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Size and quality of wood used by *Rosalia alpina* (Linnaeus, 1758) (Coleoptera: Cerambycidae) in beech woodlands of Gipuzkoa (northern Spain)

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Abstract

The conservation of the legally protected saproxylophagous species *Rosalia alpina* (Linnaeus, 1758) in European beech woodlands and forests involves the proper management of dead, dying and decaying trees. However, the characteristics of preferred trees (their size and wood quality) are still poorly known. In this paper we analyze data obtained from six year surveys on the distribution of *R. alpina* in four Sites of Community Interest of the province of Gipuzkoa (northern Spain). Living individuals of *R. alpina* and their emergence holes were recorded in European beeches exclusively. 72 living individuals and 520 holes were recorded in 77 trees. Evidences of occupation (presence of living individuals or holes or both) were more frequent on trunks Ø > 25 cm of standing beeches (either dead or still alive) than on branches, logs and thinner trees. However, the number of holes did not show differences among classes of main trunk size and wood quality. The thickest branches (Ø > 15 cm) registered higher rates of presence and number of holes than thinner ones. We suggest that conservation strategies for *R. alpina* should include a map of habitat availability based on tree preference.

• Key words: *Rosalia alpina*, European beech, *Fagus sylvatica*, host material selection, Gipuzkoa.

Resumen

La conservación de la especie saproxilófaga legalmente protegida *Rosalia alpina* (Linnaeus, 1758) en los hayedos de Europa conlleva una gestión adecuada de los árboles muertos y moribundos. Sin embargo, los parámetros de los árboles preferidos (tamaño y calidad de la madera) permanecen aún poco conocidos. En esta contribución se analizan los datos de distribución procedentes de seis años de trabajo en cuatro Lugares de Interés Comunitario de la

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provincia de Gipuzkoa (norte de España). Los individuos vivos de *R. alpina* y sus orificios de emergencia fueron registrados exclusivamente en hayas. 72 individuos vivos y 520 orificios fueron registrados en 77 árboles. Las evidencias de ocupación (presencia de individuos vivos o de orificios o de ambos) fueron más frecuentes en troncos Ø > 25 cm de hayas en pie (tanto aún vivas como muertas) que en ramas y árboles caídos y más delgados. Sin embargo, el número de orificios no mostró diferencias entre las clases de tamaño y la calidad de la madera de los troncos principales. Las ramas más gruesas (Ø > 15 cm) registraron mayores tasas de presencia y número de orificios que las más finas. Conociendo los tipos de árboles más seleccionados, se sugiere la elaboración de un mapa regional de disponibilidad de hábitat como herramienta práctica para planificar estrategias de conservación.

• PALABRAS CLAVE: *Rosalia alpina*, haya, *Fagus sylvatica*, selección del sustrato hospedador, Gipuzkoa.

LABURPENA

Europako pagadietan *Rosalia alpina* (Linnaeus, 1758) espezie saproxilofago babestuaren kontserbazioak hildako zuhaitzen, hilzorian daudenen eta deskonposizioan daudenen kudeaketa egokiaren beharra dakar. Dena den, espezieak nahiago dituen zuhaitzen ezaugarriak (egurraren tamaina eta kalitatea) ezezagunak dira. Ekarpen honetan Gipuzkoan (Espainia iparraldea) lau Garrantzi Komunitarioko Lekutan sei urtetan zehar jasotako banaketa datuak aztertzen dira. *R. alpina* ale biziak eta euren irteera zuloak pagoetan bakarrik aurkitu ziren. 77 zuhaitzetann 72 ale bizi eta 520 zulo aurkitu ziren. Espeziea bertan egon zenaren aztarnak (ale biziak aurkitzea, zuloak aurkitzea edo biak batera) maizago aurkitu ziren Ø > 25 cm zuten eta zutik zeuden pagoetan (oraindik bizirik edo hilik zeudenetan) adarretan eta erorita zeuden zuhaitz meharragoetan baino. Hala ere, egurraren kalitate eta tamaina klase desberdinen artean ez zen zulo kopuruan desberdintasunik ageri. Adar mardulenek (Ø > 15 cm) argalagoek baino agerpen-tasa eta zulo kopuru handiagoa zeukaten. Espezieak gehien aukeratzen dituen zuhaitza motak ezagututa, kontserbazio-estrategiak planifikatzeko tresna moduan habitat-baliabideei buruzko eskualdeko mapa bat sortzea proposatzen da.

• GAKO HITZAK: *Rosalia alpina*, pagoa, *Fagus sylvatica*, substratu ostalariaren hautaketa, Gipuzkoa.

INTRODUCTION

The longhorn beetle *Rosalia alpina* (Linnaeus, 1758) is legally protected by the European Habitats Directive (COUNCIL OF THE EUROPEAN COMMUNITIES, 1992) in which it is listed as a priority species because of the historical decline of its habitat and its potential role as a flagship species (LUCE, 1996; GALANTE & VERDÚ, 2000). This legal status implies that measures must be taken to conserve, enhance and restore the habitat of this beetle. However, despite of being a noticeable species, detailed studies of the habitat of *R. alpina* have only started recently (DUELLI & WERMELINGER, 2005; RUSSO *et al.*, 2010; DRAG *et al.*, 2011). According to the current knowledge, *R. alpina* is a xylophagous species that colonizes sun-exposed dead wood of both, dead and living trees (LUCE, 1996; DUELLI & WERMELINGER, 2005; RUSSO *et al.*, 2010), usually beeches (*Fagus sylvatica* L.), although other tree species may be important regionally (CIZEK *et al.*, 2009; MICHALCEWICZ *et al.*, 2011; MICHALCEWICZ & CIACH, 2012). It also has been found that *R. alpina* prefers trees with thicker barks, and not surrounded by tall undergrowth (RUSSO *et al.*, 2010). Besides, the rate of beech colonization depends on the historical land use and the derived current landscape (RUSSO *et al.*, 2010). This means that the specific conditions of the habitat structure and management of each forested region may determine the way in which *R. alpina* selects the trees to colonize. Hence, research on habitat selection at the regional scale is necessary to adapt the management of the forest to preserve *R. alpina.*

Still little is known about the diameters of trunks and branches, and condition and parts of the tree preferred by *R. alpina.* Experimental studies in Switzerland with trunks set vertically showed *R. alpina* to prefer and develop more successfully in trunks larger than 25 cm in diameter (DUELLI & WERMELINGER, 2005). However, studies carried out in Italy in three types of beech forest found no differences in trunk diameters between colonized and uncolonized trees (RUSSO *et al.*, 2010), although it must be noted that sampled trees were much wider (average Ø ≈100 cm). These works suggest that there is a diameter threshold beyond which *R. alpina* does not respond to trunk size. However, the different nature of both studies lets this hypothesis to be checked, revealing the need of further research. Regarding the influence of tree condition, DUELLI & WERMELINGER (2005) showed *R. alpina* to prefer standing over fallen dead wood, although this conclusion is based on artificial simulations of snags and logs, and no difference has been detected in preference for real trees (RUSSO *et al.*, 2010). The present contribution is the first to analyze numerically the influence of the different parts (branches/trunks) on the colonization by *R. alpina.*

Here we show a compilation of the information gathered during six years of research on the distribution of *R. alpina* on Red Natura 2000 spaces of Gipuzkoa, which includes data of trunk and branch diameters, tree condition, and location. The main aim of this study is to contribute to the knowledge of the effect of these variables on the abundance (number of emergence holes) and frequency of observations of *R. alpina* (holes and living individuals). Additionally, new data on the distribution of *R. alpina* in the province of Gipuzkoa are reported. Complementary data relative to the diametrical branch growth is also analyzed as it could affect the management of the species in the frame of experimental repollarding that is currently carried out in the study area (LIFE+ "Biodiversity and Pollards" project: https://www.lifetrasmochos.net/network/_).

Methods

Study area

The work was carried out in beech forests and woodlands of four Sites of Community Interest (SCI) of the province of Gipuzkoa (Fig. 1), all of them located in the Atlantic Biogeographic Region (Canales *et al.*, 2003): Pagoeta (1336 Ha), Ernio-Gatzume (2158 Ha), Aralar (10962 Ha), and Aizkorri-Aratz (14947 Ha). The altitude of sampled places ranged between 250-1200 m. According to the bioclimatic classification proposed by Rivas-Martínez (2007), the study sites show a temperate climate between mesotemperate and supratemperate thermotypes, and humid and hyperhumid ombrotypes (Loidi *et al.*, 2009). The potential vegetation of most of the study area corresponds to beech forests (Loidi *et al.*, 2009). The research focused on beech woodlands because *R. alpina* has not been found associated to another tree species in Gipuzkoa (Bahillo De La Puebla & Iturrondobeitia, 1996; Ugarte San Vicente *et al.*, 2002; Martínez De Murguía *et al.*, 2007).

The study area included a variety of habitats, from sparse woodland pastures, to groves, forest patches in regeneration or maturing processes, mixed forests, exploited and unexploited plantations, and lapsed pollards. All these areas containing beech trees make up an heterogeneous landscape in which limits among types of wooded lands are, in most cases, very difficult to determine. Beech forests have been shaped in this way due to their uninterrupted use for centuries as source of firewood and charcoal (currently abandoned) and wood for furniture and building industries, as well as pasture woodlands (Lizaur & Morante, 1996; Aragón, 2003; Loidi *et al.*, 2009). On the other hand, in the last two decades part of the forest has been in regeneration and maturing processes because of the cessation of some types of exploitation and the declaration of the SCI for conservation purposes (Loidi *et al.*, 2009; Aragón, 2010). Currently almost all remaining old beech trees in the study area are pollards. Several lapsed pollards have been lost because uncut crowns grow large and eventually collapse. For this reason, in the framework of a LIFE project during 2010-2011 some experimental repollarding treatments were carried out by public managers in order to extend the standing life of pollards. The branches cut in five experimental plots (Table 1) were analyzed to measure their rate of diametrical growth.

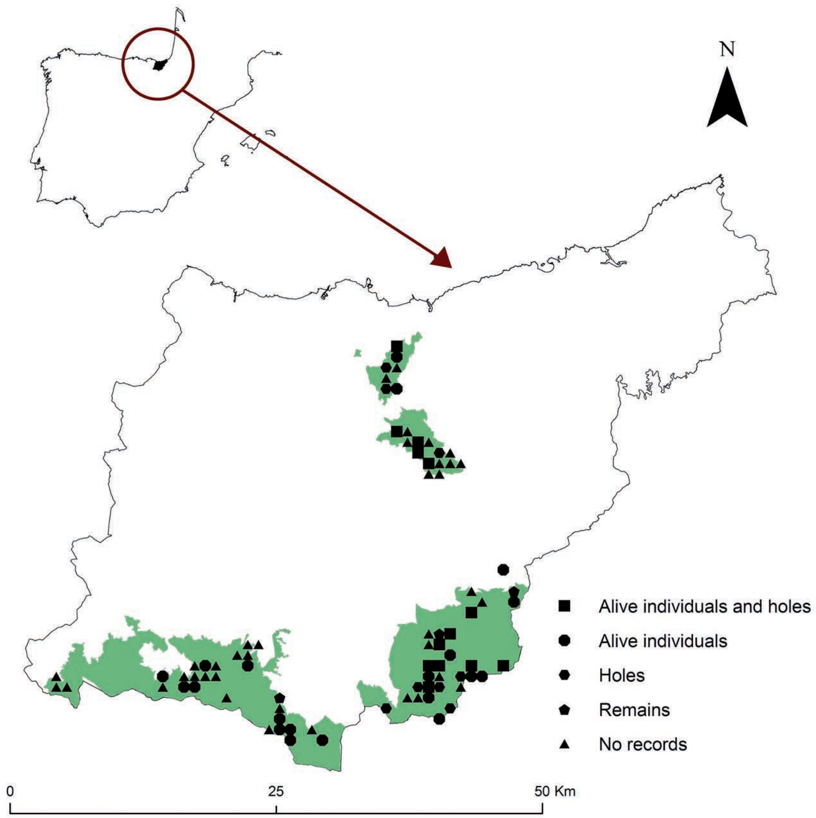

Fig. 1.- Location of the study area in the Iberian Peninsula (up-left corner) and in the four SCI sampled in the province of Gipuzkoa (down) where all the explored 1 x 1 km UTM squares and types of records of *Rosalia alpina* found in every one are showed.

Fig 1.- Localización en el área de estudio en la Península Ibérica (arriba a la izquierda) y en los cuatro Lugares de Importancia Comunitaria muestreados en la provincia de Gipuzkoa (abajo) donde se muestran todas las cuadrículas UTM 1 X 1 km prospectadas así como la naturaleza de las citas obtenidas.

Sampling of *Rosalia alpina*

R. alpina was sampled for six years during its peak activity period (July and August, Martínez De Murguía *et al.*, 2007). The whole sampling effort was spread over 151 days, and included beeches located in 81 1x1km UTM grids (Table 2). Each year several routes that passed through accessible potential habitat (woodlands and forests with old or dead trees) were established (Martínez De Murguía *et al.*, 2007). All sun-exposed dying and dead beeches (snags and logs) detected in these potential habitats were surveyed for *R. alpina.* Alive adults were searched in all sampling campaigns. Emergence holes were counted all years except in 2004. Holes were detected as far as the eye

Plot (SCI)	Municipality	Coordinates (ED50)		Altitude (m)	Aspect	Dates of experimental cuts
		X	Y			
Artaso 1 (Aizkorri-Aratz)	Oñati	548050	4757250	871	NW	11.2010-1.2011
Artaso 2 (Aizkorri-Aratz)	Oñati	548050	4757750	802	NE	11.2010-1.2011
Artaso 3 (Aizkorri-Aratz)	Oñati	548050	4758050	759	Several	11.2010-1.2011
Basogain (Ernio-Gatzume)	Bidegoian	569650	4779350	929	SW	11.2010
Guardetxe (Pagoeta)	Aia	567750	4789050	276	NW	12.2010-1.2011

Table 1.- Location of the five 1 Ha-square plots where experimental repollarding cuts and estimations of diametrical growths were carried out. Coordinates and altitudes indicate the central point of the corresponding plot.

Tabla 1.- Localización de las cinco parcelas de muestreo (1 Ha cada una) donde se llevaron a cabo las podas de retrasmocheo y las estimaciones de los crecimientos diametrales. Las coordenadas y altitudes corresponden al punto central de cada parcela.

could see and identified by their oval shape, size (6-11 mm long x 4-8 mm wide) and parallel position respecting to the longitudinal axis of the trunk or branch, as described by MICHALCEWICZ & BODZIARCZYK (2001) and DUELLI & WERMELINGER (2005). All these holes were assumed to correspond to *R. alpina* because the only two species of similar body size and shape, *Hesperophanes* sp. and *Melanoleptura scutellata* (Fabricius, 1781), are rare in our region (BAHILLO LA PUEBLA & ITURRONDOBEITIA, 1996). *M. scutellata* was recorded only in the SCI of Aizkorri-Aratz, where emergence holes were not counted, and only one larva of *Hesperophanes* was found in Errenaga, Aralar. Extraction of larvae from fallen branches took place on 18 August and 2 and 24 September of 2005 (Appendix 1), by mean of chainsaws and picks. The position and location of larvae inside the wood were registered to obtain complementary data about the biology of the species. Larvae were collected, preserved in ethanol (70%), identified in the lab, and stored in the entomological collections of FRANCISCO MOLINO and the Society of Sciences Aranzadi.

The diameter and condition of the tree and location of *R. alpina* observations (main trunk/branch) were recorded. Trunk diameters were taken at breast height (1.3 m above ground level) or at the closest regular section when the trunk was gnarled at breast level. Branch diameters were measured at the level of the observed emergence holes or beetles. In the case of presence of two or more individuals and/or holes on one branch, the diameters for every level of

Site of Community Interest	Year	1x1 km grids X_{05}-Y_{47} (UTM ED50)	Sampling dates					
			04	05	06	07	08	09
Aizkorri-Aratz	2004	35-57, 35-58,	-	-	24,25	2,5	2,11	1,3
		36-57, 45-57,			30	9,12	13,16	
		45-58, 47-53				13,14	18,20	
		47-57, 47-58,				15,16	25,27	
		48-57, 48-58,				22,23	30	
		48-59, 49-58				27,30		
		49-59, 50-58,						
		50-59, 51-56,						
		52-60, 53-59						
		53-60, 53-61,						
		54-61, 55-53,						
		56-53, 56-54						
		56-55, 56-56,						
		57-52, 57-53,						
		59-53, 60-52						
Aralar	2003	68-56, 70-57	16	1,8	7,14	4,7	3,4	22
		70-59, 74-58		15,16	15,22	11,14	13,18	
		75-58, 75-65		23,30	29,30	16,22	28	
		78-65		31		29		
	2005	66-55, 68-56				5,7	3,4,5	2,24
		69-56, 69-57				11,12	8,9	
		70-57, 70-58				13,14	10,12	
		70-59, 71-61				15,19	15,16	
		72-55, 72-60				20,21	17,18	
		72-62, 73-57				26,28	22,24	
		73-58, 74-59					25,29	
		74-64, 75-58					30,31	
		77-59, 77-68						
		78-65, 78-66						

Table 2.- Sampling locations and dates.
Tabla 2.- Lugares y fechas de muestreo.

Site of Community Interest	Year	1x1 km grids X_{05}-Y_{47} (UTM ED50)	Sampling dates					
			04	05	06	07	08	09
Aralar	2006	68-56, 69-56				3,7	1,2,3	2,16
		69-57, 70-56				10,14	4,6,7	
		70-57, 70-58				17,19	9,10	
		70-59, 70-61				24,27	11,14	
		70-62 71-54					16,17	
		71-61, 71-62					18,21	
		72-60, 72-62					23,25	
		73-57, 74-59					30,31	
		74-66, 78-65						
		78-66						
	2011	69-57, 70-57				All	All	
		770-58 70-59				even	odd	
		771-57, 71-58				dates	dates	
		71-59						
Ernio - Gatzume	2010	67-81, 68-80				7,20	6,17	
		68-81 69-79					19	
		69-80, 70-77						
		70-78, 70-80						
		71-77 71-78						
		71-79, 72-78						
		72-79, 73-78						
Pagoeta-	2010	66-85, 66-86				15,30	11	
		67-85, 66-87						
		67-87, 67-88						
		67-89						

Table 2.- Sampling locations and dates (continue).

Tabla 2.- Lugares y fechas de muestreo (continuación).

observation were averaged. The measurements were done with the help of a diametrical tape. Adults and their remains found out of trees were also recorded because they provided new chorological information.

Estimation of the rate of diametrical growth of branches

To estimate the growth rate of branches their diameters and number of rings (as indicator of branch age) were registered in the plots where experimental repollardings were carried out (Table 1). Cuts of the sampled branches were made around one meter above the tree bole. 202 branches from piles of cut wood made with the intention to provide habitat for saproxylic species were analyzed. Branch ring countings and diameters were taken from the widest end of the two or three widest branches of each pile. The diameter was obtained averaging the largest and smallest diameters of the cutting surface.

Data treatment

The analysis of tree and trunk/branch selection was carried out following two different approaches, one based on the frequency of presence of the species (revealed by the occurrence of living individuals and/or emergence holes) and the other on the average number of emergence holes.

In the former case, the relative frequencies of the different categories of each independent variable were tested against the null hypothesis of all expected to be equal by performing Chi-square (χ^2) tests (Zar, 2010). In this way, trunk and branch diameters were divided in six and four categories defined by 25 and 15 cm intervals, respectively. All trunks bigger than 124 cm, and branches surpassing 44 cm were pooled in the last diameter category because of their scarcity in the study area. Location on the tree included three categories: presence of *R. alpina* observed only on trunks, only on branches and on both. Three categories were also distinguished for tree condition: living tree snag, and log (entire fallen tree or broken with stumps below 1.3 m high).

In the latter case, the average number of emergence holes was compared among categories for each independent variable testing the null hypothesis of equality. The requirements of occurrence of several replicates per each factor level to allow statistical analysis dictated the number of categories defined per independent variable. According to this, three categories were analyzed for trunk diameter (<50 cm, ≥50 to <100 cm, and ≥100 cm) and tree condition (living tree snag, and log), and two for branch diameter (<25 cm, and ≥25 cm) and location on the tree (trunks, and branches). As data from trunk diameter did not meet with the assumptions of normality and equality of variances (even log-transformed), the non-parametric Kruskal Wallis was performed (Zar, 2010). The Student's *T* test was used for the statistical analysis of branch diameter (data log-transformed). The non-parametric Mann-Whitney test was used to analyze location on the tree data.

The records of adults observed in habitats other than trees were excluded from above analyses. However, they were included in *R. alpina* distribution mapping.

To estimate the diametrical growth rate of branches each ring was assumed to correspond to one year. The rate of growth per branch was obtained by dividing the branch diameter by the number of rings. Growth rates were averaged per experimental plots and age class (intervals of 10 rings each) to check for changes due to geographic and branch age differences.

Statistical analysis were carried out using SPSS 12.0. The significance threshold was established at $P < 0.05$. Means are presented with their standard errors.

Results

Overall results and distributional data

All the recorded observations of *R. alpina* sum up a total of 61 adults, 11 larvae, and 520 emergence holes (Appendices 1 and 2). Only 9 adults were recorded in locations other than trees. *R. alpina* was detected in 44 (54.3%) 1 x 1km squares (Fig. 1). In 8 squares adults and their emergence holes, in 20 adults, in 13 emergence holes, and in 3 only remains were recorded.

Diameters of occupied trunks and branches

Emergence holes or living individuals of *R. alpina* were registered in 58 trunks and 28 branches (Appendices 1 and 2). Diameters of trunks and branches ranged between 20-144 cm (average = 78.5 ± 4.6) and 9-124 cm (35.0 ± 5.1), respectively.

The density of emergence holes was higher in wider branches, but not in wider trunks (Fig. 2). However, the analysis of presences of emergence holes or living individuals showed that the frequency of trunks and branches with *R. alpina* was concentrated in 25-100 cm and 15-45 cm diameter classes for trunks and branches, respectively. The relative frequencies of trunks and branches below these sizes showed the largest deviations from the expected results (Fig. 3). In any case, 79.3% of the trunks and 89.3% of the branches with signs of the presence of the species were above 50 cm and 15 cm in diameter, respectively. Additionally, *R. alpina* was registered only once on a trunk and a branch smaller than 25 cm and 10 cm, respectively.

Location of records of *R. alpina* on the tree

Emergence holes or living individuals of *R. alpina* were observed in 77 trees. In most trees (71.4%) the presence of the species was recorded only from tree trunks, while observations made only on branches or on both trunks

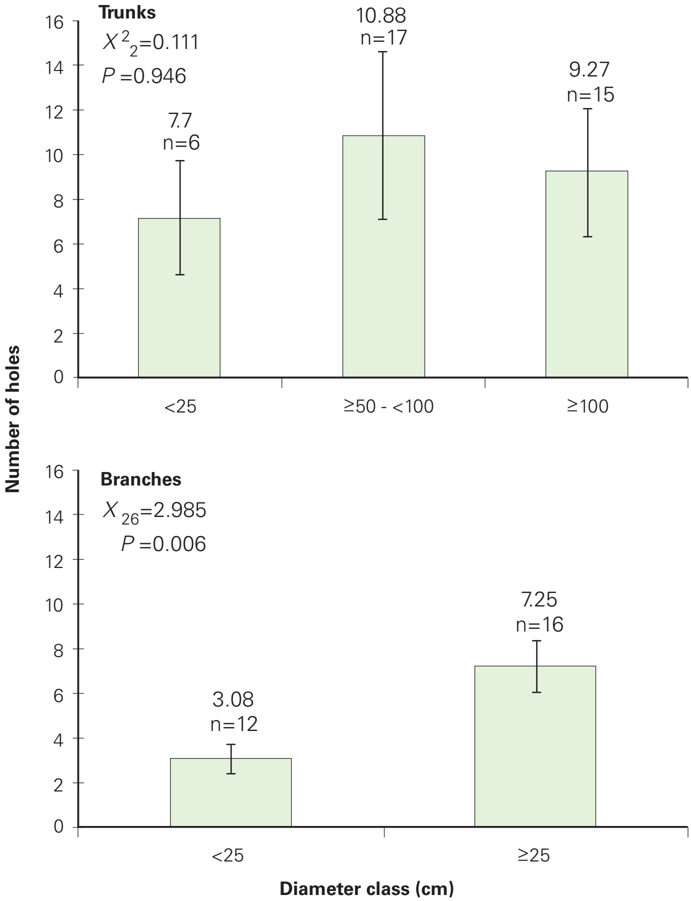

Fig. 2.- Average number of holes per trunk (up) and branch (down) registered per each diameter class in trees where the presence of *R. alpina* was observed. Presented statistics correspond to the Kruskal Wallis's χ^2 (trunks) and Student's T (branches. Log-transformed data) tests.

Fig 2.- Promedio del número de orificios por tronco (arriba) y rama (abajo) registrados por clase de diámetro en árboles con presencia observada de *R. alpina*. Los estadísticos presentados corresponden a la χ^2 de Kruskal Wallis (troncos) y a la T de Student (ramas. Datos transformados logarítmicamente).

and branches accounted for 26.0% and 2.6%, respectively (χ^2_2 = 56.597, P < 0.001. See also Table 3). Although the density of holes per trunk (9.7 ± 2.0) showed an average of 1.8x higher than per branch (5.5 ± 0.8), these differences were not statistically significant (Mann Whitney's U = 498, P = 0.658). Larvae lived in the sapwood (70%, n = 7) and 80% of them faced parallel to the longitudinal axis (Table 4).

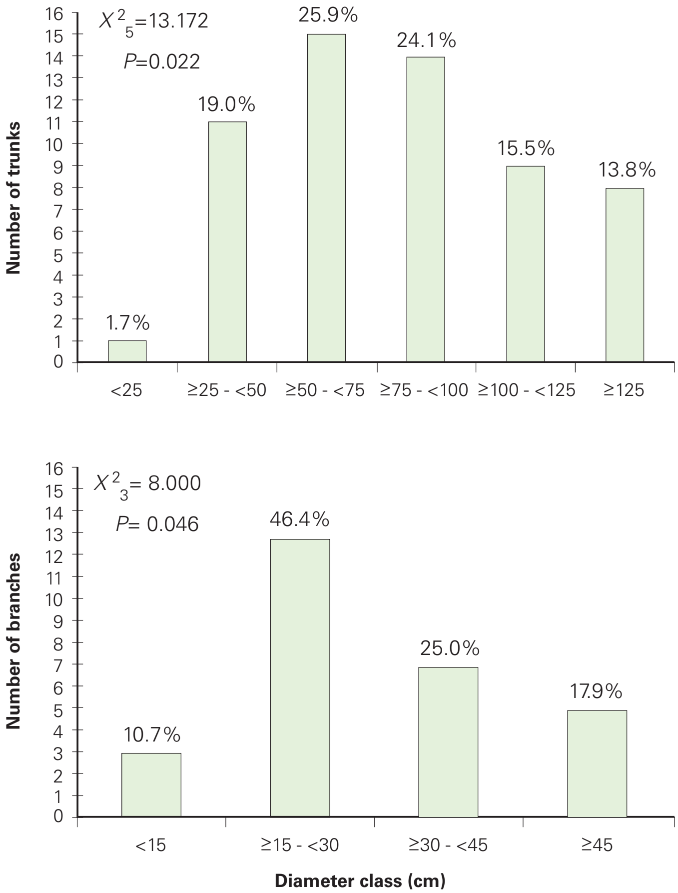

Fig. 3.- Numbers and corresponding percentages of trunks (up) and branches (down) with presence of *R. alpina* observed for each diameter class.

Fig. 3.- Número de troncos (arriba) y ramas (abajo) y correspondientes porcentajes con presencia de *R. alpina* observados para cada clase diametral

Condition of occupied trees

The wood pieces were *R. alpina* was found were standing trees (62.3% of records), fallen logs (22.1%) and fallen branches (15.6%).

In spite of the fact that *R. alpina* was found more frequent on standing beeches (living and snags) than in logs (χ^2_2 = 6.163, *P* = 0.046), there was no statistically significant difference in the average number of holes among living trees, snags and logs (Kruskal Wallis's χ^2_2 = 3.277, *P* = 0.194). The analysis of larvae showed that most fallen branches hosted several generations, as revealed by the simultaneous presence of individuals of different sizes and more emergence holes than larvae (Table 4).

Tree condition	Average number of holes	Location on the tree	Nº of trees	% of trees
Living tree	11.04 ± 2.30	Trunk	18	23.3
		Attached branches	5	6.5
		Fallen branches	1	1.3
		Total	24	31.2
Snag	5.40 ± 1.42	Trunk	23	29.9
		Trunk and fallen branches	1	1.3
		Total	24	31.2
Log	10.50 ± 5.96	Trunk	14	18.2
		Trunk and fallen branches	1	1.3
		Fallen branches	2	2.6
		Total	17	22.1
Unknown	5.75 ± 1.09	Fallen branches	12	15.6

Table 3.- Average number of emergence holes and number of trees of the observed presences of *R. alpina* per each category of tree condition arranged by locations on the tree.

Tabla 3.- Promedio de orificios de emergencia y número de árboles correspondientes a las observaciones de presencia de *R. alpina* por cada categoría de condición del árbol ordenadas por la localización en el mismo.

Place name	Holes	Larvae number	Lenght (mm)	Inner location		
				Wood layer	Depth (cm)	Orientation
Errenaga	0	2	10	Heartwood		Parallel
			24	Heartwood		
Errenaga	5	2	15	Sapwood	1	Parallel
			21	Sapwood	4	
Errenaga	3	1	26	Sapwood	3	Parallel
Errenaga	14	1	25	Sapwood	3	Parallel
			17	Heartwood	7	
Errenaga	8	2	30	Sapwood	4.5	Perpendicular
Errenaga	4	1	34	Sapwood	2,5	Parallel
Iturtxoko	2	1	27	Sapwood	1.5	Parallel

Table 4.- Number of holes and number, size and location inside the wood of the larvae sampled in fallen branches. Orientation refers to the position of the larvae respecting to the longitudinal axis of the branch.

Tabla 4.- Número de orificios y número, tamaño y localización en el interior de la madera de las larvas muestreadas en ramas caídas. La orientación hace referencia a la posición de la larva respecto al eje longitudinal de la rama.

Branch diametrical growth

On average, it takes 55 years to develop a branch of 23 cm (Table 5). However, the rate of growth varied according to branch age and plot location: ageing tended towards growth deceleration, whereas branches from Artaso showed the lowest rates.

Plot	Artaso 1	Artaso 2	Artaso 3	Basogain	Guardetxe	Average
Nº branches	41	27	39	47	48	40.4 ± 3.8
Mean number	65.00	56.04	40.62	59.53	52.17	54.67 ± 4.10
Mean Ø (cm)	24.05	21.33	17.33	25.91	26.88	23.10 ± 1.73
Mean growth (cm x ring^{-1}) observed per number of ring class						
20-29	-	-	0.655	-	0.581	0.618 ± 0.027
30-39	-	0.471	0.486	0.526	0.590	0.518 ± 0.037
40-49	0.314	0.386	0.400	0.468	0.499	0.413 ± 0.032
50-59	0.385	0.389	0.358	0.454	0.543	0.426 ± 0.033
60-69	0.364	0.377	-	0.430	0.512	0.421 ± 0.033
70-79	0.388	0.296	-	0.414	0.442	0.385 ± 0.032
80-89	0.338	-	-	-	-	0.338

Table 5.- Average number of rings, diameters and estimated diametrical growths of measured branches per plot.

Tabla 5.- Promedios de los números de anillos, diámetros y crecimientos diametrales estimados de las ramas medidas en cada parcela.

Discussion

Old and thick trees are rare in regenerating woodlands as those studied. This may explain why *R. alpina* has been observed in fewer trees in the highest than in the intermediate diameter classes for both, trunks and branches. Colonization of the thickest trees could be also limited by the fact that old pollards often show hollow (Read, 1999) and hence a reduced volume of exploitable dead wood. Preliminary unpublished data from trees of the aforementioned LIFE project show that the frequency of hollowed trees increases with trunk diameter, from 0% for trunks thinner than 25 cm in diameter to 36% for trunks thicker than 100 cm. Taking trunk diameters by half-meter intervals showed the highest proportion of occupied beeches (50%) at the intermediate ranges of 50-100 cm. Additionally, most sampled branches belong to pollard beeches, as they are more accessible to researchers. According to the growth rates measured, these branches can rarely reach more than 30 cm in diameter in the 50-70 years elapsed since pollarding stopped in Gipuzkoa (ARAGÓN, 2003; 2010). These diametrical rates of growth of branches have to be taken cautiously, because narrow rings cannot always be identified in the field, and trees in favourable years can develop two rings (KUNIHOLM, 2001). The obtained rates (0.42-0.43 cm year^{-1} for branches around 50-70 years old) are smaller to those estimated for tree trunks (0.56 cm year^{-1}) in research carried out in beech forests close to the study area where tree rings were properly analyzed in the laboratory (HERRERA *et al.*, 2002), and the age of the forest was previously known (CASTRO, 2009).

On the other hand, it is difficult to assess the effect of not having analyzed the size of uncolonized trees, because there are no data on the relative availability of snags, logs and living trees in the study area. Perhaps, we have underestimated the importance of snags versus logs because the volume of dead wood is usually smaller in the standing than in the laying stage in European beech forest reserves (CHRISTENSEN *et al.*, 2005).

This work showed that most occupied beeches correspond to standing trees with trunks and branches larger than 25 and 15 cm in diameter, respectively. Moreover, *R. alpina* appeared more frequently on trunks than on branches. However, with the exception of branch diameter, the number of emergence holes does not parallel the observed frequencies. This is explained by the fact that the total number of holes per tree may not be a good indicator of the preference of *R. alpina* by specific categories of tree condition, since it is not possible to determine if logs and branches with holes were in a standing position when they were colonized. Therefore, a distinction between recent and old holes would reduce the bias due to this lack of knowledge and hence increase the power of detecting differences among the different categories of tree condition if they actually exist. Recent holes could be determined checking criteria like the presence of sawdust and inner walls with the same colour as the cutting surface of freshly pruned wood, in a similar way to that described in BUSE *et al.* (2007) to identify emergence holes of *Cerambyx cerdo* Lineé, 1758.

As DUELLI & WERMELINGER (2005) found in Switzerland with cut trunks, records of *R. alpina* in standing dead wood were more frequent than in fallen logs. In agreement with the same authors, trunks bigger than 25 cm in diameter showed higher presence of the species than thinner ones. This size seems to be a threshold beyond which higher trunk diameter does not increase the presence of *R. alpina*, as has shown also in Italy (RUSSO *et al.*, 2010). However, this hypothesis is still based on a few observations, and must be taken cautiously.

Unlike the results found in the present work, tree condition had no effect on the frequency of occupancy of trees observed in Italian beech forests (Russo *et al.*, 2010). This disparity could have two possible explanations. First, it may be due to the different structure of the beech woodlands studied, a fact that may affect how *R. alpina* selects the habitat (Russo *et al.*, 2010). Second, it also may be the reflection of the different division of categories of tree condition to allow statistical analysis of data. Russo *et al.* considered three types of tree condition: living tree with some decaying parts, snag and broken snag/dead and fallen tree. The last category included snags broken above and below breast level, and in the present work logs referred to entire fallen trees and snags broken below breast height. Furthermore, Russo *et al.* found that of the 53 trees occupied by *R. alpina* only two corresponded to entire fallen trees. The number of broken snags below breast high level was not specified.

R. alpina selection of standing trunks and bigger stems may be related to food availability and isolation from too humid decay conditions of the dead wood (Duelli & Wermelinger, 2005). The bigger the trunks and branches are, the more volume of food they contain. Most larvae accumulated in the sapwood, which showed hard texture, not crumbly by hand, in agreement with their observed preference for dry wood with a low degree of moldiness (Duelli & Wermelinger, 2005). As larvae development inside the wood can take several years (Duelli & Wermelinger, 2005), it would be necessary for *R. alpina* to select locations that could keep the adequate hygrometric conditions as long as possible. Therefore, dead wood away from direct contact with the forest floor, as standing stems, would be the preferred choice to avoid an excess of humidity transmitted by the soil, a process that would accelerate the decomposition of the wood (Dajoz, 1967). As it takes more time to decompose bigger volumes of dead wood, thicker stems would provide with more durable habitat.

The present work has implications for the management of beech woodlands. The results suggest that for improving the habitat availability of *R. alpina* it is necessary to have partly decayed living trees and snags with diameters above 25 cm at least, or 50 cm optimally. Beech trees with dead attached branches above 15 cm in diameter should also be taken in account. However, these preliminary conclusions have to be taken cautiously, because of lack of data of unoccupied trees. Therefore, further research should include beeches with and without records of *R. alpina* for a robust test of these conclusions.

According to available data close to the study area (Herrera *et al.*, 2002; Castro, 2009), it takes around 45 and 89 years for a beech to grow 25 and 50 cm in diameter, respectively. Branches from pollard beeches get a diameter of 15 cm in 23-32 years. Therefore, at the regional scale of Gipuzkoa, all beech forest stands >45 years old and all pollard woodlands (characterized by thick trunks and branches usually >50 years old [Aragón, 2003; 2010]) available for conservation policies should be mapped in order to draw up strategic plans directed to conserve *R. alpina*. This step should be followed by an analysis at the stand/forest level of the populations of the species, and of the density and quality of trees potentially inhabitable. All this information is required to adopt the necessary management measures adapted to the specific conditions of each beech forest/woodland.

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Appendix 1. Tree data broken down by place name, year of sampling campaign, tree structural features, and records of emergence holes, imagos and larvae. Abbreviations: NR = not recorded, P = Presence, SCI = Site of Community Interest.

Anexo 1.- Desglose de los datos de los árboles por correspondientes topónimos, año de la campaña de muestreo, características estructurales y registros de orificios de emergencia, imagos y larvas. Abreviaturas: NR = no citada, P = presencia, SCI = Lugar de Interés Comunitario.

Place name, SCI	Year	Location on tree (tree condition)	Diameter (cm)	Holes	Adults	Larvae
Aloña, Aizkorri-Aratz	2004	Trunk (log)	54	NR	1	NR
Arrola, Aizkorri-Aratz	2004	Trunk (snag)	56	NR	4	NR
Arrola, Aizkorri-Aratz	2004	Trunk (snag)	120	NR	3	NR
Barrendiola, Aizkorri-Aratz	2004	Trunk (log)	44	NR	2	NR
Bildotx, Aizkorri-Aratz	2004	Trunk (snag)	36	NR	2	NR
Bildotx, Aizkorri-Aratz	2004	Trunk (snag)	41	NR	1	NR
Bildotx, Aizkorri-Aratz	2004	Trunk (log)	49	NR	1	NR
Neskien-egia, Aizkorri-Aratz	2004	Trunk (log)	51	NR	2	NR
San Adrián, Aizkorri-Aratz	2004	Trunk (snag)	144	NR	3	NR
Txurruko Punta, Aizkorri-Aratz	2004	Trunk (log)	39	NR	5	NR
Agautz, Aralar	2005	Trunk (snag)	50	P	0	NR
Agautz-Leizadi, Aralar	2006	Fallen Branch	19	8	0	NR
Agautz-Leizadi, Aralar	2006	Trunk (living tree)	95	18	0	NR
Agautz-Leizadi, Aralar	2006	Fallen Branch	60	10	0	NR
Agautz-Leizadi, Aralar	2006	Trunk (log)	64	59	0	NR
Agautz-Leizadi, Aralar	2006	Trunk (snag)	65	1	0	NR
Akaitz I, Aralar	2003	Trunk (log)	50	0	1	NR
Akaitz II, Aralar	2003	Trunk (log)	50	0	1	NR
Alleku, Aralar	2005	Trunk (log)	50	P	0	NR
Amiltzu, Aralar	2011	Branch (living tree)	25	17	0	NR
Amiltzu, Aralar	2011	Trunk (log)	80	1	0	NR
Arlepo, Aralar	2005	Trunk (log)	80	P	2	NR
Arraztaran, Aralar	2005	Trunk (snag)	84	0	2	1
Bedaio, Aralar	2006	Trunk (living tree)	123	3	0	NR
Bedaio, Aralar	2006	Trunk (living tree)	77	5	0	NR
Bedaio, Aralar	2006	Trunk (living tree)	90	5	0	NR

Place name, SCI	Year	Location on tree (tree condition)	Diameter (cm)	Holes	Adults	Larvae
Bedaio, Aralar	2006	Branch (living tree)	112	3	0	NR
Errenaga, Aralar	2005	Fallen Branch	18	0	0	2
Errenaga, Aralar	2005	Fallen Branch	19	5	0	2
Errenaga, Aralar	2005	Fallen Branch	17	3	0	1
Errenaga, Aralar	2005	Fallen Branch	44	14	0	1
Errenaga, Aralar	2005	Fallen Branch	38	8	0	2
Errenaga, Aralar	2005	Fallen Branch	22	4	0	1
Errekonta, Aralar	2005	Trunk (snag)	50	P	0	NR
Errekonta, Aralar	2006	Trunk (living tree)	137	18	0	NR
Errekonta, Aralar	2006	Trunk (living tree)	113	38	0	NR
Errekonta, Aralar	2006	Trunk (living tree)	80	38	0	NR
Errekonta, Aralar	2006	Trunk (living tree)	69	10	0	NR
Errekonta, Aralar	2006	Trunk (living tree)	104	3	0	NR
Errekonta, Aralar	2006	Fallen Branch	25	5	0	NR
Errekonta, Aralar	2006	Trunk (log)	128	2	0	NR
Ezkalusoro, Aralar	2006	Trunk (snag)	76	8	0	NR
Ezkalusoro, Aralar	2006	Fallen Branch	124	4	0	NR
Ezkalusoro, Aralar	2006	Fallen Branch	38	6	0	NR
Ezkalusoro, Aralar	2006	Branch (living tree)	25	6	0	NR
Ezkalusoro, Aralar	2006	Trunk (snag)	54	15	0	NR
Ezkalusoro, Aralar	2006	Branch (living tree)	40	3	0	NR
Ezkalusoro, Aralar	2006	Branch (living tree)	29	1	0	NR
Ezkalusoro, Aralar	2011	Trunk (snag)	93	2	1	NR
		Fallen Branch	58	2	1	NR
		Fallen Branch	47	6	1	NR
Ezkalusoro, Aralar	2011	Trunk (log)	108	6	0	NR
Ezkalusoro, Aralar	2011	Trunk (snag)	95	2	1	NR
Ezkalusoro, Aralar	2011	Trunk (living tree)	106	17	0	NR
Ezkalusoro, Aralar	2011	Trunk (snag)	63	3	0	NR
Ezkalusoro, Aralar	2011	Fallen Branch (living tree)	35	14	0	NR
		Fallen Branch	18	5	0	NR
		Fallen Branch	15	1	0	NR
		Fallen Branch	9	1	0	NR

Place name, SCI	Year	Location on tree (tree condition)	Diameter (cm)	Holes	Adults	Larvae
Irumugaeta, Aralar	2006	Trunk (snag)	78	1	0	NR
Iturtxoko, Aralar	2005	Fallen Branch	14	2	0	1
Leizadi, Aralar	2005	Trunk (snag)	28	0	1	NR
Maizegi, Aralar	2005	Trunk (snag)	90	P	3	NR
Salsamendi, Aralar	2005	Trunk (snag)	50	P	0	NR
Txotxeta, Aralar	2011	Trunk (living tree)	144	2	2	NR
Txotxeta, Aralar	2011	Trunk (living tree)	141	0	2	NR
Txotxeta, Aralar	2011	Trunk (living tree)	125	0	1	NR
Aizpel, Ernio-Gatzume	2010	Trunk (living tree)	20	18	1	NR
Aizpel, Ernio-Gatzume	2010	Trunk (snag)	35	3	0	NR
Aizpel, Ernio-Gatzume (coppiced tree)	2010	Trunk (snag)	25	8	0	NR
		Trunk (snag)	39	5	0	NR
Basogain, Ernio-Gatzume	2010	Trunk (living tree)	77	2	0	NR
Basogain, Ernio-Gatzume	2010	Trunk (log)	108	12	1	NR
		Fallen Branch	33	7	1	NR
		Fallen Branch	19	3	0	NR
		Fallen Branch	12	4	0	NR
Basogain, Ernio-Gatzume	2010	Trunk (snag)	71	2	2	NR
Endaitzburu, Ernio-Gatzume	2010	Fallen Branch (log)	40	10	0	NR
Ernio-Erniozabal, Ernio-Gatzume	2010	Fallen Branch (log)	24	1	1	NR
Erniozabal, Ernio-Gatzume	2010	Trunk (snag)	126	14	5	NR
Harrierreaga, Ernio-Gatzume	2010	Trunk (log)	44	0	1	NR
Gazume, Ernio-Gatzume	2010	Trunk (snag)	29	9	1	NR
Guardetxe, Pagoeta	2010	Trunk (snag)	132	0	2	NR
Guardetxe, Pagoeta	2010	Trunk (living tree)	113	0	3	NR
Guardetxe, Pagoeta	2010	Trunk (living tree)	82	13	0	NR
Semeola, Pagoeta	2010	Trunk (living tree)	129	24	0	NR

Appendix 2. Geographic locations of the new records of *Rosalia alpina*. Sampling dates specified to day level match the observations of adults (Appendix 1). Data from campaigns 2003 to 2006 are not presented here because they have been published elsewhere (Martínez De Murguía *et al.*, 2007).

Anexo 2.- Localizaciones geográficas de las nuevas citas de *Rosalia alpina*. Las fechas de muestreo especificadas a nivel de especie coinciden con las observaciones de individuos adultos (Anexo 1). No se presentan los datos de las campañas 2003 a 2006 porque ya han sido previamente publicados (MARTÍNEZ DE MURGUÍA *et al.*, 2007).

Place name	Site of Community Interest	Coordinates (UTM, ED50)		Altitude (m)	Date
		X	Y		
Amiltzu	Aralar	571001	4757593	741	2011
Amiltzu	Aralar	571059	4757837	806	2011
Ezkalusoro	Aralar	570241	4757176	567	8,14,20.07.2011
Ezkalusoro	Aralar	570024	4757230	556	2011
Ezkalusoro	Aralar	570435	4757251	486	12.07.2011
Ezkalusoro	Aralar	570442	4757203	563	2011
Ezkalusoro	Aralar	570242	4757180	559	2011
Ezkalusoro	Aralar	570360	4757290	531	2011
Txotxeta	Aralar	571008	4759257	819	11.08.2011
Txotxeta	Aralar	570868	4759051	804	3,11.08.2011
Txotxeta	Aralar	570914	4759043	803	17.08.2011
Aizpel	Ernio-Gatzume	569388	4779982	1035	20.07.2010
Aizpel	Ernio-Gatzume	569194	4780078	1015	20.07.2010
Aizpel	Ernio-Gatzume	569244	4780078	1015	20.07.2010
Basogain	Ernio-Gatzume	569634	4779355	950	2010
Basogain	Ernio-Gatzume	569698	4779359	925	19.08.2010
Basogain	Ernio-Gatzume	569597	4779387	920	19.08.2010
Endaitzburu	Ernio-Gatzume	571156	4779946	515	19.08.2010
Erniozabal	Ernio-Gatzume	570693	4778860	950	06.08.2010
Harrierreaga	Ernio-Gatzume	569740	4780377	745	19.08.2010
Gazume	Ernio-Gatzume	567751	4781259	945	17.08.2010
Ernio-Erniozabal	Ernio-Gatzume	569432	4779553	960	20.07.2010
Guardetxe	Pagoeta	567771	4789040	295	11.08.2010
Guardetxe	Pagoeta	567710	4788966	280	11.08.2010
Guardetxe	Pagoeta	567772	4789060	290	2010
Semeola	Pagoeta	567216	4785923	510	30.07.2010