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Biogeography and conservation of Iberian water beetles

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Abstract

An analysis is made of the main biogeographical trends and the conservation status of the aquatic Coleoptera from the Iberian peninsula. More than 600 species in 100 genera and 20 families are recognised, although knowledge of some of them is still scarce. Overall, the level of endemism is about 20%, with a highly uneven taxonomic distribution. Five main geographical regions are recognised based on geological and topographical criteria: Pyrenean, Cantabrian mountains, Hercynian, South East, and South West. These regions have a significantly distinct fauna when all species, species of the family Hydraenidae, all Iberian endemics, and Hydraenidae endemics are considered. For other groups this geographical division is not relevant, as the species follow a random distribution. The main biogeographical division is between the northern and the southern regions, with closer similarity between the Pyrenees and France, and between the South East and Morocco, than with other Iberian regions. The conservation status of the species included in the IUCN red list is reviewed, suggesting the exclusion of three species previously considered to be endangered or vulnerable, and the inclusion of two new species as vulnerable. The status of the rare species is discussed, with the distinction between local endemics, possible relict species, and species with discontinuous distributions due to habitat loss or habitat fragmentation. The habitats with the highest conservation value are medium altitude freshwater streams in the Hercynian mountains of central and western Iberia, the pre-Pyrenees and the Baetic cordilleras, together with saline streams in the South East and the central Ebro Valley. Some general guidelines are suggested for their preservation.

Keywords: Aquatic Coleoptera; Iberian peninsula; Biogeography; Endemism; Conservation

1. Introduction

The Mediterranean basin is a recognised centre of biodiversity, with high levels of endemism (Quézel, 1985, 1995; Greuter, 1991; Cowling et al., 1996; Mittermeier et al., 1998). Unlike other areas with high biodiversity, it has a long history of human settlement, and is highly populated. Freshwater habitats are among the most sensitive to human alterations, and thus are good indicators of the wider environmental quality (e.g. Hecker and Vives, 1995). Water beetles are very species rich in the Mediterranean area (around 1000 species, unpublished data), and are mostly found in the ecotone between land and inland waters, a habitat specially rich and sensitive to environmental changes (Lachavanne and Juge, 1997). Although the taxonomy and distribution of most of the northern Mediterranean area is well known, there is a lack of overall knowledge in what refers to their biogeographical relationships and conservation status.

The aims of this paper were thus: (1) to provide an initial assessment of the global biogeographical patterns among Iberian water beetles, with special attention to endemics; (2) to identify species which could be the target of conservation efforts, revising the current status of the species included in the 1996 IUCN red list (IUCN, 1996), and (3) to identify main habitats, or geographical areas, of special interest because of their aquatic beetle fauna.

2. Material and methods

2.1. Groups included in the assessment

The present analysis is based on a recently updated and annotated checklist of the aquatic Coleoptera of the Iberian peninsula (Ribera et al. 1999, see a summary of the number of species per group in Table 1). All families

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Table 1
Number of genera, species and subspecies per family of aquatic Coleoptera presently known in the Iberian peninsula, with the percentage of endemism. Family ordination follows Lawrence and Newton (1995) except for Hydrophiloidea, for which the family ordination of Hansen (1991) was used.

Suborder	Superfamily	Family	Genera	Species[a]	Sub- species[b]	Endemics[c]	% End.[d]
Myxophaga		Microsporidae	1	2 (1)	–	–	–
		Hydroscaphidae	1	1	–	–	–
Adephaga		Gyrinidae	3	10	–	–	–
		Haliplidae	3	19 (5)	–	–	–
		Noteridae	2	3	–	–	–
		Hygrobiidae	1	1	–	–	–
		Dytiscidae	33	163–165 (15)	6(4)	32	19.4
Polyphaga	Hydrophiloidea	Helophoridae	1	35 (2)	(1)	7	20.0
		Georissidae	1	3	–	–	–
		Hydrochidae	1	9	–	4	44.4
		Hydrophilidae	20	90–92 (3)	1	3	3.3
	Staphylinoidea	Hydraenidae	6	138 (4)	1	60	43.5
	Scirtoidea	Scirtidae	6	34 (4)	–	11	32.3
	Byrrhoidea	Elmidae	10	29–30 (1)	2(2)	3	10.0
		Dryopidae	2	17 (2)	–	1	5.9
		Limnichidae	3	6	–	–	–
		Heteroceridae	2	17 (1)	–	–	–
		Psephenidae	1	1	–	–	–
	Chrysomeloidea	Chrysomelidae Donaciinae	2	19–20(1)	–	1	5.0
	Curculionoidea	Curculionidae Bagoini	1	23	–	4	17.4
Totals			100	627 (43)	11(7)	126	20.0

[a] When some of the species are likely to be synonyms a range is given. In brackets, species in need of confirmation (included in the total number).
[b] Subspecies other than the nominate form of the species (except for *Helophorus leontis leontis*, of which the nominate form is an Iberian endemic). Number of endemic subspecies in brackets (included in the total). Taxa of doubtful subspecies status are excluded.
[c] Endemic subspecies not included.
[d] Percentage of the maximum range of the Species column (endemic subspecies not included).

for which at least a substantial proportion of species is linked with water in any of their developmental stages were included, although the treatment of some groups as aquatic or not is sometimes more the product of tradition than of objective evaluation (e.g. riparian species of Staphylinidae and Carabidae were excluded, whereas riparian families of Byrrhoidea — Limnichidae and Heteroceridae—were included). In the family Chrysomelidae only the subfamily Donaciinae, and in the Curculionidae only the tribe Bagoini, were included (see Ribera et al., 1999 for details).

Well established subspecies were also considered, especially in the analysis of the endemic fauna, as they provide useful biogeographical information (e.g. Hewitt, 1996). For most purposes, species of Scirtidae, Donaciinae and Bagoini were not included, owing to insufficient knowledge of their distribution and/or taxonomy.

Species of aquatic Coleoptera present in France or Morocco but not in Iberia were compiled from various sources for comparative purposes. In total, 42 and 105 species living in Morocco and France, respectively, are not known to occur in Iberia (excluding Scirtidae, Donaciinae and Bagoini). The limit of these geographical zones (Morocco and France) is political and not biogeographical, but for the purpose of the analysis the only relevant information was the total number of species, and results proved to be very robust with respect to relatively large deviations of this number (full data used in the analysis available on request).

2.2. Biogeographical criteria

The geographical limits of the Iberian Peninsula considered in this paper are those of the Spanish–French political border (with the inclusion of the Pyrenean state Andorra), which in general agrees with the division of the north and south sides of the Pyrenees. The Balearic islands were not included, as they do not form a biogeographical unit with mainland Iberia (despite the obvious relationships of the faunas).

The knowledge of the detailed distribution of the species within the Iberian peninsula, and in particular of the endemics, is essential for the conservation assessment of the fauna. This knowledge is still incomplete in some instances, and in consequence it was preferred to define geographical regions by independent criteria, not based on the distribution of the species. The question to be answered is then not what biogeographical regions could be defined according to the distribution of the species of a group, but if the geographical regions defined have significantly different faunas. This has the advantage of directly testing the relevance of specific criteria (those used in the definition of the areas) in the distribution of the species, while biogeographical areas constructed purely on distribution maps do not provide, on their own, any information on their underlying causes, which have to be tested separately.

The Iberian peninsula was divided into five major regions or areas according to their geological history and their present topography (Fig. 1).

1. Pyrenean: the area north or the river Ebro valley up to the north side of the Pyrenees, including the eastern parts of the Basque country mountains. This area corresponds to the Tertiary basin of the Ebro river, the south side of the Pyrenean thrust belt, and the Catalan coastal ranges (forming the eastern Pyrenees river basin) (Anadón and Roca, 1996). Its limit is well defined in the south, but the region of the upper Ebro valley, when the Pyrenees and the Iberian cordillera merge, is less clearly delimited.
2. Cantabrian: the Cantabrian mountains, from the eastern parts of the Basque Country to Galicia. The southern boundary of this region is well delimited by the plains of the Tertiary basin of the river Duero (Santisteban et al., 1996). Its eastern and western limits are less clear, as they intermix with the Pyrenees and the northernmost mountain systems of the Hercynian Iberian massifs respectively.
3. Hercynian Iberia: the Iberian cordillera, all the Hercynian mountain systems of the Iberian massif, and the Tertiary basins of the Duero and the upper Tajo rivers. It includes the river basins of the Guadiana, Tajo (except the southern part), Duero and Miño. This is the largest and most heterogeneous area, and it is likely to be the aggregation of at least two geologically well defined zones (the Iberian massif and the Iberian cordillera, Fig. 1, see e.g. Sanz de Galdeano, 1996). However, owing to lack of knowledge of the distribution of many species in central Spain, it was preferred provisionally to keep them as a single unit.
4. SE Iberia: the Tertiary basin of the Guadalquivir river, with all the Baetic cordilleras (including Sierra de Alcaraz in Albacete) and the Baetic and Rif internal zones (Sanz de Galdeano, 1996). It includes the river basins of the Segura and Gualquivir rivers, plus those of the southern side of Sierra Nevada and other mountain systems between Cádiz and Granada. It is the best defined area from a tectonic and geological point of view (Uchupi, 1988; Friend and Dabrio, 1996).
5. SW Iberia: the area south of the Sistema Central and the river Tajo (the limit of the Hercynian zone), and west of the Guadalquivir basin. This is a lowland area including the Tertiary basin of the lower Tajo river, plus some lowland areas and some isolated mountain massifs in the Algarve (south Portugal). Geologically it is linked to the Iberian Massif, but it forms a well defined area because of the abrupt end of the mountain systems of the Sistema Central and related mountains in Spain and Portugal.

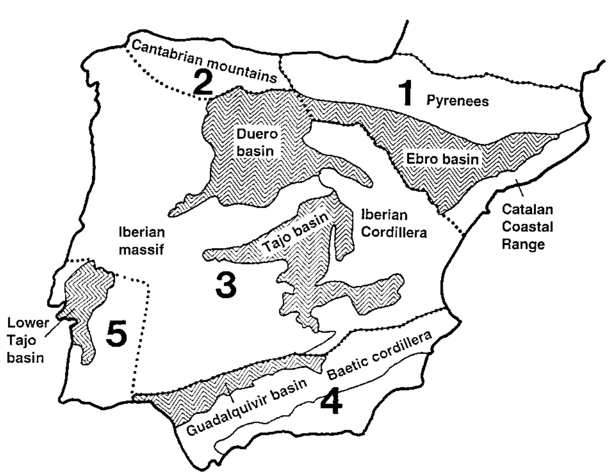

Fig. 1. Geographical areas defined within the Iberian peninsula. Continuous lines: limits of the main geological domains (after Friend and Dabrio, 1996, simplified). Crossed areas: main Tertiary basins. Dotted lines: limits of the regions considered in this study: 1, Pyrenean; 2, Cantabrian; 3, Hercynian; 4, South East; 5, South West.

These five areas were not defined according to any ecological criteria and most of them include zones with a wide range of ecological characteristics. Thus, the Hercynian, Pyrenean and South East areas range from alpine lakes and mountain streams to arid, steppe habitats with saline water, and include different general phytoecological associations (Ozenda, 1990).

To characterise the general range of the species in addition to their distribution within Iberia they were divided into five main biogeographical categories: (1) southern species (S), corresponding to species present in north Africa and in some areas of the Iberian peninsula, but not extending north of the Pyrenees; (2) northern species (N), present in Europe north of the Pyrenees and some areas in the Iberian peninsula, but not in north Africa; (3) eastern species (E), present in some areas in the Iberian peninsula and in some areas in the central and eastern Mediterranean, but not in Europe north of the Pyrenees; (4) Iberian endemic species (X), present only in the Iberian peninsula, with the extension to the north face of the Pyrenees (and some areas in the extreme south of France) in some cases; and (5) trans-Iberian species (T), species present in Europe north of the Pyrenees, the Iberian peninsula, and north Africa.

Information on the species which are considered to be rare is also presented. Following in part Rabinowitz (1981) and Gaston (1994), three different types of rarity were considered: (1) species known from only a few localities very close together, but not in low abundance in at least one of them, (2) species known from at least two distant localities, but with low abundance in all of them, and (3) species known from only a few localities very close together, and with low abundance in all of them.

2.3. Analysis of the data

To assess the relevance of the defined geographical limits for the fauna of aquatic Coleoptera, I used the distribution of the number of areas in which each species occurs. If species are randomly distributed across regions, the expected null distribution for this variable is a Poisson, provided that the occurrence of species are independent one of another, and the average number of areas per species is relatively low (Sokal and Rohlf, 1995). If the number of areas per species does not follow a Poisson distribution, it can be assumed that the distribution of the species is not random with respect to the areas defined. Note that the variable of interest is not the number of species per area, which could give similar results but would have only a maximum of eight data points (the five Iberian regions plus north Africa, France, and the eastern Mediterranean), but the number of areas per species, with a much higher number of replicates.

The goodness of fit to a Poisson distribution was measured by means of a Chi-squared test for 12 data sets: all species, Iberian species (i.e. excluding those found only in France or Morocco), and Iberian endemic species; in each case for the whole fauna and for the three most numerous taxonomic groups (aquatic Adephaga, Hydrophiloidea, and Hydraenidae). In all cases, species with trans-Iberian distributions were excluded (as they do not provide useful information concerning similarities between areas), as well as some species with widespread distributions in western Europe but for which the faunistic data in the Iberian peninsula is most incomplete.

Using just the groups for which the geographical areas proved relevant, the relationship between areas was studied with the Jaccard similarity index (Q) (Jaccard, 1908) because of its wide applicability (e.g. Baroni Urbani, 1980; Hengeveld, 1990; Real and Vargas, 1996). The similarity matrix was analysed with standard clustering methods (simple average linkage, Jongman et al., 1995). Alternative procedures gave the same results (e.g. single or complete linkage), the main patterns being very robust. The statistical table provided by Baroni Urbani (1980) was used to assess the statistical significance of the Jaccard similarity index between pairs of areas.

3. Results

3.1. Adequacy of the geographical areas defined

When all non trans-Iberian species and subspecies of all groups were considered together (430 taxa, excluding Scirtidae, Donaciinae and Bagoini), the number of areas in which each of them occurs did not follow a random Poisson distribution (Tables 2 and 3). The same result was obtained when only the Iberian endemic species and subspecies of all groups were considered (117 taxa). On the other hand, for all Iberian species (278 taxa, excluding trans-Iberian species and species only found in France or Morocco), the distribution of the number of areas was not significantly different from a random Poisson, and in consequence the geographical limits used were not considered to be of relevance (Table 2).

When the taxonomic groups were analysed separately, the same pattern was observed for species of Hydraenidae (143 taxa), with all species and Iberian endemic species showing a significant deviation from a Poisson, although in this case the deviation when all species were pooled was only marginally significant ($p=0.10$, Tables 2 and 3). In the aquatic families of Adephaga, only when all species were considered was the deviation marginally significant (Table 2). Other groups showed no significant deviations from a random pattern.

In all cases the sampled variance of the distribution was lower than the expected variance, and this was mostly due to the higher than expected frequency of species occurring in one area only (Table 3).

3.2. General faunal relationships

Only the faunal relationships based on all species and on species of Hydraenidae were studied, as these were the groups for which the geographical areas defined were considered to be significant.

The cluster analysis of the all non trans-Iberian taxa revealed two main groups of areas: a northern one, including France, the Pyrenees, the Cantabrian mountains and the Hercynian Iberia; and a southern one, including north Africa and both southern areas in Iberia (Fig. 2a). Within the main groups, the fauna of the Pyrenees was closer to that of France than to that of the Cantabrian mountains and Hercynian Iberia; and the fauna of the south east closer to the fauna of north Africa than to that of the south west. Differences between individual areas were all significant ($p<0.05$) except between France and the Pyrenean area, Pyrenean and Cantabrian, Hercynian and Cantabrian, and north

Table 2
Significance of the comparison of the number of geographical areas in which species and subspecies occur with a Poisson distribution (see Methods), as measured with a Chi-squared test. Significant values mean than the distribution cannot be said to follow a Poisson

Species included[a]	All groups	Aquatic Adephaga	Hydrophiloidea	Hydraenidae	Byrrhoidea[b]
All[c]	0.01	0.10	n.s.	0.10	n.s.
Iberian[d]	n.s.	n.s.	n.s.	n.s.	–
Northern	n.s.	n.s.	n.s.	n.s.	–
Southern	n.s.	n.s.	n.s.	n.s.	–
Endemic	0.01	n.s.	n.s.	0.01	–

[a] Eastern species were not studied because of their low number (only two).
[b] The only distribution tested was that of all species, as the number of species in the individual categories was not enough for analysis.
[c] Iberian species plus those only present in north Africa or France.
[d] Iberian species (i.e. Iberian endemics plus northern, southern and eastern species).

Table 3
Observed (O) and predicted (P) mean, variance, and number of taxa occurring from only one to a maximum of six areas (those present in all five Iberian regions plus either France or north Africa) according to a random Poisson distribution, for the data sets with differences significant at a $p < 0.01$ level (see Table 2)

	All species[a]			All Iberian endemics			Hydraenid endemics		
	O	P	Chi^2	O	P	Chi^2	O	P	Chi^2
Mean	1.90	1.90		1.42	1.42		1.75	1.75	
Variance	1.39	1.90		1.37	1.42		1.58	1.75	
No. areas									
1	227	187.1	8.5	74	56.4	5.5	41.0	28.7	5.3
2	93	116.1	3.8	20	31.1	3.9	5.0	16.0	7.5
3	54	73.3	5.1	9	18.0	4.5	5.0	9.3	2.0
4	35	34.7	0.0	8	7.8	0.0	6.0	4.1	0.9
5	18	13.2	1.8	6	3.7	1.4	3.0	2.0	0.5
6	1	5.6	3.8	–	–	–	–	–	–
Total	430	430	23.0	117	117	15.3	60	60	16.3

[a] Iberian species plus those only present in north Africa or France (see methods).

African and South East areas. In these four cases, Q values were greater than 0.294 (the expected random Q value for 400 samples at $p=0.05$, Baroni Urbani, 1980), and therefore, the hypothesis that the two areas in question have the same fauna (i.e. differences are random) cannot be rejected. It must be noted that in the final dendrogram these pair-wise comparisons cannot be perfectly reflected, as they are not transitive (i.e. A = B and B = C do not imply A = C). Thus, the Pyrenean fauna was clustered with the French one, despite not being significantly different from that of Cantabria when compared individually, because the latter was more similar to that of the Hercynian region, which did differ significantly from that of the Pyrenean.

For family Hydraenidae the main division separated the Pyrenees plus France from all remaining areas [Fig. 2(b)], with the Cantabrian and Hercynian regions closer to the southern areas and to north Africa than to the Pyrenees and France. Individual differences between Cantabrian and Pyrenean, Hercynian and Cantabrian, South West and Hercynian, South West and Cantabrian, and north Africa and South East were not significant, as all of them had Q values greater than 0.271 (the expected random value for 140 samples at $p=0.05$).

The relationships between the fauna of the geographical regions based on the Iberian endemics only were very similar to those obtained using the whole fauna. The main division was between the northern (Pyrenean, Cantabrian and Hercynian) and the southern (South East and South West) areas, with Cantabrian closer to Pyrenean than to Hercynian [Fig. 3(a)]. Differences between pairs of areas were all significant, with the exception of the Pyrenean with Cantabrian, Cantabrian with Hercynian, and Cantabrian with South West, all of them with a Q value greater than 0.263 (the expected random value for 110 species at $p=0.05$).

The relationships between regions according to the endemic species of Hydraenidae were different, with the South East area occupying an isolated position at the base of the dendrogram, and the Cantabrian, South West and Hercynian regions clustering together [Fig. 3(b)]. In evaluating the position of the South West region it has to be considered that only eight species of endemic hydraenids are known from this area, none of

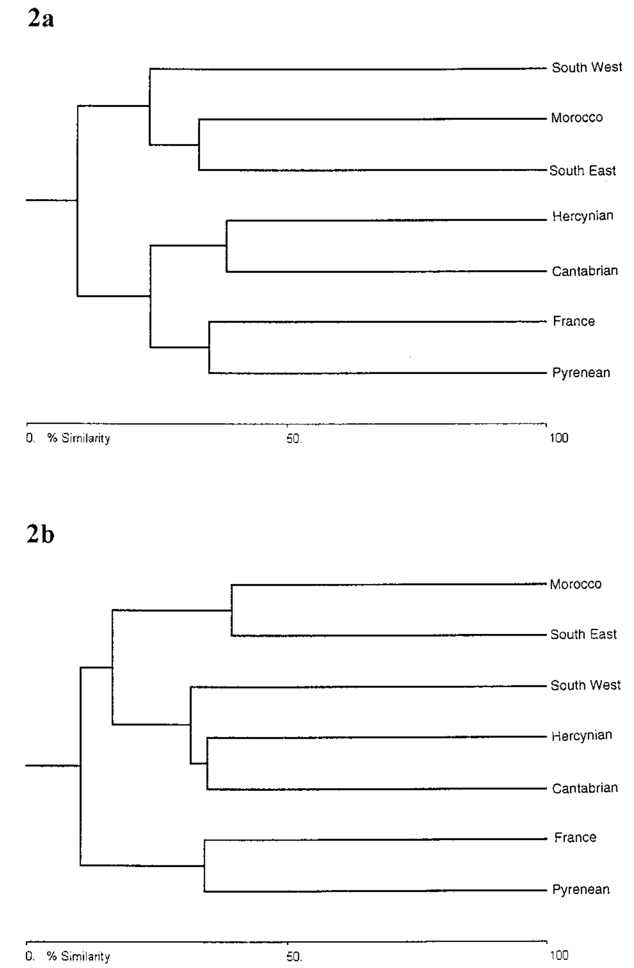

Fig. 2. Dendrogam of the similarities between the fauna of the geographical regions defined, using the Jaccard similarity index and simple average linkage. (a) All species and subspecies, (b) Hydraenidae.

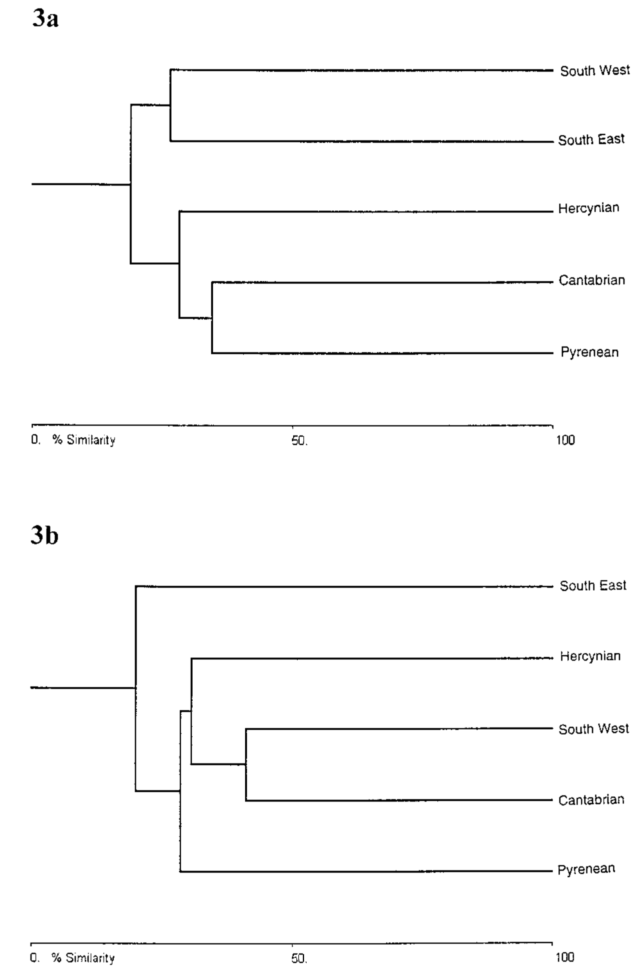

Fig. 3. Dendrogam of the similarities between the fauna of the geographical regions defined within the Iberian peninsula, using the Jaccard similarity index and simple average linkage. (a) All Iberian endemic species and subspecies, (b) Iberian endemic Hydraenidae.

them exclusively (Table 4). Its faunal similarities are thus driven by the wider distribution of these eight species. Differences between the Pyrenean, Hercynian and Cantabrian regions were not significant when compared individually, as well as differences between the Cantabrian and South West regions, all of them with Q values greater than 0.233 (the Q value for 60 species at $p = 0.05$). Differences between the South West and the Hercynian region were only significant at a $p < 0.1$ level ($Q = 0.24$). Other differences were all significant at a $p < 0.05$ level.

3.3. Level of endemism

When all species of all groups are considered, the level of endemicity of the Iberian fauna (including species occurring in the north side of the Pyrenees and some areas in south France, see Methods) is about 20% (Table 1). There are as yet no described genera endemic to the Iberian peninsula. The taxonomic distribution of the endemics is, however, highly uneven, with some families having >40% of endemics and others having none. The knowledge of the Iberian and north African fauna of Limnichidae, Scirtidae and Bagoini is still incomplete, and the figures given here have to be considered with great caution. When these less known groups are excluded, five of the remaining 90 genera account for >70% of all endemics (*Hydraena*, 34; *Ochthebius*, 13; *Limnebius*, 12; *Deronectes*, 9 and *Hydroporus*, 9 species, Table 1, Appendix A).

The total number of endemics per region is significantly correlated with their area [Table 4a and Fig. 4(a)]. Areas with positive residuals are the South East, the Hercynian region and the Cantabrian mountains; those with negative residuals are the South West and the Pyrenean region, although in all cases residuals were not high in absolute values. When only the exclusive endemics were included (i.e. those occurring only in one of the areas) the correlation was also highly significant; those from the South East fall well above the regression

Table 4
Number of endemic species and subspecies per area, for (a) all Iberian endemics (excluded Scirtidae, Chrysomelinae and Bagoini) and (b) endemics known of only one of the areas

a. Total endemics	Pyrenean	Cantabrian	Hercynian	South East	South West	r[a]
logArea	4.98	4.44	5.54	4.87	4.70	
Dytiscidae	12	12	25	8	6	0.79
Helophoridae	0	5	6	2	1	n.s.
Hydrochidae	0	0	2	2	0	–
Hydrophilidae	1	1	3	1	1	0.87
Hydraenidae	20	16	28	32	8	n.s.
Elmidae	1	2	5	1	1	0.73
Dryopidae	0	0	1	0	0	–
TOTAL	34	37	70	46	17	0.76
b. Exclusive endemics						
Dytiscidae	1	1	14	2	2	0.87
Helophoridae	0	1	2	1	0	n.s.
Hydrochidae	0	0	2	2	0	–
Hydrophilidae	0	0	2	0	0	–
Hydraenidae	5	3	14	19	0	n.s.
Elmidae	0	0	1	0	0	–
Dryopidae	0	0	1	0	0	–
TOTAL	6	7	35	24	2	0.79

[a] Correlation between the log of the area (in km^2) and the number of endemics (only results significant at $p < 0.05$ are given). Correlations with less than three non-zero values were not computed.

line, i.e. more endemics than would be expected according to its area, while those from both the Pyrenean region and the South West fall below the regression line, with fewer endemics than average [Table 4b and Fig. 4(b)].

When the different families were analysed separately, only Dytiscidae, Hydrophilidae and Elmidae showed a significant relationship with area (although the latter are only marginally significant, Table 4a). The number of endemics was not correlated with area in Helophoridae (with a low number of species) or Hydraenidae (Table 4a). For the latter, the highest number of endemics occurs in the South East, biasing the relationship with area.

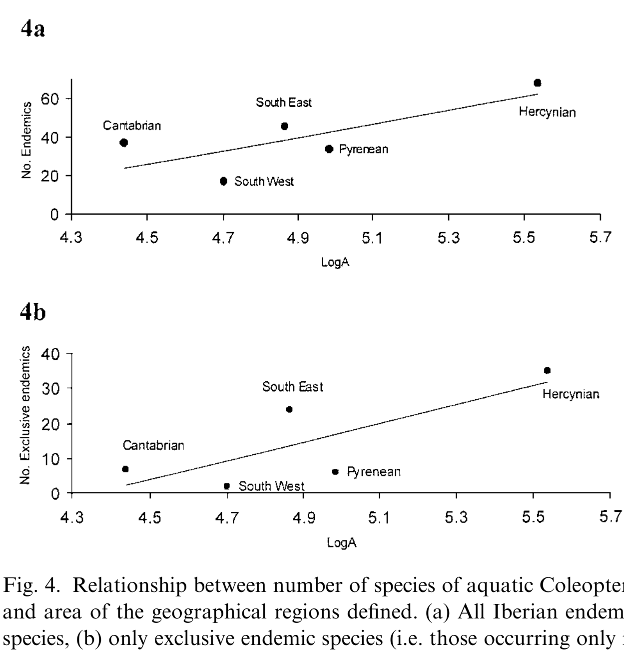

Fig. 4. Relationship between number of species of aquatic Coleoptera and area of the geographical regions defined. (a) All Iberian endemic species, (b) only exclusive endemic species (i.e. those occurring only in one of the areas).

3.4. Rare species

All but two rare species are exclusively found in running water (Appendix A). One exception is *Helophorus calpensis*, a sibling species of the widespread *H. minutus* Fabricius, 1775 recognised by chromosome analysis (Angus, 1988), and only known to occur in the extreme south of Spain (Algeciras). Its presence in north Africa and other areas in Spain is, however, most likely (R. B. Angus, pers. comm., 1998). The other exception is *Ochthebius irenae*, a species recently described from an area with saline lagoons in Albacete (Ribera and Millán, in press). Its relationships are still not known, but it belongs to a subgenus (*Asiobates*) with a high number of endemic species with apparently relict distributions in the Iberian peninsula (see Discussion).

All rare species were also found in mountain systems of medium altitude (between ca. 500 and 1500 m), with the same two exceptions (*H. calpensis* and *O. irenae*). The alpine fauna has very little endemism (see Discussion for some exceptions in *Agabus*, *Hydroporus* and *Helophorus*), and the few endemics do not have restricted distributions. On the other hand, some of the endemic species in medium-altitude mountain systems form species groups with very restricted allopatric distributions in close mountain systems, suggesting that they are endemics evolved in situ (e.g. the species of the *Limnebius nitidus* subgroup, Fresneda and Ribera, 1998; or, with less restricted distributions, the species of the *Hydraena (Haenydra) sappho* group (*H. gaditana*, *H. tatii*, *H. manfredjaechi* and *H. sappho* Janssens, 1965, the latter endemic of a Greek island; Audisio et al., 1996).

3.5. Presence of Iberian aquatic Coleoptera in national or international conservation schemes

None of the Iberian species of aquatic Coleoptera has a legal protected status; the two species included in the Annex II of the Bern convention [*Dytiscus latissimus* L., 1758 and *Graphoderus bilineatus* (De Geer, 1774)] do not occur in the Iberian peninsula, and national legislation does not cover any of the Iberian species (Viejo and Sánchez Cumplido, 1995; Helsdingen et al., 1996).

The most recent IUCN red list of threatened animals included six species of Iberian aquatic Coleoptera, all of them considered as vulnerable or endangered under criterion B1 (small, severely fragmented or restricted distribution) (IUCN, 1996, Table 5). *Acilius duvergeri* Gobert, 1874 is distributed from south-western France to west Morocco, and in the Iberian peninsula it is known from several western localities (Rico et al., 1990). It is probably the rarest and least known of the large species of western European aquatic Coleoptera, occurring in well preserved lowland or mountain ponds, always in low numbers.

The retention of *Rhitrodytes agnus* in the IUCN list of threatened species is well justified, as only two populations are known (considered to be different subspecies), and one of them is severely endangered owing to the road works in the area (Bilton and Fery, 1996). Being an insterstitial species with very restricted dispersal abilities, it is unlikely that it could be found in other areas. In contrast, *Agabus hozgargantae* Burmeister, 1983 has recently being discovered in several localities in Morocco, as well as in other localities in south Spain, and its status should be changed accordingly (Ribera et al., 1999, and unpublished data). The same is true for the Iberian endemic species *Deronectes depressicollis* and *D. ferrugineus*, of which new populations have been recently discovered and should not be regarded as especially threatened (Fery and Brancucci, 1998, and unpublished observations). The status of *Deronectes algibensis* is uncertain, as there is not enough information on the detailed distribution and the number of extant populations.

Two species of Elmidae with western Palaearctic distribution are proposed for inclusion in the ICUN red list as threatened species under criteria A1 (population reduction observed) and A2c (population decline suspected in the future due to reduction of quality of habitat, IUCN, 1996): *Potamophilus acuminatus* (Fabricius, 1792) and *Stenelmis consobrina*. The former is the only European species of the genus and of the subfamily Larinae (Olmi, 1976), and it is also the largest of the European elmids. Although present in the whole of Europe and north Africa, it has been always rare and with discontinuous distributions (Horion, 1955). Recent records are increasingly rare, and it is considered to be on the verge of extinction in central Europe (Kodada, 1991). It requires large, clean, well oxygenated rivers, a threatened and scarce habitat. In the Iberian peninsula recent records are mostly restricted to the south east, in Sierra de Alcaraz and the Guadalquivir (Millán and Soler, 1989; Rico, 1997).

Stenelmis consobrina is considered to be extinct in central Europe (M. A. Jäch, pers. comm., 1998), and it is increasingly rare in the south of Europe (Olmi, 1976; Rico, 1997). In the Iberian peninsula it was only known from a few localities in the south (Rico, 1997), to which one north-east population should be added (Ribera et al., 1999).

Table 5
Conservation status of Iberian species of aquatic Coleoptera according to the 1996 IUCN Red list, and proposed changes (see text and ICUN, 1996 for the explanation of the criteria)

	IUCN (1996)		Proposed change	
	Category	Criteria	Category	Criteria
Family Dytiscidae				
Acilius duvergeri	Vulnerable	B1 + 2b	Same	Same
Agabus hozgargantae	Endangered	B1 + 2c	Exclude	
Deronectes algibensis	Endangered	B1 + 2c	Data deficient	
D. depressicollis	Vulnerable	B1 + 2c	Exclude	
D. ferrugineus	Vulnerable	B1 + 2c	Exclude	
Rhithrodytes agnus agnus	Endangered	B1 + 2c	Same	Same
R. agnus argaensis	None		Endangered	B1 + 2c
Family Elmidae				
Potamophilus acuminatus	None		Vulnerable	A1 + 2c
Stenelmis consobrina	None		Vulnerable	A1 + 2c

None of the endemic species with restricted distributions is proposed for inclusion in the IUCN red list. Information on the actual status of most of them is still insufficient, and the small size and reduced morphological diversity of some groups (such as Hydraenidae) makes it more efficient to target conservation measures on habitats rather than species (see Discussion).

From a more local point of view, other than the endemic or globally endangered species there are a number of species with northern or southern distributions that have only a few populations in the Iberian peninsula (Appendix B). In some cases these are large species typical of well preserved ponds or lagoons, such as *Ilybius quadriguttatus*, *Hydaticus seminiger*, *Graphoderus cinereus*, *Hydrophilus piceus* and *Hydrochara caraboides* among northern taxa, which are only found in a few well vegetated lagoons in the Pyrenean region (Ribera et al., 1996, the first with a population of uncertain taxonomic status in Sierra de Alcaraz, in the SE region, Millán et al., in press). *Hydaticus transversalis* is probably extinct in the Iberian peninsula, as old records were from localities near Barcelona which are now totally urbanised (Hernando and Aguilera, 1995; Ribera et al., 1996). With only two exceptions (*Stictonectes escheri* and *Berosus bispina*), the Iberian populations of the southern species with restricted distributions are also the only known populations in continental Europe (Appendix B). Two of them (*Canthydrus diophthalmus* and *Cybister vulneratus*) are likely to be extinct in the Iberian peninsula—and continental Europe—owing to the severe degradation of the coastal lagoons in which they were found (Ribera et al., 1996). Specific interventive measures for the conservation of these species are highly desirable.

4. Discussion

4.1. Knowledge of the fauna

Although the knowledge of the aquatic Coleoptera of the Iberian peninsula is still incomplete, and new species, and species not previously recorded, are likely to be discovered in the near future (see Ribera et al., 1999), it is not expected than the general biogeographical patterns found in this paper could be altered due to new additions to the Iberian fauna. Recent additions tend to be either species with southern or northern distributions with isolated populations in Iberia, or new endemic species with very restricted distributions, typically cryptic species only distinguishable through a detailed study of their male genitalia. The main remaining task seems to be the fine-grained splitting of species complexes, as is the case for most of the western Palaearctic fauna (Ribera and Foster, 1996). The relationships between large areas with a high number of species (as those defined in this study) are likely to be robust. The study of the relationships between smaller units, such as mountain systems within the same geological region, would at present be much more problematical. Some mountain systems in central Spain, particularly in the south-west of the Iberian peninsula, are among the less studied areas, as reflected in the poor characterisation of the latter.

The fauna of north Africa is much less known than that of the Iberian peninsula. The total number of aquatic Coleoptera (ca. 450 species for Morocco, Algeria and Tunisia, unpublished checklist) is clearly too low for an area much larger than that of the Iberian peninsula, even assuming a rarefaction of the fauna because of the extreme conditions of some desert areas, and because of its geographical situation at the periphery of the south-western Palaearctic region. In the last few years a number of species supposed to be Iberian endemics, some with restricted distributions (such as *Agabus hozgargantae*; *Limnoxenus olmoi* Hernando and Fresneda, 1994; *Limnebius bacchus* Balfour-Browne, 1978; or *Ochthebius figueroi*) have been found in north Morocco, as well as a number of species new to science (Ribera et al., 1999, and unpublished data). It is likely that some other presumed southern Iberian endemics will be found in north Africa, but this will have the effect of reinforcing the already recognised strong relationships between the fauna of both sides of the straits of Gibraltar.

4.2. Biogeographical relationships

For the whole aquatic Coleoptera, for the endemic species, and for the family Hydraenidae, the defined geographical regions proved to be significant. In all cases the number of species occurring in a single area was higher than expected at random, i.e. species tend to occur within individual areas. When individual groups were analysed, the one with a most clear deviation from a Poisson distribution was Hydraenidae, although other groups were marginally significant (aquatic Adephaga). In other groups the number of species occurring in only one region was lower than expected at random, but differences were not enough to be considered significant at the usual error levels.

According to the analysis of all species (Iberian plus French and Moroccan), the fauna of aquatic Coleoptera of the Iberian peninsula cannot be considered to form a biogeographical unit. The main division of the dendrograms obtained using Jaccard similarity index separated northern and southern regions within Iberia, with the Pyrenean region more similar to France than to the southern regions, and the South East more similar to Morocco than to northern regions. The lack of significance of the regions defined when only Iberian species were analysed is another clear indication that they do not form a homogeneous group.

Within the northern biogeographical areas, the fauna of the Pyrenean region is very similar to that of the Cantabrian mountains, with no significant differences when compared individually. The Cantabrian fauna is also very similar to that of the Hercynian region (individual differences were also not significant), although differences between the Pyrenean and the Hercynian regions were in general significant (all comparisons except for hydraenid endemics). The Cantabrian region can thus be considered to be a transition area between the Pyrenees (and Europe) and the Hercynian Iberia. The transition between the Pyrenean and the Hercynian regions through the Ebro valley is, however, much sharper, as already noted for water beetles by Ribera et al. (1996), but also for other groups [e.g. freshwater Cyprinids (Zardoya and Doadrio, 1998); see also references in Ribera et al., 1996].

In the south, both the global fauna and the species of Hydraenidae of the south east region cannot be considered to be significantly different from those of Morocco when compared individually with the Jaccard similarity index. The strong relationships between the fauna and flora of the north African Rif and the south east of Spain are well known, with many common species and vicariant species-pairs. The same floristic assemblages can be recognised on both sides of the Strait, with parallel areas according to geological and orographic characteristics (Valdés, 1991). In contrast, the flora of Sierra Morena, which lies north of the Guadalquivir basin, and was in consequence included in the Hercynian Iberia, has no counterpart in north Morocco (Valdés, 1991).

The fauna of the South West was poorly defined, being in most cases not significantly different from that of the Cantabrian region, despite not being in direct contact. This is because of the low number of species recorded from this area, and the general widespread distributions of those that are recorded. It is expected that further data will contribute to a better definition of the faunal relationships of this region.

The patterns obtained with an analysis of similarities are purely descriptive, and without additional information it is not possible to interpret their underlying causes. However, because the areas considered here were a priori defined according to general geological characteristics, it is likely that the historical factors determining their geological origin were also prevalent in determining their faunistic relationships. Most of the regions were defined according to the limits of Tertiary basins, which were probably very effective barriers during most of the Tertiary, as they were flooded by open or inland seas until they drained at different times at the end of that period (Dercourt et al., 1985; Uchupi, 1988; Friend and Dabrio, 1996). Most of the extant species of Coleoptera, and almost certainly most of the species groups or higher taxa, date back to at least Late Tertiary or Early Pleistocene (Coope, 1979, 1995), and it is likely that the distribution of at least the endemic fauna is strongly influenced by the geography of the Iberian peninsula in that period. In a study of the amphibians and freshwater fish in the main river basins of the Iberian peninsula, Vargas et al. (1998) also suggest the main role of the Middle and Upper Tertiary geography in the patterns of distribution of Iberian endemics, with a similar division between northern and southern areas, and in particular the South East.

Despite the strong indication of the role of the late Tertiary geography in the distribution of at least the endemic fauna of the Iberian peninsula, and until more detailed phylogenetic or phylogeographic studies are available, it should be considered that other processes may result in similar general distribution patterns. In particular, possible hidden ecological similarities between some of the areas (derived by their common geological history or their similar geographical situation), despite their apparent heterogeneity, may confound the historical factors influencing the composition of the regional fauna. The separation of ecological from historical factors determining the distribution of species is always complex: a robust and complete phylogeny and phylogeography of the species are necessary, as well as detailed knowledge of ranges and autecological requirements (Endler, 1982; Herrera, 1992; see e.g. Johnson et al., 1998 for a recent example of environmental explanations for centres of endemism).

4.3. Patterns of endemism

The correlation between the size of the regions and the number of endemics was highly significant, as expected when different groups and heterogeneous areas are plotted together (Rosenzweig, 1995). The correlation between the total number of species and area (including non-endemics) could not be investigated, because the detailed knowledge of the distribution of trans-Iberian species is still incomplete. The distribution of the endemic species is, however, much better known.

The region with the highest proportion of exclusive endemics is the South East; the higher absolute number of Hercynian endemics is mostly accounted for by its larger area. The high endemicity of the South East may be due to: (1) its geological origin, forming a well defined isolated plate until Late Miocene (Dercourt et al., 1985; Uchupi, 1988); (2) its particular environmental conditions, with an arid climate and gypsum soils resulting in a very characteristic array of saline habitats originating in Messinian deposits (Friend and Dabrio, 1996); or simply (3) to the incomplete knowledge of the fauna of north Morocco, which results in the overestimation of the number of endemics by the inclusion of species that also occur in north Africa but have yet to be discovered (see above). Similar patterns in other groups (such as flora, Valdés, 1991; or amphibians and freshwater fishes, Vargas et al., 1998) are strong indications of the biogeographical distinctiveness of the South East region, although this does not contribute to the resolution of the possible causes of its peculiarity.

When considered individually, the different taxonomic groups of aquatic Coleoptera did not show a common pattern. While for Dytiscidae the number of endemics was always significantly correlated with area, for Hydraenidae, the other family with large number of endemics, this correlation was not significant. This was due to the high number of endemics in the South East region, despite its relatively small area. The peculiarity of the hydraenid fauna of the South East is also demonstrated by its isolated position on the dendrogram of faunal similarities, at the base of all groups [Fig. 4(b)]. In Helophoridae a disproportionate number of the endemics (with respect to its area) occur in the Cantabrian region, with five of the eight endemic species and subspecies, one of them exclusive to this area. This lack of coincidence of areas of endemism of different taxa seems to be a common pattern for many groups and geographical scales (e.g. Gaston et al., 1995; Prendergast and Eversham, 1997; Williams and Gaston, 1998.) However, for certain groups and areas there seems to be some agreement, e.g. Pearson and Carroll (1998 and references therein), which questions the existence of all-purpose biodiversity indicators.

Among Iberian aquatic Coleoptera there is a high proportion of endemics in low and medium altitude mountain systems, but not in the alpine area, above ca. 1500 m. No endemics are found in the main chain of the Pyrenees, and the few endemics in the alpine zone of the central and southern Iberian mountain systems do not have restricted distributions; they are likely to be relict glacial species with much wider former ranges. This lack of alpine endemics is contrary to what is observed with many terrestrial Coleoptera, such as carabids or chrysomelids, for which a high number of endemics species and genera with very local distributions are known from the alpine area of high mountains (e.g. Zaballos and Jeanne, 1994; Petitpierre, in press). One striking case is the Sierra Nevada, considered to be the most important centre of plant diversity in the western Mediterranean region, specially for alpines (Domínguez Lozano et al., 1996; Blanca et al., 1998), and with percentages of endemism from 30 to 80% depending on the habitats. Its alpine insect fauna also has a high number of endemics, specially among Carabidae and Chrysomelidae (Mateu and Colás, 1954; Zaballos and Jeanne, 1994; Petitpierre, in press). In contrast, the only water beetle that can be considered endemic to Sierra Nevada is *Limnebius monfortei*, which so far has only been found in a medium altitude stream (around 1500 m), not in the alpine area (Fresneda and Ribera, 1998). Other Iberian endemic species are at least found in some of the nearby mountain systems in the South East region (such as *Deronectes depressicollis* or *Hydraena tatii*).

4.4. Conservation status of the rare species

Rare species tend to be the focus of conservation efforts for their vulnerability and public appeal. However, the causes of rarity are manifold (Gaston, 1994), and it is not possible (or desirable) to automatically designate all rare species as vulnerable and in need of protection.

A first category of rare species include those for which there is some reason to suspect that their actual distribution and/or abundance is larger. Some of the rare Iberian endemics have been discovered very recently, and there is insufficient information available about their actual distribution (e.g. *Ochthebius irenae* and *Laccobius gloriana*, although the latter is of special concern as one of the type localities has been severely disrupted recently, Gentili and Ribera, 1998). For others, new populations have been recently discovered, thus suggesting a wider distribution of the species (e.g. *Agabus hozgargantae*, *Deronectes depressicollis* and *D. ferrugineus*, the former no longer considered to be an Iberian endemic, see above). They may also belong to species complexes that are still to be studied in detail (e.g. *Agabus picotae*). None of these species is proposed for inclusion in the IUCN Red list, and *Agabus hozgargantae* is excluded.

A second category of rare species includes relict species (i.e. rare species which have not evolved in situ, but are the remnants of a former wider distribution). Some isolated populations of species considered to be rare in Iberia may in fact be relicts, e.g. some boreoalpine species such as *Helophorus lapponicus* Thomson, 1854 (Angus, 1983), but the sole criterion of isolation is not enough to guarantee their relict status. Isolation may be simply due to ecological reasons and the population of a favourable patch may have a recent origin (see e.g. Cain et al., 1998, Clark, 1998 and Tollefsrud et al., 1998 for recent examples with poorly dispersing plants).

Species with isolated but distant populations are strong candidates to be relicts, as is the case of other species of the subgenus *Asiobates* within the genus *Ochthebius* (*O. bellieri* and *O. figueroi*, Appendix A). The case of *O. figueroi* is particularly demonstrative, as it is known in Spain only from the type localities in the head of the river Ebro, but was subsequently identified as a Pleistocene fossil from England by Angus (1993), and it is also present in Morocco (M. A. Jäch, pers. comm., 1998, included in Ribera et al., 1999). Similarly, *O. bellieri* was only known from a few specimens from the extreme south of Spain, but it has recently been discovered in two localities in the Sierra de Alcaraz, in Albacete, at a distance of about 400 km (Ribera et al., 1998). *Ochthebius cantabricus* and *O. ferroi* are only known from the type locality, and little can be said about their possible distributions.

Acilius duvergeri is a possible relict species with a very fragmented distribution, although the extend to which its present rarity is the result of natural processes (i.e. it is a true relict) or human activity (habitat loss and fragmentation) is unknown. It is a potential candidate to be considered for inclusion in the Bern Convention, as it fulfils all requirements: it is a large and conspicuous beetle, and in comparison with the two species of aquatic Coleoptera already included (*Dytiscus latissimus* and *Graphoderus bilineatus*, Helsdingen et al., 1996) it has a more restricted distribution, fewer populations are known, and none is at present known to sustain a large number of specimens. More detailed studies are necessary to both assess its status and to design action plans to guarantee its persistence. Its permanence in the IUCN red list is fully justified.

A third group includes true rare local endemics. Although they should be regarded as potentially vulnerable, the inclusion of long lists of local, inconspicuous species in the IUCN red list is questionable, since these species are rarely suitable for special actions. The number of invertebrates from Portugal and Spain in the 1996 list is already large, and probably disproportionate in relation to their relative area (IUCN, 1996). The best option would be measures directed to the conservation of the habitat (e.g. through the Habitat 2000 European Commission directive).

Some species of the *Limnebius nitidus* subgroup (*L. ordunayi*, *L. hilaris*, *L. millani* and *L. monfortei*, Appendix A) provide good examples of potentially vulnerable species with restricted distributions. Their range is not only restricted on a regional scale, but even within the individual river or stream in which they are found, as they occur only in some of their permanent sections (typically in the headwaters). In more temporary sections, or in the lower reach of the rivers, they are replaced by common widespread species of the same group (such as *L. maurus* Balfour-Browne, 1978). The same pattern (replacement of an endemic with a widespread species of the same group) is found in many of the endemics with restricted distributions among Hydraenidae and Dytiscidae. The individual protection of all these species is problematic, owing to their small size and lack of public appeal, but the habitats in which they live (upper reaches of well preserved, undisturbed, streams at medium altitudes) are specially vulnerable, and should be a target for conservation actions (see below).

The two subspecies of *Rhithrodytes agnus* are the only rare endemics proposed to be left in the IUCN red list. As already noted, they have a very restricted distribution which is assumed to be well known, and the protection of the two extant populations is feasible through the conservation of the streams and springs in which they occur.

Finally, a fourth category includes species that have become increasingly rare due to human activities, resulting in habitat loss and fragmentation. These species are particularly suitable for conservation efforts, as the cause of their rarity is generally known. *Potamophilus acuminatus* and *Stenelmis consobrina* are among the species likely to have become rare due to habitat degradation. As with *A. duvergeri*, the first necessary step would be a survey of their present status, with a detailed census of the number and size of at least the most important populations. Individual conservation measures will become possible with knowledge of the insect's biology.

4.5. Geographical areas and habitats of special conservation value

Based on the results of this paper, three main types of habitat can be considered to have the highest conservation value in what refers to Iberian aquatic Coleoptera: (1) freshwater streams at medium altitude for the Iberian endemics, (2) large freshwater lagoons (coastal and inland) for southern or northern species at the limit of their distribution (and for their high diversity), and (3) saline streams in the south east of Spain and the central Ebro valley for their most particular fauna and ecological conditions. The detailed analysis of the specific sites to be preserved is out of the scope of this paper, and what follows are only some general considerations, with some examples of particularly interesting localities.

1. Medium altitude streams (ca. 1000–1500 m). In the Iberian peninsula most, if not all, montane protected areas are at high elevations (e.g. the National Parks of Picos de Europa in the Cantabrian mountains, Ordesa in the Pyrenees, or Sierra Nevada in the South East, include mostly alpine areas). This benefits sensitive subalpine and alpine communities, which are certainly endangered and worthy of protected status. However, based on the criteria of both maximising total biodiversity and endemic diversity, medium altitude mountains certainly deserve more attention, and human impact should be regulated (see also Fleishman et al., 1998 for similar considerations on the Great Basin mountain ranges of the USA). Some examples of habitats with a very rich fauna of aquatic Coleoptera, in particular endemic species, are the medium altitude streams of Serra del Cadi (pre-Pyrenees); Sierra de la Demanda (NE Spain, in the Hercynian Iberia); the east part of the provinces of Lugo and Orense (NW Spain); Serra da Estrela (N Portugal); Sierra de Guadarrama (central Spain); the streams in the Parque Natural de los Alcornocales (Cádiz, in the South East region); and Sierra

de Alcaraz in SE Spain (e.g. Arroyo de la Fuenfría, with 16 species of Hydraenidae, 6 of them Iberian endemics).

2. Freshwater lagoons. A more detailed analysis of the conservation value of Mediterranean coastal habitats can be found in Ribera et al. (1996). Other interesting lagoons with a high diversity of aquatic Coleoptera, including some likely glacial relict species, are the Estanys de Capmany and Laguna de Pitillas (in the provinces Girona and Navarra respectively, Pyrenean region) (Ribera and Aguilera, 1996); Laguna del Arquillo and Ojos de Villaverde (Sierra de Alcaraz, south east of Spain) (Millán et al., 1999); and the lagoons around Vilanova de Milfontes (south Portugal).

   A particular case are ponds in high altitude platoos, usually at ca. 2000 m, in the Pyrenees (e.g. Pla de Beret in Val d'Aran and Meranges in La Cerdanya), the Cantabrian mountains and in Serra da Estrela. In them some of the scarce Iberian endemics of stagnant waters can be found, as well as some likely glacial relicts (mainly species of the genera *Helophorus*, *Hydroporus* and *Agabus*, Appendix A). In some cases conservation of these areas may depend on their traditional use as summer pastures (Ribera and Foster, 1995).

3. Of special relevance is the conservation of the fauna associated with the saline streams in the central Ebro Valley and the lowlands of South East Spain ("barrancos" or "vales" in the Ebro valley, and "ramblas" in the South East, see e.g. Moreno et al., 1997). Because some of these barrancos and ramblas are in the middle of agricultural areas, they face multiple environmental risks, despite the locally protected status of some sites. This is the case of Rambla Salada, which has suffered a strong decline in abundance of some endemic species of the genus *Ochthebius* owing to desalinisation (Andrés Millán, personal communication, 1998). The high salinity of the water, necessary for the survival of these and other species, is influenced by alterations on a wider scale, and in this sense these species act as bioindicators of the conditions of the whole catchment, not only at the small scale of the local habitat.

   The fauna of aquatic Coleoptera of the central Ebro valley is relatively poor, owing to extreme aridity; so far the only local endemic species is *O. caesaraugustae*, known from some saline streams in Zaragoza and Navarra (Jäch et al., 1998; Ribera et al., 1998). Nevertheless, many southern species or Iberian endemics exclusively found in saline rivers and streams have there the northern limit of their distributions, as it shares many geological, historical and ecological characteristics with the South East area. The global insect fauna of some arid gypsiferous areas in the central Ebro valley is well known. Although the general composition is western Mediterranean in origin, there is a qualitatively important number of species so far considered to be endemic to the area (>150 species of insects have been recently described as new to science from an area of 20 km^2, Melic and Blasco-Zumeta, in press).

   Urgent conservation priorities in the central Ebro valley therefore include all aquatic systems, as irrigation plans for agricultural development are already using the natural drainage network for construction of irrigation channels and the drainage of runoff from the cultivated fields. In the recent proposal for the Habitat 2000 directive, the autonomous government of Aragón has not included any of these unique, relict, arid areas among the habitats worthy of conservation (Melic and Blasco-Zumeta, in press).

5. Conclusions

From the present study it can be concluded that the main measures to be taken in order to promote the conservation of Iberian aquatic Coleoptera are: (1) the updating of the IUCN red list and, eventually, the Bern convention, with the practical consequences that this action implies (such as a survey of the status of the Iberian populations, and the implementation of protection measures for at least some of them); (2) a survey of some of the rare endemic species, to assess their conservation status for inclusion in national or international red lists; (3) the inclusion of some northern, southern or eastern species with restricted distribution within Iberia in national red lists, with special attention to southern ones, as these are in most cases the only populations in continental Europe; (4) the extension of the protected alpine areas of national parks to include medium altitude streams; and (5) the inclusion of other well preserved medium altitude streams, and saline lowland streams in the South East and the central Ebro valley, in protection plans at an international (e.g. Habitat 2000 European directive), national or local level, taking into consideration the effect of possible alterations in the whole catchment area and not only in their physical proximity.

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Appendix A

Iberian endemic species of aquatic Coleoptera (including some species occurring in the northern side of the Pyrenees and some areas in southern France). Synonyms and species with uncertain taxonomic status are not included (see Ribera et al., 1999 for details). Species of Scirtidae, Donaciinae and Bagoini were excluded from the detailed analysis of the fauna, and hence no distribution or ecological data are given for them. Endemic subspecies are not numbered.

Rar.: rarity. 1, Restricted distribution, not low abundance; 2, not restricted distribution, low abundance; 3, restricted distribution, low abundance (see Methods).

Hab.: main habitat type. 0, Strictly stagnant waters; 1, strictly running waters; 2, running and stagnant waters.

Regions: 0, absent; 1, present; Pyr, Pyrenean; Cant, Cantabrian; Herc, Hercynian. No R.: Number of regions in which the species occur.

Table A1

No	Species	Rar.	Hab.	Region					No R.
				Pyr	Cant	Herc	South East	South West	
	Dytiscidae								
1	*Agabus albarracinensis* Fery, 1986		2	1[a]	1	1	0	0	3
2	*A. dettneri* Fery, 1986		0	0	0	1	0	0	1
3	*A. picotae* Foster & Bilton, 1997	1	1	0	0	0	0	1	1
4	*Deronectes algibensis* Fery & Fresneda, 1988	1	1	0	0	0	1	0	1
5	*D. angusi* Fery & Brancucci, 1997		1	0	0	1	0	0	1
	D. aubei sanfilippoi Fery & Brancucci, 1997		1	1[a]	1	0	0	0	2
6	*D. bicostatus* (Schaum, 1864)		1	0	0	1	0	0	1
7	*D. costipennis costipennis* Brancucci, 1983		1	0	0	1	0	0	1
	D. costipennis gignouxi Fery & Brancucci, 1997		1	0	1	0	0	0	1
8	*D. delarouzei* (Jac. du Val, 1857)		1	1[a]	1	0	0	0	2
9	*D. depressicollis* (Rosenhauer, 1856)		1	0	0	0	1	0	1
10	*D. ferrugineus* Fery & Brancucci, 1997		1	0	0	1	0	0	1
11	*D. fosteri* Aguilera & Ribera, 1996		1	1	0	0	0	0	1
12	*D. wewalkai* Fery & Fresneda, 1988		1	0	0	1	0	0	1
13	*Graptodytes castilianus* Fery, 1995		2	1	0	1	0	0	2
14	*Hydroporus brancoi* Rocchi, 1981		2	0	0	1	0	0	1
15	*H. brancuccii* Fery, 1986		1	0	0	1	0	0	1
16	*H. constantini* Hernando & Fresneda, 1994	1	1	0	0	1	0	0	1
17	*H. decipiens* Sharp, 1877		2	0	0	0	1	1	2
18	*H. nevadensis* Sharp, 1882		2	0	1	1	1	1	4
19	*H. normandi* Régimbart, 1903		1	1[a]	1	1	1	1	5
20	*H. paganettianus* Scholz, 1923		2	0	1	1	0	0	2
21	*H. vagepictus* Fairmaire & Laboulbène, 1854		2	1[a]	1	1	0	0	3
22	*H. vespertinus* Fery & Heindrich, 1988		0	0	1	1	0	0	2
23	*Hygrotus fresnedai* (Fery, 1992)		0	0	0	1	0	0	1
24	*Nebrioporus* (*Zimmermannius*) *baeticus* (Schaum, 1864)		1	1	0	1	1	0	3
	N. (*Nebrioporus*) *bucheti cazorlensis* (Lagar, Fresneda & Hernando, 1987)		1	1	0	0	1	0	2
25	*N.* (*N.*) *carinatus* (Aubé, 1836)		1	0	1	1	0	0	2
26	*N.* (*N.*) *croceus* Angus, Fresneda & Fery, 1992	1[b]	1	0	0	1	0	0	1
27	*N.* (*N.*) *fabressei* (Régimbart, 1901)		1	1[a]	0	1	0	0	2
28	*Rhithrodytes agnus* Foster, 1993	1[b]	1	0	0	1	0	0	1
	R. agnus argaensis Bilton & Fery, 1996	1[b]	1	0	0	1	0	0	1
29	*R.bimaculatus* (Dufour, 1852)		1	1[a]	1	0	0	0	2
30	*Stictonectes epipleuricus* (Seidlitz, 1887)		1	1[a]	1	1	1	1	5
31	*S. occidentalis* Fresneda & Fery, 1990		1	0	0	0	0	1	1
32	*Stictotarsus bertrandi* (Legros, 1956)		1	0	0	1	0	0	1
	Helophoridae								
33	*Helophorus* (*Empleurus*) *hispanicus* (Sharp, 1915)		T	0	0	1	0	0	1
34	*H.* (*Atracthelophorus*) *bameuli* Angus, 1987		0	0	1	1	0	0	1
35	*H.* (*A.*) *korotyaevi* Angus, 1985		1	0	1	0	0	0	1
	H. (*A.*) *leontis leontis* Angus, 1985		2	0	1	1	0	0	2

(continued)

Table A1 (*continued*)

No	Species	Rar.	Hab.	Region Pyr	Cant	Herc	South East	South West	No R.
36	*H.* (*A.*) *nevadensis* Sharp, 1916		2	0	1	1	0	0	2
37	*H.* (*Rhopalohelophorus*) *calpensis* Angus, 1988	1[b]	0	0	0	0	1	0	1
38	*H.* (*R.*) *jocoteroi* Angus & Díaz Pazos, 1991		2	0	0	1	0	0	1
39	*H.* (*R.*) *seidlitzii* Kuwert, 1885		2	0	1	1	1	1	4
	Hydrochidae								
40	*Hydrochus angusi* Valladares, 1988		2	0	0	1	0	0	1
41	*H. ibericus* Valladares, Díaz Pazos & Delgado, 1999		1	0	0	0	1	0	1
42	*H. interruptus* Heyden, 1870		1	0	0	1	0	0	1
43	*H. nooreinus* Henegouwen & Sáinz-Cantero, 1992		1	0	0	0	1	0	1
	Hydrophilidae								
44	*Enochrus* (*Methydrus*) *morenae* (Heyden, 1870)		1	1[a]	1	1	1	1	5
45	*Hemisphaera infima* Pandellé in Uhagón, 1876		1	0	0	1	0	0	1
46	*Laccobius* (*Dimorpholaccobius*) *gloriana* Gentili & Ribera, 1998	1	1	0	0	1	0	0	1
	Hydraenidae								
47	*Enicocerus legionensis* Hebauer & Valladares, 1985		1	0	0	1	0	0	1
48	*Hydraena* (*Haenydra*) *altamirensis* Díaz Pazos & Garrido, 1993	1[b]	1	0	0	1	0	0	1
49	*H.* (*Haenydra*) *bitruncata* Orchymont, 1934		1	1[a]	0	1	0	0	2
50	*H.* (*Haenydra*) *catalonica* Fresneda, Aguilera & Hernando, 1995		1	1	0	0	0	0	1
51	*H.* (*Haenydra*) *emarginata* Rey, 1885		1	1[a]	1	0	0	0	2
52	*H.* (*Haenydra*) *exasperata* Orchymont, 1935		1	0	1	1	1	1	4
53	*H.* (*Haenydra*) *gaditana* Lagar & Fresneda, 1990	1	1	0	0	0	1	0	1
54	*H.* (*Haenydra*) *hispanica* Ganglbauer, 1901		1	0	0	1	0	0	1
55	*H.* (*Haenydra*) *iberica* Orchymont, 1936		1	0	0	1	0	0	1
56	*H.* (*Haenydra*) *lusitana* Berthélemy, 1977		1	0	0	1	0	0	1
57	*H.* (*Haenydra*) *manfredjaechi* Delgado & Soler, 1991		1	0	0	0	1	0	1
58	*H.* (*Haenydra*) *monstruosipes* Ferro, 1986		1	0	1	0	0	0	1
59	*H.* (*Haenydra*) *tatii* Sáinz-Cantero & Alba-Tercedor, 1989		1	0	0	0	1	0	1
60	*H.* (*Haenydra*) *zezerensis* Díaz Pazos & Bilton, 1995	1	1	0	0	1	0	0	1
61	*H.* (*Hydraena*) *affusa* Orchymont, 1936		1	1	1	1	1	0	4
62	*H.* (*Hydraena*) *albai* Sáinz-Cantero, 1993		1	0	0	0	1	0	1
63	*H.* (*Hydraena*) *alcantarana* Ieniestea, 1985	1	1	0	0	0	1	0	1
64	*H.* (*Hydraena*) *barrosi* Orchymont, 1934		1	1[a]	1	1	0	0	3
65	*H.* (*Hydraena*) *bolivari* Orchymont, 1936		1	0	0	0	1	1	2
66	*H.* (*Hydraena*) *brachymera* Orchymont, 1936		1	1[a]	1	1	0	0	3
67	*H.* (*Hydraena*) *carbonaria* Kiesenwetter, 1849		1	1[a]	0	1	1	0	3
68	*H.* (*Hydraena*) *corinna* Orchymont, 1936		1	0	0	1	0	0	1
69	*H.* (*Hydraena*) *corrugis* Orchymont, 1934		1	1[a]	1	1	1	1	5
70	*H.* (*Hydraena*) *curta* Kiesenwetter, 1849		1	1[a]	0	0	0	0	1
71	*H.* (*Hydraena*) *delia* J.Balfour-Browne, 1978		1	1	0	0	0	0	1
72	*H.* (*Hydraena*) *inapicipalpis* Pic, 1918		1	1[a]	1	1	0	0	3
73	*H.* (*Hydraena*) *n.sp.* Jäch & Díaz-Pazos, p.c. 1998		1	0	1	0	0	0	1
74	*H.* (*Hydraena*) *lucasi* Lagar, 1984		1	1	0	0	1	0	2
75	*H.* (*Hydraena*) *marcosae* Aguilera, Hernando & Ribera, 1997		1	0	0	1	0	0	1
76	*H.* (*Hydraena*) *m.sp.* Millán & Aguilera, p.c. 1999	3	1	0	0	0	1	0	1
77	*H.* (*Hydraena*) *quilisi* Lagar, Fresneda & Hernando, 1987		1	1[a]	0	0	1	0	2
78	*H.* (*Hydraena*) *servilia* Orchymont, 1936		1	0	0	0	1	0	1
79	*H.* (*Hydraena*) *sharpi* Rey, 1886		1	0	0	1	0	0	1
80	*H.* (*Hydraena*) *stussineri* Kuwert, 1888		1	1[a]	1	1	1	0	4
81	*H.* (*Hydraena*) *unca* Valladares, 1989		1	0	1	1	1	1	4
82	*Limnebius cordobanus* Orchymont, 1938		1	1	1	1	1	1	5
83	*L. gerhardti* Heyden, 1870		1	0	1	1	1	1	4
84	*L.hilaris* J.Balfour-Browne, 1978	1	1	0	0	0	1	0	1
85	*L.hispanicus* Orchymont, 1941		1	0	0	0	1	0	1
86	*L.ibericus* J.Balfour-Browne, 1978		1	0	0	1	0	0	1
87	*L.ignarus* J.Balfour-Browne, 1978		1	0	0	0	1	0	1
88	*L.lusitanus* J.Balfour-Browne, 1978		1	0	0	1	0	0	1
89	*L.millani* Ribera & Hernando, 1998	1	1	0	0	0	1	0	1
90	*L.monfortei* Fresneda & Ribera, 1998	1[b]	1	0	0	0	1	0	1

(continued)

Table A1 (*continued*)

No	Species	Rar.	Hab.	Region					No R.
				Pyr	Cant	Herc	South East	South West	
91	*L.montanus* J.Balfour-Browne, 1978		1	0	0	1	0	0	1
92	*L.nanus* Jäch, 1993		1	0	0	1	0	0	1
93	*L.ordunyai* Fresneda & Ribera, 1998	1	1	0	0	1	0	0	1
94	*Ochthebius* (*Asiobates*) *bellieri* Kuwert, 1887	2	1	0	0	0	1	0	1
95	*O.* (*A.*) *cantabricus* J.Balfour-Browne, 1978	1[b]	1	0	1	0	0	0	1
96	*O.* (*A.*) *ferroi* Fresneda, Lagar & Hernando, 1993	3[c]	1	1	0	0	0	0	1
97	*O.* (*A.*) *heydeni* Kuwert, 1887		1	1[a]	1	1	0	1	4
98	*O.* (*A.*) *irenae* Ribera & Millán, in press	1	0	0	0	0	1	0	1
99	*O.* (*Cobalius*) *serratus* Rosenhauer, 1856	1	1	0	0	0	1	0	1
100	*O.* (*Ochthebius*) *albacetinus* Ferro, 1984	1	1	0	0	0	1	0	1
101	*O.* (*O.*) *caesaraugustae* Jäch, Ribera & Aguilera, 1998		1	1	0	0	0	0	1
102	*O.* (*O.*) *delgadoi* Jäch, 1994		2	1	0	0	1	0	2
103	*O.* (*O.*) *glaber* Montes & Soler, 1988[d]		1	0	0	0	1	0	1
104	*O.* (*O.*) *marginalis* Rey, 1886		1	1[a]	1	1	1	1	5
105	*O.* (*O.*) *montesi* Ferro, 1984		1	0	0	0	1	0	1
106	*O.* (*O.*) *tudmirensis* Jäch, 1997		1	0	0	0	1	0	1
	Elmidae								
107	*Elmis perezi* Heyden, 1870		1	1[a]	0	1	0	0	2
	Limnius perrisi carinatus Pérez-Arcas, 1865		1	0	1	1	0	0	2
108	*Oulimnius bertrandi* Berthélemy, 1964		1	0	0	1	0	0	1
109	*O. cyneticus* Berthélemy & Whytton da Terra, 1979	2	1	0	0	1	0	1	2
	O. tuberculatus perezi Crotch in Sharp, 1872		1	0	1	1	1	0	3
	Dryopidae								
110	*Dryops championi* Dodero, 1918		1	0	0	1	0	0	1
	Scirtidae								
111	*Cyphon iberus* Nyholm, 1976								
112	*C. pandellei* Bourgeois, 1884								
113	*Elodes peninsularis* Pic, 1898								
114	*E. scutellaris* Tournier, 1868								
115	*E. trilineatus* Chevrolat, 1865								
116	*Hydrocyphon championi* Reitter, 1903								
117	*H. fulvescens* Nyholm, 1977								
118	*H. hamiota* Nyholm, 1972								
119	*H. laeticolor* Nyholm, 1967								
120	*H. pernigrans* Nyholm, 1967								
121	*Microcara dispar* Seidlitz, 1872								
	Chyrysomelidae Donaciinae								
122	*Donacia* (*Donaciomima*) *galaica* Báguena, 1959								
	Curculionidae Bagoini								
123	*Bagous andalusiacus* González, 1971								
124	*B. franzi* González, 1967								
125	*B. fuentei* Pic, 1908								
126	*B. ibericus* González, 1971								

[a] Also found in the north side of the Pyrenees, and, in some cases, in some areas in southern France.
[b] So far only recorded from one locality.
[c] Only the holotype of the species is known.
[d] Some dubious specimens were recorded from the Balearic islands (Jäch, 1992), in which case the species would not be an Iberian endemic.

Appendix B

Eastern, southern or northern species with only few known localities in the Iberian peninsula (ca. < five). Species the presence of which is uncertain are excluded (see Ribera et al., 1999 for details, and for selected references of the distribution of the species). Species of Limnichidae, Scirtidae, Donaciinae and Bagoini are not included, due to the incomplete knowledge or their distribution. Codes of the main habitat and the geographical zones as in Appendix A.

Table B1

No	Species	Hab.	Region Pyr	Cant	Herc	South East	South West	No R.
	Eastern species							
	Hydrophilidae							
1	*Chasmogenus livornicus* (Kuwert, 1890)	0	1	0	0	0	0	1
	Northern species							
	Hydroscaphidae							
2	*Hydroscapha granulum* (Motschulsky, 1855)	1	0?	0	1	0	0	1
	Gyrinidae							
3	*Gyrinus minutus* Fabricius, 1798	0	1	1	0	0	0	2
4	*Gyrinus suffriani* Scriba, 1855	0	0?	0	0?	1	0	1
5	*G. paykulli* Ochs, 1927	0	1	0	0	0	0	1
	Haliplidae							
6	*Haliplus flavicollis* Sturm, 1834	2	1	0	0	0	0	1
7	*H. laminatus* (Schaller, 1783)	2	1	0	0	0	0	1
8	*H. variegatus* Sturm, 1834	0	1	0	0	0	0	1
9	*H. wehnckei* Gerhardt, 1877	1	1	0	0	0	0	1
	Dytiscidae							
10	*Agabus sturmii* (Gyllenhal, 1808)	0	1	1	0	0	0	2
11	*Graphoderus cinereus* (Linnaeus, 1758)	0	1	0	0	0	0	1
12	*Graptodytes pictus* (Fabricius, 1787)	2	1	0	0	0	0	1
13	*Hydaticus seminiger* (De Geer, 1774)	0	1	0	0	1	0	2
14	*H. transversalis* (Pontoppidan, 1763)[b]	0	1	0	0	0	0	1
15	*Hydroporus ferrugineus* Stephens, 1828	1	1	1	0	0	0	2
16	*H. incognitus* Sharp, 1869	0	1	1	0	0	0	2
17	*H. nigellus* Mannerheim, 1853	0	1	0	0	0	0	1
18	*H. palustris* (Linnaeus, 1761)	2	1	0	0	0	0	1
19	*Hygrotus parallelogrammus* (Ahrens, 1812)	0	1	0	0	0	0	1
20	*Ilybius fenestratus* (Fabricius, 1781)	0	1	0	0	0	0	1
21	*I. fuliginosus* (Fabricius, 1792)	2	1	0	0	0	0	1
22	*I. quadriguttatus* (Lacordaire, 1835)	0	1	0	0	0	0	1
23	*Nebrioporus luctuosus* (Aubé, 1836)	1	1	1	0	0	0	2
24	*Oreodytes septentrionalis* (Gyllenhal, 1827)	1	1	0	0	0	0	1
25	*Porhydrus lineatus* (Fabricius, 1775)	0	1	0	0	0	0	1
	Helophoridae							
26	*Helophorus granularis* (Linnaeus, 1761)	0	1	1	0	0	0	2
27	*H. illustris* Sharp, 1916	0	1	0	0	0	0	1
	Georissidae							
28	*Georissus laesicollis* Germar, 1831	1	1	1	0	0	0	2
	Hydrophilidae							
29	*Berosus jaechi* Schödl, 1991	0	1	0	0	0	0	1
30	*Cymbiodyta marginella* (Fabricius, 1792)	0	1	1	1	0	0	3
31	*Enochrus testaceus* (Fabricius, 1801)	0	1	0	0	0	0	1
32	*Hydrochara caraboides* Leach, 1815	0	1	0	0	0	0	1
33	*Hydrophilus piceus* (Linnaeus, 1758)	0	1	0	0	0	0	1
34	*Laccobius alternus* Motschulsky, 1855	1	1	0	1	0	0	2
	Hydraenidae							
35	*Limnebius myrmidon* Rey, 1883	1	1	1	0	0	0	2
36	*Ochthebius lejolisi* Mulsant & Rey, 1861	0	0	1	0	0	0	1
37	*O. sidanus* Orchymont, 1942	1	0	1	0	0	0	1
	Dryopidae							
38	*Dryops similaris* Bollow, 1936	1	0	1	1	0	0	2
39	*D. vienensis* (Heer, 1841)	1	1	0	0	0	0	1
	Elmidae							
40	*Stenelmis consobrina consobrina* Dufour, 1835	1	1	0	0	0	1	2
	Southern species							
	Noteridae							
41	*Canthydrus diophthalmus* (Reiche & Saulcy, 1855)[a,b]	0	0	0	0	1	0	1
	Dytiscidae							

(continued)

Table B1 (*continued*)

No	Species	Hab.	Region					No R.
			Pyr	Cant	Herc	South East	South West	
42	*Cybister vulneratus* Klug, 1834[a,b]	0	0	0	0	1	0	1
43	*Methles cribratellus* (Fairmaire, 1880)[a]	0	1	0	0	1	1	3
44	*Porhydrus vicinus* (Aubé, 1838) [a]	0	0	0	0	0	1	1
45	*Stictonectes escheri* (Aubé, 1836)	1	0	0	0	1	0	1
46	*S. formosus* (Aubé, 1836) [a]	1	0	0	0	1	0	1
47	*Stictotarsus otini* (Guignot, 1941) [a]	1	0	0	0	1	1	2
	Helophoridae							
48	*Helophorus gratus* Orchymont, 1934[a]	0	0	0	0	1	0	1
49	*H. cincticollis* Guillebeau, 1893[a]	0	0	0	0	1	0	1
	Hydrophilidae							
50	*Berosus bispina* Reiche & Saulcy, 1856	0	0	0	0	0	1	1
51	*Enochrus natalensis* (Gemminger & Harold, 1868) [a]	0	0	0	0	0	1	1
52	*Limnoxenus olmoi* Hernando & Fresneda, 1993[a]	0	0	0	1	0	1	2
	Hydraenidae							
53	*Hydraena allomorpha* Lagar & Fresneda, 1990[a]	1	0	0	0	1	0	1
54	*Ochthebius figueroi* Garrido, Valladares & Régil, 1992[a]	1	0	1	0	0	0	1
55	*O. merinidicus* Ferro, 1985[a]	1	0	0	0	1	0	1
56	*O. salinator* Peyerimhoff, 1924[a]	0	0	0	0	1	0	1
	Elmidae							
57	*Oulimnius fuscipes* (Reiche, 1879) [a]	1	0	0	0	1	0	1

[a] Only known populations in continental Europe.
[b] Probably extinct in the Iberian peninsula (see Ribera et al., 1996).

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