management of *T. cordata* stands seems to be more promising than of oak stands because hollows in lime develop faster.

Avenues with trees that are old enough to harbour saproxylic organisms are quite frequent landscape elements in some parts of Poland, especially in East Prussia (Oleksa et al. 2005). However, such trees have so far not been investigated on a large scale. Thus, at least in some parts of Poland, *P. lugubris* might not be as rare as suggested by the available data (Burakowski et al. 1983). This should also hold for other European countries.

The presence of *P. lugubris* indicates habitat conditions necessary also for the development of other saproxylic arthropod species (Ranius 2002). The presence of *P. lugubris* might indicate a high diversity of threatened invertebrates associated with old trees (Ranius 2002). Thus, the preservation of the marbled rose-chafer might be of importance for the survival of other species too. Further studies are necessary to infer whether the beetle might serve as an indicator or even as an umbrella species (Lambeck 1997; Caro and O'Doherty 1999).

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