Baltic J. Coleopterol. 15(2) 2015
ISSN 1407 - 8619
Published: 15.12.2015

Dead wood modifies mobility of ground beetles

Jarosław Skłodowski, Jakub Szczeszek

Skłodowski J., Szczeszek J. 2015. Dead wood modifies mobility of ground beetles. *Baltic J. Coleopterol. 15(2): 91 - 98.*

During the period from the 1st to 31st July 2013, individuals representing large species of *Carabus hortensis* and *Carabus violaceus* were captured in 3 fenced plots with dead wood and 3 fenced control plots, marked and subsequently released (CMR method). The study revealed that the average time spent by large carabids in the plots with the dead wood was significantly longer than the time spent by them in the control plots. Furthermore, the catch rate of marked individuals representing the small species of *Pterostichus oblongopunctatus* was higher in the plots with dead wood than in the control plots. The study has proved in a quantifiable way that the presence of dead wood has a positive effect on the carabid fauna.

Key words: Carabid movement, CMR method, fenced area, dead wood

Jarosław Skłodowski, Deprtment of Forest Protection and Ecology, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776, Warsaw, Poland; e-mail: sklodowski@wl.sggw.pl

INTRODUCTION

The role of dead wood in shaping biodiversity of various groups of organisms is undeniable. Opinions stressing the effect of dead wood on forest species of the Carabidae can be found in published sources. There are authors who suggest either significant or not particularly significant importance of dead wood for the carabids (Fuller et al. 2008; Ulyshen & Hanula 2012), but it is not clear what is actually meant by such statements. It has also been suggested that dead wood does not significantly affect ground beetles (Klepzig et al. 2012). Furthermore, the authors of some studies report observations of carabids gathering in the autumn, sometimes in quite large numbers, in mouldering tree stumps for the purpose of hibernation (Burakowski 1973). What is more, it has been noted that some species of the Carabidae, e.g. *Carabus hortensis* (Gryuntal & Szyszko 2002), can climb trees, and therefore are able to penetrate tree hollows containing dead wood, which are situated several metres above the ground surface (Skłodowski 2003).

The studies that have been published so far, even though they state that dead wood is important for the carabids, do not attempt to analyse how it affects the parameters of carabid mobility. This may seem surprising, especially in light of the fact that carabid movement has been studied by deploying a number of diversified methods: isotope tracing (Baars 1979), camera in a laboratory (Mols 1979, 1987), catch-mark-recapture technique, i.e. CMR (Petit & Burel 1993; Joyce et al., 1999; Skłodowski 1994, 1999, 2008), portable radar (Charrier et al., 1996), harmonic radar (Wallin & Ekbom 1988; Lövei et al. 1997; Weber &

Heimbach 2001), and radio telemetry (Riecken & Raths 1996).

It was assumed that since dead wood effected the Carabidae, it must modify carabid patterns of movement, decreasing the speed of relocation and prolonging the stay of carabid individuals in the proximity of lying mouldering tree trunks. This assumption was tested by comparing the amounts of time spent by the carabids on specially fenced plots with dead wood and on control plots without dead wood. The following hypothesis was formulated: by modifying the movement patterns of carabids, the presence of dead wood affected the average time spent by the carabids in the fenced plots with the dead wood, which exceeded the average time spent by the carabids in the fenced plots without the dead wood.

STUDY AREA

The studies were conducted in a middle-aged mixed forest stand composed of pines (80%) and birches (20%). The tree stand volume was moderate; it was growing on brown arenosols. In administrative terms, the tree stand belonged to Ujście forest division situated in Biłgoraj forest district (east-central Poland). The area was characterised by the presence of tree stands where pines were the prevalent tree species.

METHODOLOGY

For the purposes of the study, 3 plots surrounding mouldering trunks of felled trees (DW) and 3 plots without such tree trunks (C) were fenced out. The selected plots were characterised by a comparatively even ground surface and the absence of living trees, since some carabid species might be climbing up the trunks. Lying tree trunks with bark peeling off, indicating that they had been lying on the ground for several years, were selected as the sources of dead wood.
Plots were fenced out with flexible plastic (linoleum) stuck 5 cm deep into the ground, with further 20 cm remaining above the ground and functioning as the fencing proper. Each of the fenced out plots was 4 x 6 m large. Inside and outside each plot, beside the fence, 5 live traps were set (60 such traps in total). The traps were constructed out of oval 0.5 l plastic containers with upper opening diameter of 12 cm. In order to protect the traps from inundation and the trapped beetles from drowning, several holes with 1.5 mm were made in each trap and each trap was covered with a roof.

The traps were checked every day for the whole month, from the 1st to 31st July 2013. Every instance of trap checking involved noting down the number of the trap where the beetle specimen was trapped and reading out the specimen's individual number, or – in the cases where it did not have such a number – marking it with one according to the calendar of captures (catch-mark-recapture method, CMR). The beetles were marked with a number by making delicate incisions in four different zones on the edge of the elytra, each of which represented a different number: 1, 3, 10 or 50 (Fig. 1). For instance, in order to mark a specimen with the number 88, the zones indicating "1" and "3" both had to be incised 2 times, the zone indicating "10" had to be incised 3 times, and the zone indicating "50" had to be incised just once. Such marking was possible only in the case of large carabid species. The sizes of smaller species, such as *Pterostichus oblongopunctatus*, were usually only 10 to 12 mm, and thus the specimens were not marked but just counted.

The carabids trapped in the traps located outside the plots were marked with the respective individual numbers and released inside the fenced plots. The carabids trapped in the traps located inside the plots had their individual numbers noted down and were released outside the plots. Deploying such a procedure made it possible to estimate the amount of time and average time spent inside the plot by every individual. The time spent by beetles in the fenced plots was counted in days and days were the time units used in calculations presented in the "Results" section. The results were analysed using Generalized Linear Model GLM, transforming data lognormally, with the aid of Statistica data mining software (StatSoft Inc. 2011).

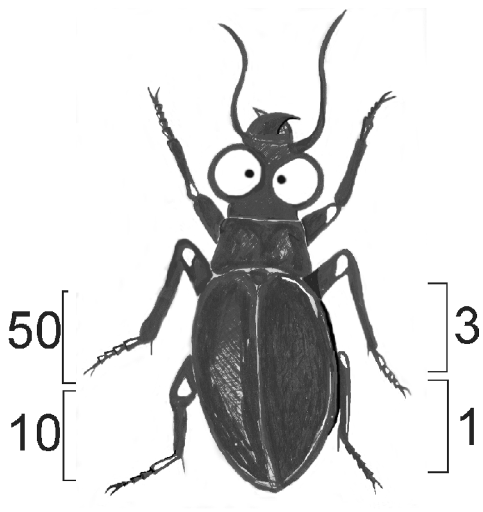

Fig. 1. The four zones on the ground beetle elytra where respective numbers were incised (drawing by J. Skłodowski)

RESULTS

The following species were marked with individual numbers: *Carabus violaceus* (36 individuals) and *Carabus hortensis* (17 individuals). In the first fenced plot with dead wood (DW1) 13 carabid individuals marked with an individual number were recaptured, including 8 recaptures of *C. violaceus* and 5 recaptures of *C. hortensis*; in the second plot (DW2) – 12 individuals, including 11 recaptures of *C. violaceus* and 5 recaptures of *C. hortensis*; and in the third plot (DW 3) – 11 individuals, including 7 recaptures of *C. violaceus* and 4 recaptures of *C. hortensis*. At the same time, in the control plots, fewer marked specimens were captured: in the first plot: (C1) – 9 individuals, including 7 recaptures of *C. violaceus* and 4 recaptures of *C. hortensis*; in the second plot (C2) – 6 individuals, including 4 recaptures of *C. violaceus* and 2 recaptures of *C. hortensis*; and in the third plot (C3) – 5 individuals, including 4 recaptures of *C. violaceus* and 1 recapture of *C. hortensis*.

The average time of beetle stay in the DW plots was significantly longer in comparison to the C plots (1.57 > 1.25; Fig 2; Table 1). Also, the average number of carabid individual recapture was significantly higher in the DW plots than in the C plots (13.3 > 6.67; Fig. 3; Table 1).

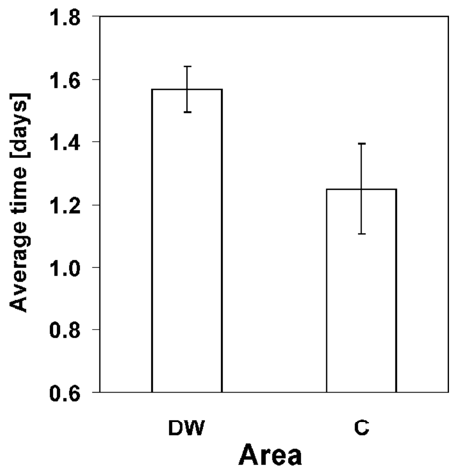

Fig. 2. The average amount of time spent by carabids inside the fenced plots with dead wood (DW) and inside the fenced control plots (C)

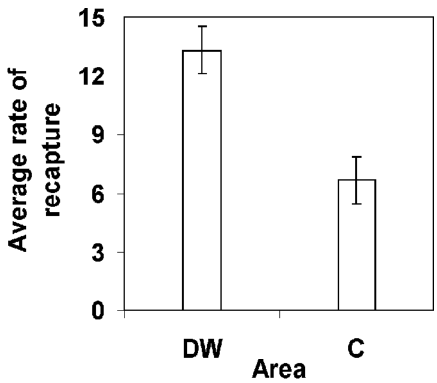

Fig. 3. The rate of marked individual recapture inside the fenced plots DW and C

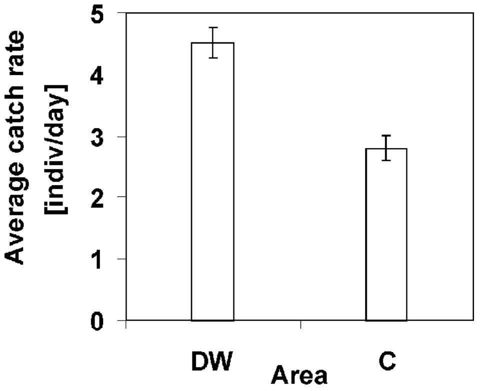

Fig. 4. The catch rate of unmarked individuals of *P. oblongopunctatus* inside fenced the DW and C plots

At the same time, the numbers of individuals representing a smaller species, i.e. *Pterostichus oblongopuctatus*, were counted in the DW and C plots. In the plots with dead wood the following numbers were captured: DW1 – 144 individuals; DW2 – 124 individuals; DW3 – 120 individuals; while in the control plots the numbers of captured individuals were the following: C1 – 92 individuals; C2 – 76 individuals; and C3 – 77 individuals. The catch rate of *P. oblongopunctatus* was higher inside the fenced DW plots than inside the fenced C plots (4.5 > 2.8; Fig. 4; Table 1).

Table 1. GLM analysis of the average time spent by carabids in plots DW and C (a); the rate of carabid recapture in the DW and C plots (b); the catch rate of *P. oblongopunctatus* in the DW and C plots (c)

Factor	df	Wald test	p
a			
Intercept	1	19.4144	<0.001
Average time	1	3.8306	0.05
b			
Intercept	1	743.5177	<0.001
Rate of recapture	1	17.7401	<0.001
c			
Intercept	1	721,9423	<0.001
Catch rate of *P. oblongopunctatus*	1	25,5298	<0.001

DISCUSSION

In the course of the study, only the carabids trapped in the traps outside or inside the fenced plots were collected (i.e. no individuals were collected from other locations beyond those areas), and probably that was why the collected individuals represented mostly the 2 large species: *C. violaceus* and *C. hortensis*. *Pterostichus niger*, usually common in tree stands of the studied type, was collected only incidentally and therefore was not taken into account. The large species of *C. violaceus* was much more abundant than the other one, *C. hortensis*, which might be associated with the moderate fertility of the forest habitat where the experiment was being conducted. Studies that had been conducted in Białowieża Forest revealed a less abundant presence of *C. violaceus* in fertile habitats and a more abundant presence of that species in less fertile habitats (Skłodowski 2006). In habitats characterised by a higher tree stand volume, the abundance of the other species, *C. hortensis*, was higher (Skłodowski 2006).

Another interesting study that had been conducted in Białowieża Forest provided insights into the interest of the two carabid species in various forms of dead wood, i.e. the dead wood that was either found in tree hollows or on the ground surface (Skłodowski 2002). According to that study, *C. hortensis* was a more abundant species. The ratio of individuals collected from tree hollows ad those collected from the dead wood on the ground surface was higher for *C. hortensis* than for *C. violaceus* (1 *vs.* 0.33). That might indicate that *C. hortensis* was more likely to penetrate less accessible locations with dead wood (i.e. tree hollows) than *C. violaceus*, especially considering the fact that some of the hollows were situated several metres above the ground level.

The fact that those carabid species were attracted to dead wood could be explained by the crepuscular activity of *C. violaceus* (Turin et al. 2006) and the nocturnal activity of *C. hortensis* (Szyszko et al. 2005; Turin et al. 2006), and perhaps also by *C. hortensis* avoiding the fallow land and preferring to stay within the tree stands (Skłodowski 1994). This might be one of the reasons why carabids had a tendency to hide in various nooks and crannies. Two forest species *C. hortensis* and *P. oblongopunctatus*, while being observed in a laboratory, hid in the logging slash residue, where they spent more time than in the uncovered observation area of the experiment site (Nittérus & Gunnarsson 2006; Nittérus et al. 2008). Similar behaviour was observed among forest carabid species in clear-cut areas where two metre high and over a dozen metre long piles of branches had been left (Sklodowski 2010). Even individuals representing *Carabus variolosus*, a species associated with water, tended to rest in woody debris (Drees et al. 2008). Seemingly, the presence of dead wood was as important for forest carabid species as a proper thickness of soil litter, which had been highlighted by Magura et al. (2001).

In the study, the catch rate of unmarked *P. olongopunctatus* individuals was higher by 40% in fenced plots with dead wood in comparison to control plots. Even though that species was reluctant to penetrate tree hollows as it did not climb trees very well, it was eager to explore dead wood lying on the ground, and was collected from the ground locations in numbers several times higher in comparison to those collected from the tree hollows (Skłodowski 2003).

In the present study, *C. violaceus* and *C. hortensis* stayed much longer in the fenced plots with dead wood than in the control plots without dead wood. The difference in the lengths of their stay in the two plots were due to the presence of the dead wood and could not be explained by micro-diversity of the soil litter or the soil itself in the particular plots. For instance, in the pine and birch tree stands, characterised by different soil litter composition, no significant differences in carabid movement parameters had been observed (Szyszko et al. 2004a). Therefore, the presence of the dead wood seemed to be the major factor determining why the carabid species stayed for a longer time in some fenced plots. The reason why they stayed longer in the proximity of the dead wood could be either resting or penetrating the dead wood in search of nutrition. Carabid individuals which were not hungry modified their pattern of movement, usually by decreasing speed of their movement (Mols 1979, 1987; Szyszko et al. 2004b). Thus, the time they spent near the dead wood might be prolonged. However, in the present study it was not taken into account whether the individual beetles were hungry or not.

Nevertheless, the conducted research allows for a positive verification of the study hypothesis and leads to a conclusion that during the vegetation season dead wood attracts the carabids, significantly prolonging the time spent by them in its proximity. Therefore, what has been, so far, a hypothetical statement in the studies devoted to ecology and biology of the Carabidae will have the status of an empirical fact from now on. Moreover, it provides one more reason justifying the need to leave dead wood in managed forests. It seems that by leaving the dead wood in the forest we provide an opportunity of survival for a higher number of large and moderately large carabid species which, being predators, regulate the detritus food chain.

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Received: 12.11.2015.
Accepted: 01.12.2015