Rosalia alpina adults (Linnaeus, 1758) (Insecta, Coleoptera) avoid direct sunlight

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Abstract
Rosalia alpina *adults (Linnaeus, 1758) (Insecta, Coleoptera) avoid direct sunlight.* Adults of the threatened beetle species *Rosalia alpina* are usually associated with sun–exposed dead wood. In previous fieldwork, however, we frequently found adult beetles on shaded surfaces of trees. We thus studied whether adults preferred different lightning conditions depending on their behavior on 447 beech trees located in four forests in two distant locations in Europe. From a total of 542 individuals, we observed that 54 % of them occurred in shaded conditions, and 35 % in predominantly shaded conditions. This avoidance of direct sunlight could be widespread in the species because it was independent of the location and behavior.

Key words: Beech forest, Behavior, Cerambycidae, Longhorn beetle

Resumen
Los adultos de Rosalia alpina *(Linnaeus, 1758) (Insecta, Coleoptera) evitan la exposición directa a la luz solar.* Por lo general, se considera que los adultos del escarabajo amenazado *Rosalia alpina* están asociados a la madera muerta expuesta al sol. Sin embargo, en algunos trabajos previos de los autores se observaron adultos en superficies sombreadas de árboles. Así, se comprobaron sus preferencias por distintas condiciones de iluminación dependiendo de su comportamiento en 447 hayas localizadas en cuatro bosques diferentes de dos localidades europeas lejanas. El 54 % y el 35 % de 542 individuos observados se encontraron en condiciones de sombra total y parcial, respectivamente. Esta evitación de la luz solar directa podría estar generalizada en la especie, ya que se mostró independiente de la localización y el comportamiento.

Palabras clave: Cerambycidae, Comportamiento, Hayedo, Longicornio

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Introduction

Sun–exposed, dead or partially dead trees are the preferred habitat of *Rosalia alpina* (Russo et al., 2011, 2015; Castro and Fernández, 2016), a threatened and legally protected species facing decline in Europe (Luce, 1996; Adamski et al., 2013; Bosso et al., 2013, 2018). *R. alpina* adults appear in summer and are diurnal. Their activity peaks in the afternoon, and they are mainly found on sun–exposed trees (Drag et al., 2011; Russo et al., 2011; Castro and Fernández, 2016). Thus, like many other saproxylic beetles (Lindhe et al., 2005, Vodka et al., 2009), *R. alpina* is considered to be a sun–loving species. The fact that an organism inhabits trees in sunny places, however, does not necessarily mean that its activity is concentrated on surfaces receiving direct sunlight (Kreuger and Potter, 2001; Bancroft and Smith, 2005). We analyzed the frequencies of observations of *R. alpina* adults on trees in relation to exposure to sun or shade. To our knowledge, this issue has not been previously studied in *R. alpina*.

Material and methods

The research took place at three sites in the Czech Republic (Maly Bezdez, Velky Bezdez and Slatinne Hills) and one site in Spain (Artaso; table 1). Maly Bezdez and Velky Bezdez are hills that are mainly covered by semi–open beech forests with rather small and crooked trees, while the beech forest in Slatinne Hills consists mainly of tall trees. The Spanish location, Artaso, is a closed forest with abandoned pollard beech and sporadic clearings mainly on the northern slope. A detailed description of the study sites and observations methods can be found in Drag et al. (2011) and Castro and Fernández (2016).

Observations were conducted between July 12th to August 10th of 2008 (10–19 visits per tree) at all three sites in the Czech Republic, and also from July 5th and August 16th of 2009 (39) in Slatinne Hills, and from July 1st to August 31st of 2010 (8) in Artaso. Over this three–year period, 157, 155 and 135 trees each year, respectively, were visually inspected for living adults. Observations were always made in suitable weather (sunny days), between 10:00 and 18:00 h in the Czech Republic, and between 11:00 and 18:00 h in Spain. Two variables were recorded for all observed beetles, exposure to sunlight and behavior. Exposure to sunlight consisted of three categories: sun, dim light, and shade. Sun and shade categories meant the individuals were in totally in sunlight or totally in the shade. Dimly light meant the individuals were in partial shade. Behavior categories were defined as resting, reproduction and movement. Rest referred to not–moving individuals; reproduction included mating, males fighting for females, and females ovipositing or looking for oviposition sites; and movement referred to individuals walking, exploring, landing on trees, and territorial fights between males.

For each study site, we tested the relative frequencies of the different categories against the null hypothesis assuming all categories to be equal by performing χ^2–tests, goodness of fit (Zar, 2010). Whenever these tests yielded significant results at the $P < 0.05$ threshold, pairwise χ^2 comparisons were carried out. In the first step, we analyzed whether the frequencies of individuals were affected by the degree of exposure to sunlight. In the second step, we tested whether individuals selected different exposures to sunlight according to their behaviors. Due to the low sample size in Artaso, pairwise comparisons were performed applying the Yates correction for continuity (Zar, 2010), and no statistical analysis was carried out to explore interactions between sunlight exposure and behavior. Statistical analyses were performed using the PAST program (Hammer et al., 2001) version 3.06 (http://folk.uio.no/ohammer/past/).

Results

We observed a total of 542 *R. alpina* adults. Regardless of the location, frequencies of individuals were

Table 1. Location of the study sites.

Tabla 1. Localización de las zonas de estudio.

Site	Year	Place	Country	Altitude (m a.s.l.)	Area (ha)	North	East
Maly Bezdez,	2008	Ralska Upland,	Czech	400–577	17.9	50.540	14.713
Velky Bezdez,		Northern Bohemia	Republic	400–604	20.3	50.539	14.720
Slatinne Hills				350–430	12.1	50.553	14.707
Slatinne Hills	2009	Ralska Upland, Northern Bohemia	Czech Republic	350–430	12.1	50.553	14.707
Artaso	2010	Oñati, Basque Country	Spain	690–940	33.4	42.975	–2.406

higher in locations with less exposure to sunlight (table 2). This higher abundance in more shaded sites was also independent of the behavior shown by individuals (fig. 1). For any combination of location and behavior, the percentage of individuals exposed to direct sunlight never exceeded 19 % (fig. 1). Hence, 89 % of individuals avoided any activity on sun–exposed surfaces.

Discussion

The avoidance of tree surfaces exposed to sunlight by *R. alpina* adults was consistent in sites as far apart as southwest Europe and central Europe, and in three different habitat types, suggesting that this behavior is characteristic of the species. The causes of this behavioral pattern could be understood by evaluating several hypotheses. For example, avoidance of surfaces exposed to sunlight could be related to body thermoregulation, camouflage against predators, or a trade–off between the two. The grayish blue coloration of the body and the dark dorsal spots in the elytra and antenna seem to camouflage with the surface of trunks and branches of trees where the species lives (Luce, 1996). There is also evidence that the dark spots on the elytra and antenna can perform a thermoregulatory function to quickly absorb and retain heat (Kostić et al., 2016). *R. alpina* adults are relatively active and rarely feed (Drag et al., 2011). However, activity involves energy costs and greater

Table 2. Results of testing the equality of frequencies from the different categories of sunlight exposure.

Tabla 2. Resultados de las pruebas de igualdad de frecuencias de las diferentes categorías de exposición a la luz solar.

Categories tested	d.f.	χ^2	*P*
Bezdez (n = 356)			
All	2	88.342	< 0.001
Sun vs. dim light	1	58.449	< 0.001
Sun vs. shade	1	90.741	< 0.001
Dim light vs. shade	1	4.541	0.033
Slatinne Hills (n = 152)			
All	2	56.235	< 0.001
Sun vs. dim light	1	7.053	0.008
Sun vs. shade	1	48.485	< 0.001
Dim light vs. shade	1	20.961	< 0.001
Artaso (n = 34)			
All	2	24.060	< 0.001
Sun vs. dim light	1	4.9	0.027
Sun vs. shade	1	19.36	< 0.001
Dim light vs. shade	1	7.84	0.005

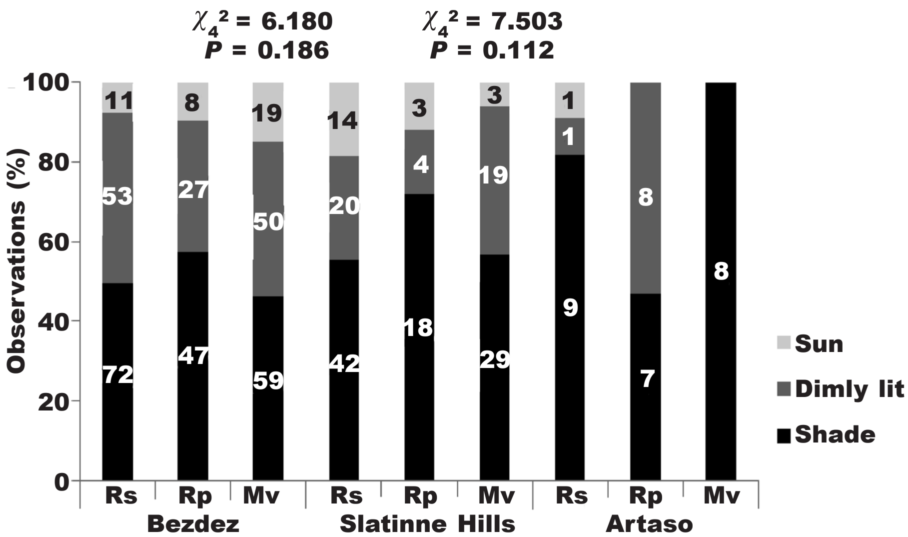

Fig. 1. Numbers of individuals (inside bars) and their frequencies expressed as percentages observed per behavior and exposure to sunlight categories: Rs, resting; Rp, reproduction; Mv, movement. (The χ^2–test for Artaso was not performed due to statistical constraints, see text).

Fig. 1. Número de individuos (interior de las barras) y sus frecuencias expresadas como porcentajes observados por comportamiento y categoría de exposición a la luz solar: Rs, descansando; Rp, reproduciendo; Mv, en movimiento. (No se realizaron las pruebas χ^2 para Artaso debido a restricciones en los requerimientos estadísticos, véase el texto).

risk of predation, primarily by good visual hunters such as birds, which are known to feed on *R. alpina* (Adamski et al., 2013). Activity in the shade may lessen the chances of predators detecting this prey (Carrascal et al., 2001; Carr and Lima, 2014) and meet *R. alpina* energetic demands by being active on the shaded surfaces (after short exposures to the sun) of tree trunks and branches during the hottest times of the day and year. Additionally, it is possible that females oviposit in the shaded areas to avoid exposing eggs to lethal temperatures (Keena, 2006).

As the trees in our study were randomly chosen, the sun–exposed and shaded parts were probably not balanced, but we do not consider that such selection would fully explain the pattern we observed. Accordingly, in the Artaso pollard forest we observed only one out of 21 adults in sunny places in trees that provided larger surfaces exposed to sunlight ('big clearings', see Castro and Fernández, 2016).

Although the individuals of *R. alpina* are more likely to be found more active on the shaded portions of the tree, it is highly probable that the sun–exposed habitats can still be preferred (Drag et al., 2011; Russo et al., 2011). Open habitats always offer some shaded parts of the wood, but in addition to that they may provide other benefits for the beetle.

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