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The Hydradephaga of the Segura basin (SE Spain): twentyfive years studying water beetles
(Coleoptera)

Abstract - We present the results of 25 years of study of the faunistics, biogeography, ecology and conservation of the Hydradephaga of the Segura river basin. Eighty one species have been recorded from the area, ca. 45% of the total of species found in the Iberian peninsula. Six of them are Iberian endemics, and fourteen are considered to be rare within the basin, although most of these are not rare in an Iberian context.

The phenetic hierarchy of relationships among the western-Palaearctic regions considered shows a clear similarity of the fauna of the Segura basin with that of the Maghreb, which, together with the rest of the Iberian fauna form a well defined group isolated from the rest of the European areas. Within the Iberobalear region, there is also a clear north-south division, with a secondary classification into western and eastern basins. The Balearic islands seem to be a relatively independent biogeographical unit, although more related with the southern cluster.

The environmental characteristics determining the distribution of the Hydradephagan fauna in the study area, as determined by Correspondence Analysis, are altitude, degree of mineralization of the water, and amount and type of riparian vegetation.

Using a semi-quantitative scoring system to evaluate the vulnerability of the species only *Hydroporus decipiens* had a vulnerability value considered to be high (9), due to its rarity within the basin and to its general restricted distribution, although the incomplete knowledge of its distribution and taxonomy could be a distorting factor. With a similar value (8), *Nebrioporus baeticus* is a typical inhabitant of saline running waters, highly endangered habitat due to the increasing use of irrigation in the surrounding fields.

The stations with the highest conservation interest were mountain streams in the NW of the basin, which are also of high conservation interest for other aquatic Coleoptera (e.g. Hydraenidae). A disadvantage of the index applied (IC, "conservation interest") is the lack of reference to the conservation interest of habitats outside the study area. Thus, the saline or hypersaline streams, which are extremely rare in an European (or even global) context, are not considered of particular relevance due to the poor species richness and local abundance. The use of other criteria for the selection of sites of conservation value, such as complementarity, could overcome this limitation.

Riassunto - *Gli Idroadefagi del bacino del Segura (Spagna sud-orientale): venticinque anni studiando coleotteri acquatici (Coleoptera).*

Gli autori presentano i risultati di 25 anni di studio sulla faunistica, biogeografia, ecologia e conservazione degli Hydradephaga del bacino del fiume Segura. Ottantuno specie sono state segnalate dell'area, pari a circa il 45% delle specie note della Penisola Iberica. Sei di queste specie sono endemiche iberiche e 14 sono considerate rare nel bacino, malgrado la maggior parte di queste non siano rare nel contesto iberico.

La gerarchia fenetica delle relazioni tra le aree ovest-paleartiche considerate mostra una chiara similarità della fauna del bacino del Segura con quella del Maghreb, che, insieme al resto della fauna iberica forma un gruppo ben definito isolato dalle restanti aree europee. All'interno della regione ibero-baleare, c'è anche una chiara divisione nord-sud, con una suddivisione secondaria nei bacini occidentali e orientali. Le Isole Baleari sembrano essere un'unità biogeografica relativamente indipendente, anche se più correlata al gruppo meridionale.

Le caratteristiche ambientali determinanti la distribuzione dell'Idroadefagofauna nell'area di studio, come stabilite con l'analisi della corrispondenza, sono: altitudine, grado di mineralizzazione dell'acqua, quantità e tipo della vegetazione riparia.

Utilizzando un sistema di punteggio semi-quantitativo per valutare la vulnerabilità delle specie, solo per *Hydroporus decipiens* è stato riscontrato un valore di vulnerabilità considerato elevato (9), a causa della sua rarità all'interno del bacino e della sua distribuzione generale ristretta, sebbene l'incompleta conoscenza della sua distribuzione e tassonomia potrebbero essere un fattore distorcente. Un valore simile (8) è stato riscontrato per *Nebrioporus baeticus*, un tipico abitante delle acque correnti saline, un habitat fortemente minacciato dall'aumento dell'uso dell'irrigazione nei campi circostanti.
Le stazioni con il più elevato interesse conservazionistico sono risultate i torrenti montani nel nordovest del bacino che sono anche di elevato interesse conservazionistico per altri Coleotteri acquatici (es. Hydraenidae). Un inconveniente dell'indice usato (IC, "interesse conservazionistico") è la mancanza di riferimenti all'interesse conservazionistico degli habitat al di fuori dell'area di studio. Quindi, i corsi d'acqua salini o ipersalini, che sono estremamente rari nel contesto europeo (o anche globale), non sono considerati di particolare rilevanza a causa della bassa ricchezza specifica e dell'abbondanza locale. L'uso di altri criteri per la selezione dei siti di valore conservazionistico, come per esempio la complementarità, potrebbe superare questa limitazione.

Key words: Iberian peninsula, Segura basin, Coleoptera, Hydradephaga, Faunistical, Biogeography, Ecology, Conservation.

INTRODUCTION

Waste water, dams and canalisation, overflow from surrounding irrigation fields, overexploitation of the groundwater reservoirs, or destruction of the riparian vegetation are only some of the factors that have affected the ecological dynamics of seawater bodies (Dechamps & Naiman, 1989; Velasco & Millán, 1995). A pre-requisite for reducing these impacts to preserve the ecological value of our aquatic ecosystems is to know their biodiversity and the processes that, at an ecological or historical scale, have generated this biodiversity. This is particularly so in the Mediterranean basin, one of the world's hotspots of biodiversity (Myer et al., 2000).

For about 25 years the "Ecología acuática" (Aquatic ecology) team of the University of Murcia has developed a series of research projects with the objective of studying, characterising and preserving the biodiversity of aquatic macroinvertebrates of the Segura river basin, an example of a complex and heterogeneous macro-fluvial ecosystem in the Mediterranean region. Through these studies we have gathered a wealth of information on the composition and origin of the aquatic fauna of the Segura basin, the potential role as bioindicators of some of their components, and the general conservation status of both species and habitats.

Earlier works (e.g. Vidal-Abarca, 1985) were more focused on the analysis of general environmental and human aspects at large temporal and spatial scales, but soon more specific studies on the communities of macroinvertebrates were published: water bugs (Millán et al., 1987, 1988), snails (Gómez, 1988) and more recently stoneflies and mayflies (Ubero et al., 1998). The water beetles were soon one of the preferred groups for study, with multiple taxonomic and faunistic studies appearing through this period (Gil et al., 1990; Delgado et al., 1992; Delgado & Soler, 1997), particularly about the Hydradephaga (Millán & Rocchi, 1991; Millán et al., 1992, 1993, 1996, 1997; Millán & Ribera, 2001; Sánchez-Fernández et al., 2004b). For most Spanish entomologists working with Hydradephaga – including us – the magnificent monograph of Professor Mario E. Franciscolo (1979) was a starting point and a continuous reference. With this paper we would like to contribute to paid tribute to his memory, with a summary of the most important faunistical, biogeographical, ecological and conservation conclusions obtained from the study of the Hydradephaga in the Segura river basin throughout this time.

MATERIALS AND METHODS

GEOGRAPHICAL SITUATION AND ENVIRONMENTAL CHARACTERISTICS. The river Segura drains into the Mediterranean sea, and its basin has an estimated area of 18.815 km^2. The Segura river has its source at an altitude of 1,412 m and a total length of 325 km.

The main characteristic of the climate in the basin is aridity (Vidal-Abarca et al., 1992), with long periods of hydric deficit punctuated by scarce precipitation that can nevertheless be torrential locally. The lithology and geology of the area are very complex, with a predominance of marls and chalk.

There are a large number of temporary streams with an irregular flow, usually with highly mineralised water, many of them also eutrophicated. A very important feature of the area, particularly in recent times, is the very large demand of water for irrigation, and the increasing load of organic pollution of many of the surface waters in the basin, especially in the lower reaches of the rivers and streams. All these factors combine to produce a situation of high environmental stress (anoxic waters, water deficit, etc.).

The river Segura basin includes also a large number of hypersaline habitats, which in European context are of special rarity and of high conservation value.

SAMPLING. We have been collecting data of the presence/absence and relative abundance (when available) of water beetles in general, and of Hydradephaga in particular, in 382 sampling stations distributed through the river Segura basin since 1980. In total, 116 out of a total of 231 UTM grid cells (10x10 km) of the basin have been prospected (fig. 1), i.e. approximately 50% of its surface. However, the stratified sampling has included the whole diversity of water bodies within the basin. Assuming our sampling is truly representative of the diversity of the area, we considered that species appearing in a maximum of two 10x10 km grid cells are rare.

We distinguished four main sampling periods since 1980: 1) 1980-1985, 2) 1986-1991, 3) 1992-1996, and 4) 1997-present. Sampling before 1994 included all macroinvertebrates and was not focused on water beetles. Despite the unavoidable differences in sampling methods, effort, etc. of such a long period of time, most of the data are estimates of relative abundance obtained with an entomological net of similar characteristics (pentagonal or triangular, 20-30 cm deep, with a mesh of 250 mm to 1 mm). In all cases the sampling was stratified, including all apparent habitat types considered, suitable for aquatic Coleoptera until no more new species were found (Millán et al., 2002). The information gathered in all these sampling periods was complemented with an exhaustive literature search.

To characterise the sites, 13 environmental variables were considered, six of them physical (altitude, water persistence, water depth, current speed, main substratum, type of sediment), three biological (dominant vegetation, percentage of macrophyte cover, riparian vegetation), and four chemical (conductivity, type and degree of mineralisation, dissolved oxygen, organic pollution) (Millán et al., 1996).

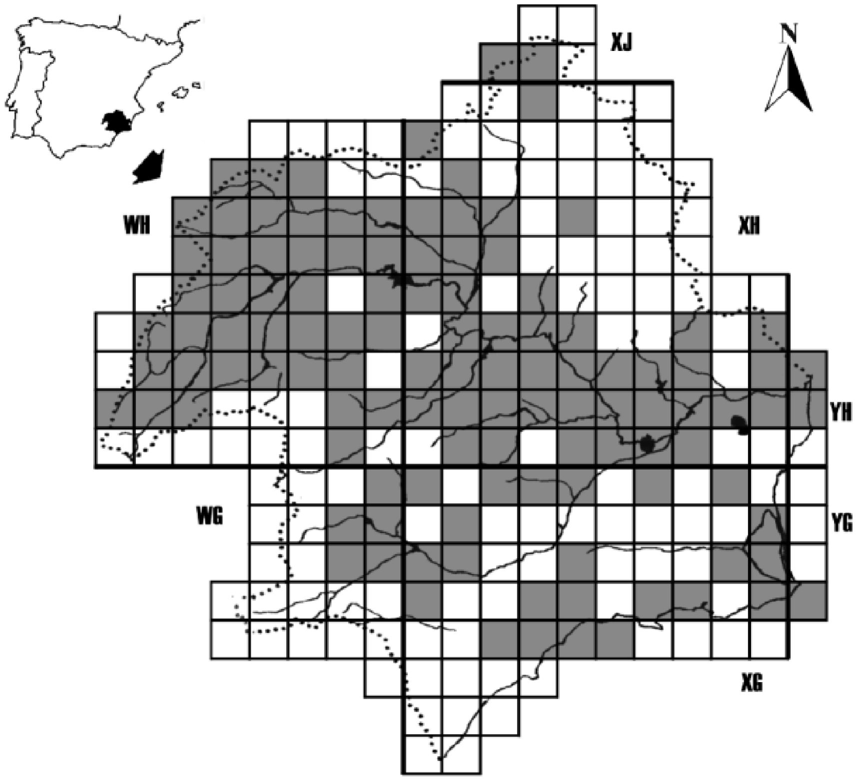

Fig. 1. Location of the Segura Basin and sampled 10 x 10 km UTM grid cells.

FAUNISTICAL STUDY. We used the program Stimates (v. 7) to obtain an estimate of the total number of species present in the basin. We used a species/samples accumulation curve, and the average value of the Mao Tau model (Colwell et al., 2004). Once the accumulation curve was obtained, we used the program Curve Expert V. 1.34 (Copyright 1995-1997 by Daniels Hyams) to estimate an asymptote.

The list of species (tab. 2) follows the systematic and or the nomenclature of the Fauna Europaea Web Service (2005).

BIOGEOGRAPHY. Analyses of the distribution of the species was based on the chorological categories used by Ribera et al. (1998), modified by Millán et al. (2002), in which five different distributional types are distinguished:

Ibero-African species (S): present in the Iberian peninsula and in north Africa, but not north of the Pyrenees (except, occasionally, a small area in south France, in which case it is noted in the text).

Ibero-European species (N): present north of the Pyrenees and in the Iberian peninsula, but not south of it (i.e. in North Africa).

Species with a disjoint distribution (D): species present in the Iberian peninsula or the Balearic islands, and in some isolated areas in Europe (either mountain areas – boreo-Alpine species – or coastal areas in the eastern Mediterranean).

Endemic species (E): species restricted to the Iberian peninsula, with in some cases a small extension to some areas on the northern side of the Pyrenees or in southern France.

Trans-Iberian species (T): species present in the Iberian peninsula, in Europe north of the Pyrenees, and in North Africa.

To compare the fauna of Hydradephaga of the Segura basin with that of other areas in the western Mediterranean data was compiled from Millán (1991), Millán et al. (1992) and Ribera et al. (2003), updated with the Palaearctic catalogues of Dytiscidae and Noteridae (Nilsson, 2003, 2004).

The areas considered were: P.I, Iberian peninsula; MAG, Maghreb; FRA, France; ITA, Italy; G.B, Great Britain; P.E, Scandinavian peninsula (Norway and Sweden); P.B, Balcanic peninsula (former Yugoslavia and Albania).

Within the Iberian peninsula, the main river basins considered were: CON, North basin; CDU, Duero basin; CTA, Tajo basin; CGA, Guadiana basin; CGR, Guadalquivir basin; CSU, south Basin; CSE, Segura basin; CJU, Júcar basin; CEB, Ebro basin; CPO, Oriental Pyrenees basin. The Balearic Islands (IBA) were considered an independent area. Data was originally taken from Millán (1991), updated whenever necessary. The phenetic affinity among basins and geographical areas was analysed using hierarchical classification methods implemented in Statistica (v. 4.5).

ECOLOGY. With the aim of identifying the main factor determining the spatial distribution of the species of Hydradephaga in the Segura basin we compiled a presence/absence matrix of species x stations. The quantitative and qualitative environmental characteristics of the stations are listed in tab. 1. The final matrix species x environmental characteristics (build as a contingency table with the frequency of the presence of each species in each category of the environmental variable) was analysed through Correspondence Analysis (CA), a standard method for analysing contingency tables (e.g. Millán et al., 1996). The multivariate analysis was conducted using the statistical package SPAD.N (Lebart et al., 1984).

CONSERVATION. The degree of vulnerability of the species was estimated through a scoring system based on the combination of six criteria, both referring to the characteristics of the species and the habitats, following Abellán et al. (2005a). These criteria were: general distribution (GD), endemicity (E), rarity of the species (RS), persistence (P), rarity of the habitat (RH) and habitat loss (HL). For each of these criteria species could score from 0 to 3, with increasing values as the estimated vulnerability increases. The sum of the scores in each of the criteria gives the total vulnerability value, which has a potential range between 0 and 18. This single score allows the linear ordination of all species of the Segura basin in a single gradient of "vulnerability". For practical purposes we have considered four categories within this continuous gradient of vulnerability: extreme ≥ 13, high ≥ 9, moderate ≥ 5 and low ≤ 4.

To identify the stations with the highest conservation value we applied an index developed by Millán (1991), the "conservation interest" index (IC), using a combined criterion of richness and rarity of the water beetle fauna. The IC is a modification of the Rarity Quality Factor (RQF) proposed by Foster (1987) and Eyre & Rushton (1989).

RESULTS

FAUNISTICAL STUDY. Of the 208 species of water beetles so far recorded from the Segura basin, 81 are Hydradephaga (tab. 2).

This corresponds to ca. 45% of the total of species of Hydradephaga found in the Iberian peninsula (182). Fourteen of them are considered to be rare within the basin, although most of these are not rare in an Iberian context.

There are no species endemic to the Segura basin, and only six Iberian endemisms are present (five species and one subspecies, tab. 2). This number is relatively small in comparison with other Iberian areas (tab. 3).

The first records of Hydradephaga species from the Segura basin are those in Kraatz (1869) (*Hydroporus pubescens*) and de la Fuente (1894) (*Orectochilus villosus*), although it was not until the end of the 20th century that the knowledge of its fauna could be considered to be minimally developed, particularly with the work of Carlos Montes and collaborators in the 1980's, when the knowledge of the water beetles of the Segura basin could be said to have started. Developments in the knowledge of the fauna in the basin since this time is represented in fig. 2, where they are divided into four periods noted in the Methods section. The increase in the number of species following the third period, when the sampling was made more specific for water beetles, is apparent.

The cumulative curve of species richness is presented in fig. 3. The best asymptotic fit was that of the sub-logistic model of Morgan-Mercer-Flodin (MMF) (Morgan et al., 1975), with a high correlation coefficient ($r = 0.999$) (standard deviation $S = 0.232$). The model is highly parametrised, with the formula $Y = ab + cxd/b + xd$ (estimation of the parameters: $a = -2.558$, $b = 15.119$, $c = 90.912$ and $d = 0.733$). The parameter c corresponds to the asymptote, i.e. the expected maximum number of species – approximately 91. According to this estimation, there are thus still ca. ten species of Hydradephaga to be recorded from the Segura basin.

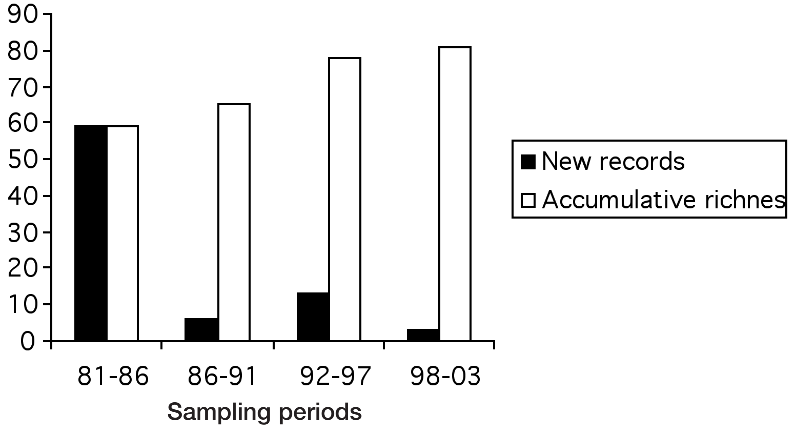

Fig. 2. Evolution of the knowledge of the Hydradephagan fauna in the Segura basin in the four periods explained in the text (see Methods).

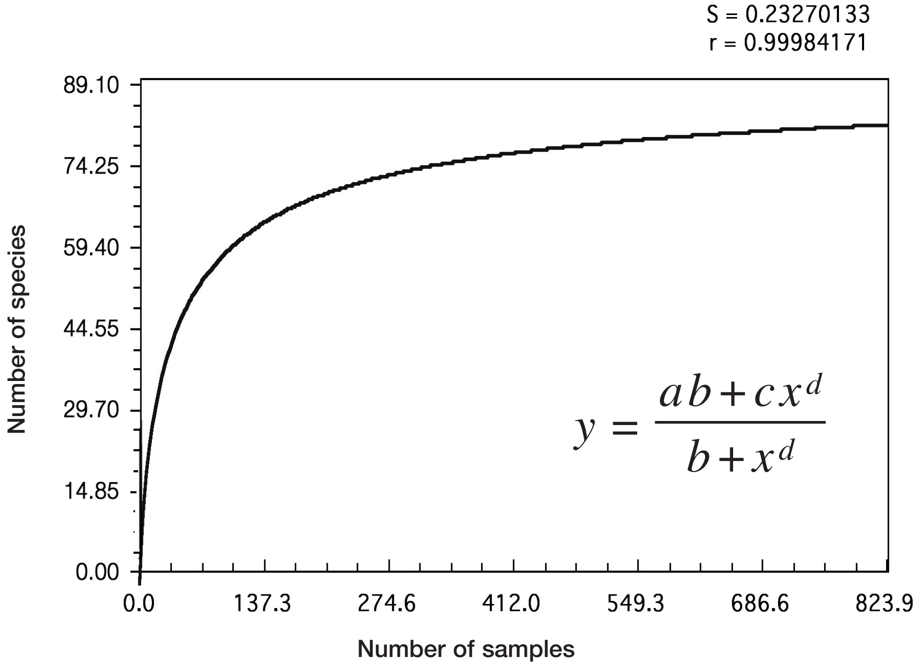

Fig. 3. Accumulative curve of species of Hydradephaga in the Segura Basin. The formula corresponds to the best estimation fitting the curve (i.e. a Morgan-Mercer-Flodin model, see text for details).

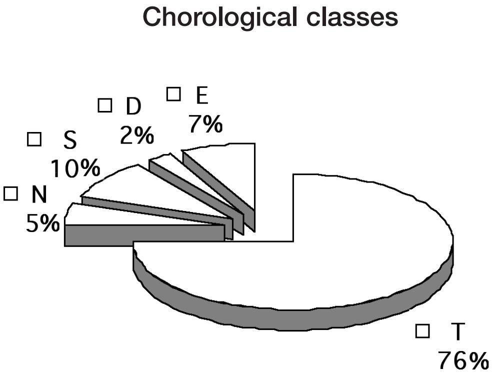

Fig. 4. Percentage of species belonging to the chorological classes considered. Symbols: T: Transiberian species; N: Ibero-European species; Ibero-African species; D: species with a disjoint distribution; E: Endemic species.

BIOGEOGRAPHY. Similarly to the wider Iberian fauna (Ribera, 2000), the majority of species in the Segura basin have a trans-Iberian distribution (fig. 4). The second most frequent category is that of the southern species, with a relatively small representation of Iberian endemics.

The phenetic hierarchy of relationships among the western-Palaearctic regions considered shows a clear similarity of the fauna of the Segura basin with that of the Maghreb (fig. 5). Together with the rest of the Iberian fauna, these three regions form a well defined group isolated from the rest of the European areas. Within the latter there is a certain grouping according to latitude, with the Mediterranean (Italy and the Balkans) and northern regions (Great Britain and Scandinavia) forming respective clusters. France is placed more as a transition region, although with higher affinities with the Mediterranean fauna.

Within the Iberobalear region there is also a clear north-south division, with a secondary classification into western and eastern basins (fig. 6). The Balearic islands seem to be a relatively independent biogeographical unit, although more related with the southern cluster.

ECOLOGY. The first axis of the CA analysis of the contingency matrix of species x environmental characteristics explained a large proportion of the variance (43%) (tab. 4), and could be related to a general longitudinal gradient, from species typical of the upper (negative values) to those typical of the lower reaches of the Segura basin. Environmental characteristics associated with the positive values of the axis are low altitude, moderate to high mineralisation and a high degree of eutrophication (Tabs 1-2; figs 7-8 – for clarity, we have represented separately the scores of the species and environmental characteristics). Although some of the species associated with the positive side of the axis are species with a wide distribution within the basin, they are considered to be typical of moderately saline waters, with a high load of organic eutrophication and standing or slowly running water.

Species significantly associated with the negative part of the axis are typical of high altitude, well developed riparian and macrophyte vegetation, and very low mineralization of the water (tabs 1-2; figs 7-8).

For practical purposes, four loose groups of species were defined according to the scores in the main ordination axis (fig. 7):

Group 1: Exclusively composed of *Nebrioporus ceresyi*, which is found in saline or hypersaline standing waters (fig. 7).

Group 2: *Nebrioporus baeticus, Laccophilus poecilus* and *Hydroglyphus signatellus* (fig. 7). Typical of running water in the lower reach of the basin, with moderate to high salinity, with a high content of organic matter (either highly polluted or eutrophied water) and scarce riparian vegetation (reed or *Arundo donax*). Two additional species, *Hydroporus limbatus* and *Herophydrus musicus* (fig. 7), could be considered to be close to this group due to the high degree of mineralization that they can withstand, although they prefer standing waters.

Group 3: *Laccophilus minutus*, *Hygrotus confluens*, *Hyphydrus aubei*, *Rhantus suturalis*, *Hydaticus leander*, *Eretes griseus* and *Noterus laevis* (fig. 7). Typical of temporary standing water bodies (or with strong seasonal level fluctuations), with abundance of fine sediment and organic matter, but with a lower degree of mineralization. Also with scarce or poorly developed riparian vegetation (reed or *Aurundo donax*).

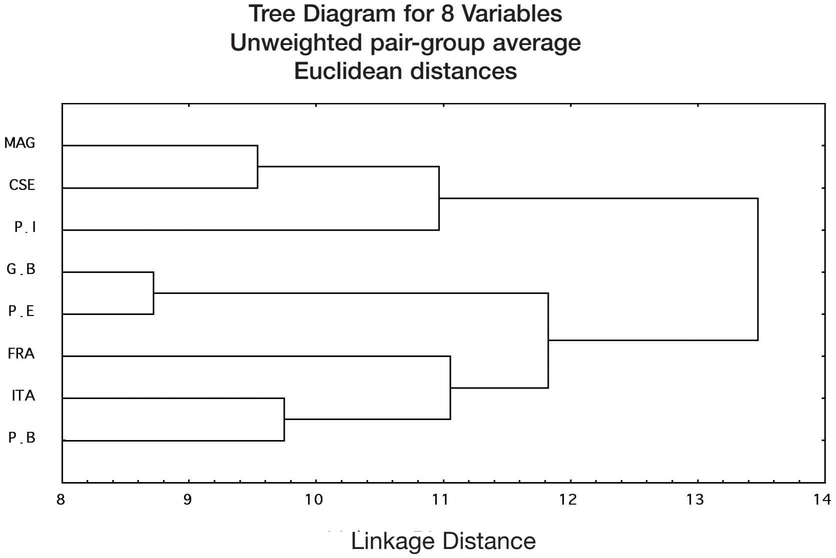

Fig. 5. Phenetic relationships of the Palearctic areas according to their Hydradephagan fauna. Symbols: P.I, Iberian peninsula; CSE, Segura Basin; MAG, Magreb; FRA, France; ITA, Italy; G.B, Great Britain; P.E, Scandinavian peninsula; P.B, Balcanic peninsula.

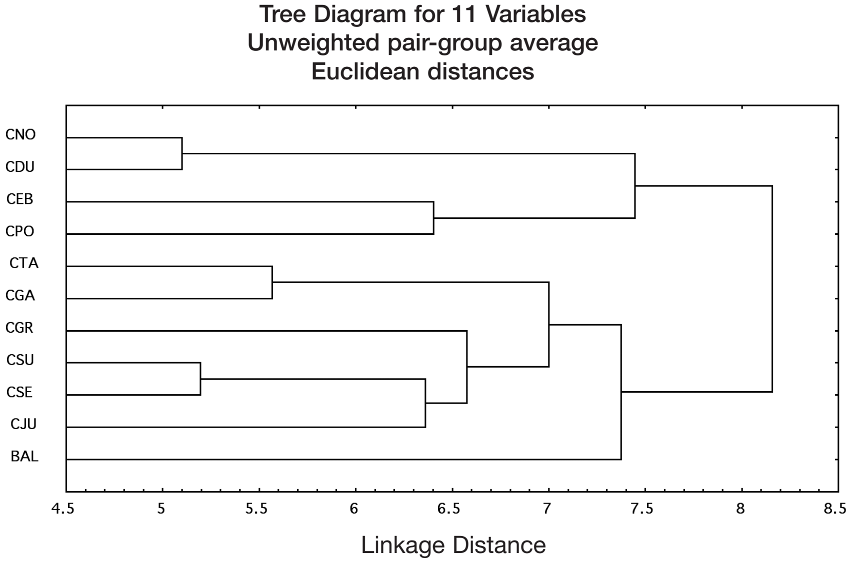

Fig. 6. Phenetic relationships of the river basins in the Iberian peninsula according to their Hydradephagan fauna. Symbols: CNO, North basin; CDU, Duero basin; CTA, Tajo basin; CGA, Guadiana basin; CGR, Guadalquivir basin; CSU, South Basin; CSE, Segura basin; CJU, Júcar basin; CEB, Ebro basin; CPO, Oriental Pyrenees basin; BAL, Balearic Islands.

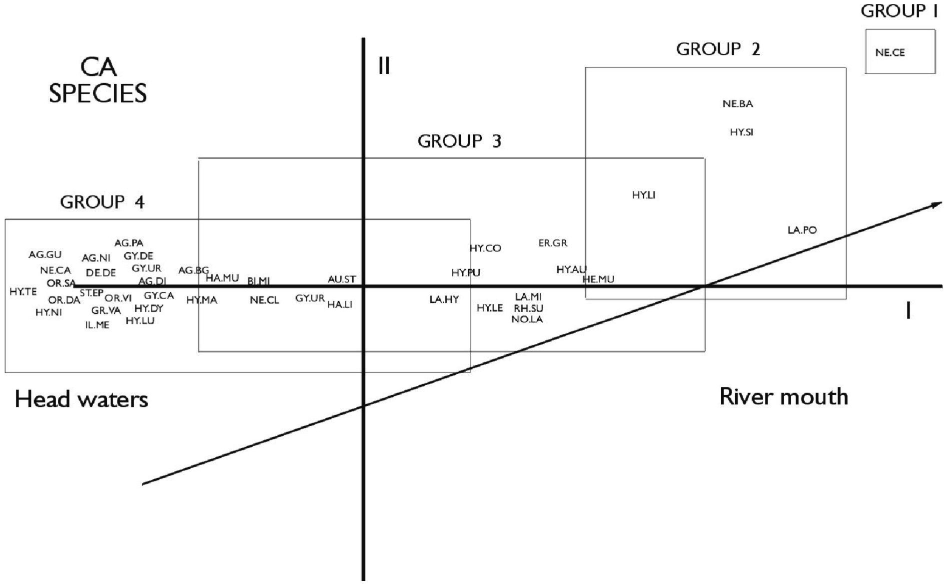

Fig. 7. Ordination plot of the species (axis I by axis II) in the Correspondence Analysis of the species x environmental characteristics matrix. See table 2 for the identification codes of the species.

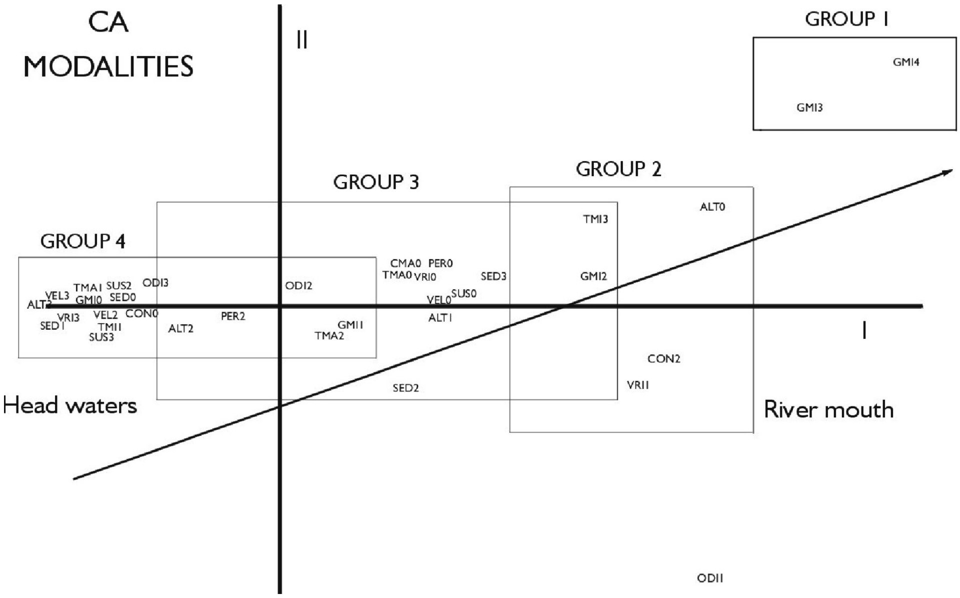

Fig. 8. Ordination plot of the range of environmental variables (axis I by axis II) in the Correspondence Analysis of the species x environmental characteristics matrix. See Table 1 for the identification codes of the variables.

Group 4: The most numerous, including *Dytiscus circumflexus*, *Hydroporus nigrita*, *H. discretus*, *H. marginatus*, *H. lucasi*, *Oreodytes davisii*, *O. septentrionalis*, *Gyrinus caspius*, *G. dejeani*, *G. distinctus*, *Orectochilus villosus*, *Nebrioporus bucheti cazorlensis*, *Stictonectes epipleuricus*, *Deronectes depressicollis*, *D. moestus*, *Agabus didymus*, *A. paludosus*, *A. nitidus*, *A. biguttatus*, *A. guttatus* and *Iliybius meridionalis* (fig. 7). They are all typical of the headwaters of the basin, in sites above 500 m of altitude, running, clean, fresh and well oxygenated waters, with coarse substratum and well developed riparian vegetation.

Finally, a number of species had a wide distribution within the basin, without clear associations with any type of habitat (i.e. with near zero scores in the CA axis, fig. 7). They include *Laccophilus hyalinus*, *Haliplus lineatocollis*, *H. mucronatus*, *Hydroglyphus pusillus*, *Bidessus minutissimus*, *Aulonogyrus striatus*, *Gyrinus urinator* and *Nebrioporus clarkii.* They can be considered as intermediate between groups 3 and 4, although they seem to prefer waters of low mineralisation.

CONSERVATION. Of the 81 species of Hydradephaga recorded from the Segura basin, only *Hydroporus decipiens* had a vulnerability value considered to be high (9), due to its rarity within the basin and to its restricted distribution (tab. 5). With a similar value (8), *Nebrioporus baeticus* is more representative of the fauna of the basin, as it is a typical inhabitant of saline running waters. These are highly endangered habitats, due to the increase in the use of irrigation in the surrounding fields, which use the natural drainage system (with the saline streams) to evacuate the excess of irrigation water.

A number of species had estimated values of vulnerability between 7 and 5, mostly because of their restricted distribution (they are Iberian endemics, such as *Graptodytes castilianus, Deronectes depresicollis* and *Nebrioporus bucheti cazorlensis*), or their rarity within the Segura basin (e.g. *Agabus guttatus, Oreodytes davisii, Hydroporus nigrita* and *Stitonectes lepidus*).

The stations with the highest conservation interest were mountain streams in the NW of the basin (tab. 6): Río Endrinales en Las Espinera, Arroyo de Fuenfría, Río de la Vega, Río Endrinales, Nacimiento del río Madera, Chorros del río Mundo and Río Zumeta en Santiago de la Espada. Only three stations with a high IC were ecologically different from the group above: Laguna de Pétrola, Laguna del Salobralejo and Laguna de los Patos, the two first, endorreic lagoons with small associated freshwater streams, and the last, a well vegetate artificial lagoon. The same mountain streams also have a high conservation interest for other aquatic Coleoptera, mainly Hydraenidae (Delgado & Soler, 1991; Ribera & Hernando, 1998; Millán & Aguilera, 2000; Sánchez-Fernandez et al., 2004b; Abellán et al., 2005b), with some species exclusive to the basin or to the sierras de Alcaraz and Segura (including the headwaters of the river Segura).

DISCUSSION

The Hydradephagan fauna of the Segura basin is one of the best known within the Iberian peninsula, as shown by the accumulation curves, but also from the number of records and the extensive sampling of their habitats. In relation to its area (18,815km^2, one of the smaller Iberian river basins), the number of species is relatively high, with only the Oriental Pyrenees basin being richer. The latter is a transition area between Europe and Iberia, and has been extensively sampled over a longer period (e.g. Rico et al., 1990).

As regards the composition of the Hydradephagan fauna of the Segura basin, of note is the predominance of species with wide distributions (trans-Iberian) and the low percentage of Iberian endemics. This is in contrast with another11groups of aquatic beetles, in which the south-east of the Iberian peninsula is one of the areas with the highest endemicity (e.g. Hydraenidae, Ribera, 2000). Most of the species are also widely distributed within the basin, with only 14 of them considered to be rare, most of them at the southern limit of their distribution, but common in northern areas within Iberia. The level of endemicity of the Hydradephagan fauna is not only low in comparison with that of other groups of aquatic Coleoptera, but low in comparison with other areas in Iberia, in particular in the north west (Ribera, 2000). The reasons for this uneven distribution of endemic species are at present unknown, and only more detailed studies on their origin (geographical and phylogenetic) can shed light on this interesting question. At the moment we can only speculate as to the possible role of the particular characteristics of the aquatic habitats in the Segura basin, with a prevalence of highly mineralised waters in which the Hydradephagan fauna is very poorly represented, in contrast to the high abundance and diversity of Hydraenidae (see e.g. Moreno et al., 1997). The richest fauna of Hydradephaga is found in the freshwater streams of the mountain areas, although these habitats are relatively scarce and limited to the headwaters – and increasingly threatened because of the expansion of agriculture and increased human pressure.

At a wider scale, the Hydradephagan fauna of the Segura basin shows greater affinities with that of north Africa than with adjacent areas within the Iberian peninsula or in Europe. The biogeographical connections between the SE Iberia and the Rif are well known, both for plants and animals (Sanz de Galdeano, 1996; Médail & Quézel, 1997). There were multiple land connections between the two areas during the Miocene up to the end of the Messinian crisis, with the separation of the Iberian peninsula and north Morocco after (5.33 MY) the re-opening of the Gibraltar straits (Krijgsman et al. 1999). Other than these historical affinities, the similarity of the available aquatic habitats in the Segura basin and in north Morocco is without doubt another factor contributing to the similarity of their faunas. The heterogeneity of the Iberian fauna of aquatic Coleoptera was already noted by Ribera (2000), with a clear separation between the northern areas (with a predominantly European fauna) and the southern ones (more related to the north African faunas).

Among the European regions, the clear north-south divide is probably the results of a similar mixture of historical and present-day ecological factors, with the Quaternary glaciations probably having a decisive impact on the distribution of many of the species (e.g. Coope, 1995; Hewitt, 1996).

The ordination method used here to link the presence/absence of the species with the environmental characteristics of the habitats in which they occur has proven particularly useful. Other methods previously used did not explain such a high percentage of the variance (more than 40% for the first axis), or where more difficult to interpret (e.g. Millán et al., 1996). Of the studied environmental characteristics, altitude, degree of mineralization of the water, and amount and type of riparian vegetation seem to have had the highest impact on the composition of the Hydradephagan fauna. This is similar to the finding of previous studies on communities of Hydradephaga in the Iberian peninsula (e.g. Garrido et al., 1994; Ribera et al., 1996),but is particularly important in the Segura basin, where there is a wide range of ecological conditions, and a large proportion of highly mineralised water bodies due to both the soil type and the general climatology. The amount and type of riparian vegetation is likely to play more of a structural role, conditioning the availability of refugia, the suitability of oviposition sites and the presence of prey (e.g. Millán et al., 1996).

The methodology used here to identify species considered to be vulnerable incorporates a degree of arbitrariness, but this is a common feature of all proposed criteria for conservation (e.g. Millsap et al., 1990; Cofré & Marquet, 1998; IUCN, 2001). Our criteria summarise factors generally acknowledged to be of relevance in determining the probability of extinction, such as restricted distribution, habitat specificity, habitat loss or scarcity of populations (Gaston, 1994). Our scoring method allows a range of between 0 and 18, but it seems very unlikely that a species could score anywhere near 18, not only among Hydradephaga but even among other groups with a higher proportion of very narrow endemics (Sánchez-Fernández et al., 2003; Abellán et al., 2005a) (which, to a certain extent, is a validation of our criteria, it could be argued that all species near the highest level of vulnerability are already extinct). It seems more reasonable to consider that species with intermediate scores have a high degree of vulnerability. A common problem to all these scoring systems is the lack of independence of the different criteria (for example, a species occurring in only one station is necessarily restricted to one habitat). In some cases this could be solved through the use of information on the general distribution or ecology of the species, but in some others the knowledge of the species is not enough to allow a sound analysis of its conservation status. This is probably the case with *Hydroporus decipiens*, which had the highest vulnerability score among the Hydradephaga of the Segura basin (collected only once, in 1997). The taxonomic identity and distribution of this species is still unclear, and so any evaluation of its conservation status is premature.

The species with the second highest vulnerability score, *Nebrioporus baeticus*, is, however, a very well known typical component of the regional fauna. It is widespread and locally very common in the saline streams in the SE of the Iberian peninsula (Millán et al., 2002), but can also be found in similar habitats in the central and upper Ebro basin. The main factor threatening its populations is human impact: due to its high habitat specificity, any alteration is potentially highly damaging. Although relatively widespread in the Segura basin, saline streams are highly endangered due to the increased irrigation of the surrounding land (which results in an increasing loss of salinity of the water), the direct effluent of residual waters, and the diffuse contamination from human settlements (Abellán et al., in press).

Other species with a relatively high vulnerability score must be considered endangered only at a regional level, such as those at the southern limit of their distributions. This is the case of *Agabus guttatus*, a typical inhabitant of small freshwater streams in most of Western Europe, including the north of the Iberian peninsula (Rico et al., 1990).

In what refers to the selection of the habitats with the highest conservation priority, the results obtained here using only Hydradephaga, are very similar to those obtained with a wider representation of the fauna (i.e. a predominance of mid-altitude freshwater streams, Ribera, 2000; Sánchez-Fernandez et al., 2004b). Furthermore, the Hydradephaga can be considered a good representation of the general beetle fauna (Sánchez-Fernández et al., 2004b), at least under the criteria of species richness and rarity used here.

An inconvenience of the index applied in this paper (IC) is the lack of reference to the conservation interest of the habitats outside the study area. Thus, the saline or hypersaline streams ("ramblas") (Millán et al., 1996; Moreno et al., 1997), which are extremely rare in an European (or even global) context, are not considered of particular relevance due to the poor richness of species and local abundance of their typical species. The use of other criteria for the selection of sites of conservation value could overcome this limitation, such as complementarity (Sánchez-Fernández et al., 2004a; Abellán et al., 2005b). As there is almost no overlap between the community of freshwater mountain streams and the community of saline "ramblas", complementary criteria always choose representative sites of both types of habitat.

During these 25 years of study, we have gathered a wealth of information on the distribution and ecology of the Hydradephagan fauna of the Segura basin. We now plan to continue completing our knowledge of the group (and of other groups of aquatic Coleoptera) through a study of the detailed ecological traits of the species, trophic relationships, metapopulation distribution and phylogentic and phylogeographic relationships between species and populations.

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Tab. 1. Ranges of biotic and abiotic parameters measured. Codes: ALT: altitude; PER, water persistence; VEL, current speed; SUS, substrate; SED, sediment; TMA, macrophyts; CMA, macrophyts cover; VRI, riparian vegetation; GMI, mineralisation and conductivity; TMI, mineralisation type; ODI, dissolved oxygen; CON, organic pollution. The codes are those used in fig. 8. CPOM, coarse particulate organic matter; FPOM, fine particulate organic matter; UPOM, ultra-fine particulate organic matter.

ALTITUDE (m) (ALT)	**WATER PERSISTENCE (PER)**	**WATER DEPTH (cm) (PRO)**	**CURRENT SPEED (cm/s) (VEL)**
0 0-20	0 Temporal	0 0-15	0 Standing water
1 >20-400	1 Permanent/fluctuating	1 >15-50	1 Slow: <15 cm/s
2 >400-1000	2 Permanent	2 >50	2 Moderate: 15-50 cm/s
3 >1000			3 High: >50 cm/s

SUSBTRATE (SUS)	**SEDIMENT (SED)**	**MACROPHYTS (TMA)**	**MACROPHYTS (%) (CMA)**
0 Silt & clay	0 Absence	0 Absence	0 Absence
1 Sand	1 CPOM	1 Bryophytes	1 5-10
2 Gravel	2 FPOM	2 Filamentous algae	2 >10-30
3 Boulder/pebble	3 UPOM	3 Charophytes	3 >30-70
4 Rock/cement		4 Phanerogams	4 >70

RIPARIAN VEGETATION (VRI)	**MINERALISATION: S (g/l), (GMI)**		**CONDUCTIVITY (µS/cm)**
0 Absence	0 Freshwater:	<0,5	<800
1 Arundo & Phragmites	1 Subsaline:	0,5-3	800-8000
2 Juncus/Typha/Taray	2 Mesosaline:	>3-20	8000-30000
3 Salix/Populus/Ulmus	3 Saline:	>20-40	30000-60000
	4 Hypersaline:	>40	>60000

MINERALISATION TYPE (TMI)	**DISSOLVED OXYGEN (mg/l) (ODI)**	**ORGANIC POLLUTION (CON)**
0 Ionic equilibrium	0 Anoxic: 0-2	0 Clean waters
1 Carbonates	1 Low: 2-5	1 Eutrophic waters
2 Sulfates	2 Medium: 5-12	2 Moderately polluted waters
3 Sodium Chloride	3 High: >12	3 Very polluted waters

Tab. 2. Species of Hydradephaga recorded from the Segura basin. The list is taxonomically sorted according to Ribera et al. (1998), to facilitate the comparison with the wider Iberian fauna. E, Iberian endemic species; R, species considered to be rare within the Segura basin (i.e., recorded from no more than two 10x10 km grid cells). The codes are those used in fig. 7. (*) specimens of uncertain status.

GYRINIDAE				
1	*Gyrinus* (*Gyrinus*) *caspius* Ménétriés, 1832			GYCA
2	*Gyrinus* (*Gyrinus*) *dejeani* Brullé, 1832			GYDE
3	*Gyrinus* (*Gyrinus*) *distinctus* Aubé, 1838			GYDI
4	*Gyrinus* (*Gyrinus*) *urinator* Illiger, 1807			GYUR
5	*Aulonogyrus striatus* (Fabricius, 1792)			AUST
6	*Orectochilus villosus* (O.F. Müller, 1776)			ORVI
HALIPLIDAE				
7	*Peltodytes rotundatus* (Aubé, 1836)			PERO
8	*Haliplus* (*Haliplidius*) *obliquus* (Fabricius, 1787)			HAOB
9	*Haliplus* (*Neohaliplus*) *lineatocollis* (Marsham, 1802)			HALI
10	*Haliplus* (*Liaphlus*) *mucronatus* Stephens, 1832			HAMU
NOTERIDAE				
11	*Noterus laevis* Sturm, 1834			NOLA
HYGROBIIDAE				
12	*Hygrobia hermanni* (Fabricius, 1775)		(R)	HYHE
DYTISCIDAE				
13	*Laccophilus hyalinus* (De Geer, 1774)			LAHY
14	*Laccophilus minutus* (Linnaeus, 1758)			LAMI
15	*Laccophilus poecilus* Klug, 1834			LAPO
16	*Hyphydrus aubei* Ganglbauer, 1892			HYAU
17	*Hydrovatus cuspidatus* (Kunze, 1818)			HYCU
18	*Yola bicarinata* (Latreille, 1804)			YOBI
19	*Bidessus minutissimus* (Germar, 1824)			BIMI
20	*Bidessus pumilus* (Aubé, 1838) (R)			BIPU
21	*Hydroglyphus geminus* (Fabricius, 1792)			HYGE
22	*Hydroglyphus signatellus* (Klug, 1834)			HYSI
23	*Hygrotus* (*Coelambus*) *confluens* (Fabricius, 1787)			HYCO
24	*Hygrotus* (*Coelambus*) *impressopunctatus* (Schaller, 1783)			HYIM
25	*Hygrotus* (*Coelambus*) *lagari* (Fery, 1992)			HYLA
26	*Hygrotus* (*Coelambus*) *pallidulus* (Aubé, 1850)			HYPA
27	*Herophydrus musicus* (Klug, 1833)			HEMU
28	*Hydroporus decipiens* Sharp, 1877	(E)	(R)	HYDE
29	*Hydroporus discretus* Fairmaire & Brisout, 1859			HYDI
30	*Hydroporus limbatus* Aubé, 1838			HYLI
31	*Hydroporus lucasi* Reiche, 1866			HYLU
32	*Hydroporus marginatus* (Duftschmid, 1805)			HYMA
33	*Hydroporus nigrita* (Fabricius, 1792)			HYNI
34	*Hydroporus normandi* Régimbart, 1903			HYNO
35	*Hydroporus planus* (Fabricius, 1781)		(R)	HYPL

36	*Hydroporus pubescens* (Gyllenhal, 1808)			HYPU
37	*Hydroporus tessellatus* Drapiez, 1819			HYTE
38	*Graptodytes aequalis* Zimmermann, 1918			GRAE
39	*Graptodytes castilianus* Fery, 1995	(E)	(R)	GRCA
40	*Graptodytes fractus* (Sharp, 1882)			GRFR
41	*Graptodytes ignotus* (Mulsant, 1861)			GRIG
42	*Graptodytes varius* (Aubé, 1838)			GRVA
43	*Metaporus meridionalis* (Aubé, 1838)			MEME
44	*Stictonectes epipleuricus* (Seidlitz, 1887)	(E)		STEP
45	*Stictonectes lepidus* (Olivier, 1795)		(R)	STLE
46	*Stictonectes optatus* (Seidlitz, 1887)			STOP
47	*Deronectes depressicollis* (Rosenhauer, 1856)	(E)		DEDE
48	*Deronectes fairmairei* (Leprieur, 1876)			DEFA
49	*Deronectes hispanicus* (Rosenhauer, 1856)			DEHI
50	*Deronectes moestus* (Fairmaire, 1858)			DEMO
51	*Stictotarsus duodecimpustulatus* (Fabricius, 1792)		(R)	STDU
52	*Stictotarsus griseostriatus* (De Geer, 1774)		(R)	STGR
53	*Nebrioporus* (*Nebrioporus*) *bucheti cazorlensis* (Lagar, Fresneda & Hernando, 1987)	(E)		NECA
54	*Nebrioporus* (*Nebrioporus*) *clarkii* (Wollaston, 1862)			NECL
55	*Nebrioporus* (*Zimmermannius*) *baeticus* (Schaum, 1864)	(E)		NEBA
56	*Nebrioporus* (*Zimmermannius*) *ceresyi* (Aubé, 1838)			NECE
57	*Oreodytes davisii* (Curtis, 1831)		(R)	ORDA
58	*Oreodytes septentrionalis* (Gyllenhal, 1827)*		(R)	ORSE
59	*Agabus biguttatus* (Olivier, 1795)			AGBG
60	*Agabus bipustulatus* (Linnaeus, 1767)			AGBP
61	*Agabus brunneus* (Fabricius, 1798)			AGBR
62	*Agabus conspersus* (Marsham, 1802)			AGCO
63	*Agabus didymus* (Olivier, 1795)			AGDI
64	*Agabus guttatus* (Paykull, 1798)		(R)	AGGU
65	*Agabus nebulosus* (Forster, 1771)			AGNE
66	*Agabus nitidus* (Fabricius, 1801)			AGNI
67	*Agabus paludosus* (Fabricius, 1801)			AGPA
68	*Agabus ramblae* Millán & Ribera, 2001			AGRA
69	*Ilybius chalconatus* (Panzer, 1796)		(R)	ILCH
70	*Ilybius meridionalis* Aubé, 1837			ILME
71	*Ilybius montanus* (Stephens, 1828)		(R)	ILMO
72	*Rhantus* (*Rhantus*) *suturalis* (McLeay, 1825)			RHSU
73	*Colymbetes fuscus* (Linnaeus, 1758)			COFU
74	*Meladema coriacea* Castelnau, 1834			MECO
75	*Eretes griseus* (Fabricius, 1781)			ERGR
76	*Hydaticus* (*Guignotites*) *leander* (Rossi, 1790)			HYLE
77	*Dytiscus circumflexus* Fabricius, 1801			DYCI
78	*Dytiscus pisanus* Castelnau, 1834		(R)	DYPI
79	*Dytiscus semisulcatus* O.F. Müller, 1776		(R)	DYSE
80	*Cybister* (*Cybister*) *tripunctatus africanus* Castelnau, 1834		(R)	CYTR
81	*Cybister* (*Scaphinectes*) *lateralimarginalis* (De Geer, 1774)			CYLA

Tab. 3. Species richness and level of endemism of the Hydradephagan fauna of the main Iberian river basins. CNO, North basin; CDU, Duero basin; CTA, Tajo basin; CGA, Guadiana basin; CGR, Guadalquivir basin; CSU, South Basin; CSE, Segura basin; CJU, Júcar basin; CEB, Ebro basin; CPO, Oriental Pyrenees basin; BAL, Balearic Islands.

	CNO	CDU	CTA	CGA	CGR	CSU	CSE	CJU	CEB	CPO	BAL
Local endemism	1	2	3	0	1	0	0	0	1	0	3
Iberian endemism	13	14	11	6	8	5	6	4	14	5	4
Hydradephaga species richness	112	131	108	105	110	76	81	101	131	110	70
Area of basins (km^2)	60224	111072	93289	74853	63085	18391	18815	42904	86098	16493	4964

Tab. 4. Eigenvalues, inertia, cumulative inertia and absolute contributions of species and environmental variables for the I and II axis of the CA.

CA	**axis I**	**axis II**
Eigenvalues	0.17	0.04
Inertia	0.43	0.10
Cumulative inertia	0.43	0.54

ABSOLUTE CONTRIBUTIONS

Axis I

Species		Modalities	
HA.LI	13.94	ODI1	11.26
HE.MU	8.69	ALT0	8.30
NO.LA	8.02	GMI3	6.97
DY.CI	5.31	ALT3	6.64
HY.MA	5.00	GMI2	6.05
AG.DI	4.89	GMI4	5.96
RH.SU	3.89	SED1	5.41
		CON2	5.09
		VRI1	4.93
		VRI3	3.87
		TMI3	3.79

Axis II

Species		Modalities	
RH.SU	23.95	ODI1	52.28
AG.DI	20.44	GMI3	11.51
HE.MU	19.53	GMI4	10.66
HA.LI	16.87	ALT0	5.20
DY.CI	8.16	SED2	4.57
HY.MA	5.31		

Tab. 5. Scores of the variables used in the vulnerability analysis at local level for the species found in the study area.
Symbols: GD, general distribution; E, endemicity; RS, rarity of species; P, persistence; HR, habitat rarity; HL, habitat loss.

Species	**GD**	**E**	**RS**	**P**	**HR**	**HL**	**V**	**Category**
Hydroporus decipiens	3	2	3	1	0	0	9	High
Nebrioporus baeticus	3	1	1	0	0	3	8	Moderate
Agabus guttatus	1	0	3	2	0	1	7	Moderate
Graptodytes castilianus	3	1	3	0	0	0	7	Moderate
Deronectes depresicollis	3	2	1	0	0	0	6	Moderate
Oreodytes davisii	0	0	3	2	0	1	6	Moderate
Stictonectes lepidus	0	0	3	3	0	0	6	Moderate
Hydroporus nigrita	1	0	2	2	0	0	5	Moderate
Nebrioporus bucheti cazorlensis	3	1	1	0	0	0	5	Moderate

Tab. 6. Ranking of the 10 sites with the highest conservation interest using the IC index for the Hydradephaga species.
Symbols: S, richness; IC, "conservation interest" index.

	Sites	S	IC
1	Río Endrinales en Las Espineras	28	108.20
2	Arroyo de Fuenfría	25	69.44
3	Laguna de Pétrola	21	48.22
4	Laguna del Salobralejo	17	36.76
5	Río de la Vega	22	35.09
6	Río Endrinales	18	33.81
7	Nacimiento del río Madera	19	28.58
8	Chorros del río Mundo	13	28.25
9	Río Zumeta en Santiago de la Espada	17	28.22
10	Laguna de los Patos	12	21.70

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