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Aquatic Coleoptera and Hemiptera assemblages in three coastal lagoons of the NW Iberian Peninsula: assessment of conservation value and response to environmental factors

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ABSTRACT

1. The objectives of the present study were to describe and analyse the composition and structure of aquatic Coleoptera and Hemiptera assemblages in three coastal lagoons of north-western Spain during a one year cycle, in order to evaluate their relative adequacy to provide information about the conservation value of lagoonal habitats and sites. The lagoons are designated as Special Areas of Conservation (SAC) under the European Union Habitats Directive and two of them are also protected by the Ramsar Agreement. Several abiotic variables, including salinity, were recorded at the time of sampling.

2. In total, 67 species (52 Coleoptera and 15 Hemiptera) and 6568 adult individuals (2664 Coleoptera and 3904 Hemiptera) were collected. In all pair-wise comparisons Kendall's coefficients of concordance between lagoons were higher for Hemiptera than for Coleoptera, indicating that Hemiptera assemblages were more similar across sites.

3. Most species recorded had a wide Palearctic distribution and only three species of water beetles could be considered endemic to Iberia: *Hydroporus vagepictus*, *Hydroporus vespertinus* and *Hydrochus angusi*. Similarly, the species collected had a widespread distribution in the Iberian Peninsula as the only species considered to be rare taxa at this scale were *Hydrochus angusi* and *Cymbiodyta marginella* among the Coleoptera and *Sigara scotti* and *Notonecta glauca glauca* among the Hemiptera.

4. The results do not support the idea of distinct aquatic insect assemblages for coastal lagoons in the Iberian Peninsula. Comparisons of the numbers of interior (non-coastal) and coastal provinces of the Iberian Peninsula where the species had been recorded showed they had been recorded in a larger proportion of interior provinces.

5. Salinity seemed to reduce species richness in both groups while the results of a canonical correspondence analysis (CCA) showed that the majority of species responded negatively to salinity.

6. This study suggests that species richness and rarity of aquatic insect assemblages may underestimate the conservation value of lagoonal habitats because their net contribution to catchment biodiversity is likely to be low.

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INTRODUCTION

Major gaps still remain in aquatic conservation knowledge about lagoons and other coastal brackish water habitats in temperate regions, and much more emphasis is needed on the investigation of the ecology of such systems to ensure their effective management (Barnes, 1999). Information about the relative biodiversity value of different waterbody types is a vital pre-requisite for many strategic conservation goals (Williams *et al.*, 2003), including sustainable catchment management as required by the EC Water Framework Directive (2000/60/EC). In particular, little is known of the communities of aquatic insects in coastal lagoons, especially when compared with freshwater ecosystems. In the Iberian Peninsula, the few studies to date in such habitats refer exclusively to Mediterranean environments and deal mostly with water beetles (Montes *et al.*, 1982; Garrido *et al.*, 1996, 1997; Ribera *et al.*, 1996; Moreno *et al.*, 1997).

Coastal wetlands, including coastal brackish water systems, have been subject to massive environmental degradation and habitat destruction worldwide (Goudie, 1990). More than 50% of the original area of coastal wetlands that existed in 1900 has been lost in most countries of Western Europe, including Spain (Casado *et al.*, 1992; Jones and Hughes, 1993). However, not until very recently have they become the focus of conservation interest per se (Barnes, 1999; Abbiati and Basset, 2001) with the declaration of Special Areas of Conservation as a consequence of their listing on Annex I of the European Union Habitats Directive (Council Directive 92/43/EEC).

Species richness and rarity are conservation criteria easily understood by the public and have been widely used for the conservation of sites and habitats and the communities that they support. In aquatic ecosystems this often includes the study of such attributes in assemblages of aquatic insects (Painter, 1999; Williams *et al.*, 2003; Chadd and Extence, 2004). Among other biological values, coastal brackish-water systems often contain communities that include algae, vascular plants and invertebrates that rarely occur elsewhere (Barnes, 1994), and high levels of rarity have been found in some aquatic insect assemblages of saline habitats, especially in ephemeral water bodies of semi-arid ecosystems (Moreno *et al.*, 1997; Sánchez-Fernández *et al.*, 2004).

Nonetheless, the communities of many taxonomic groups in coastal brackish-water systems are typically poor in species. Large temporal and spatial variations in salinity due to the irregular mixing of fresh and saline water, has long been hypothesized as the reason for species poverty in coastal brackish-water systems. Besides this environmental hostility hypothesis other explanations are also possible (Barnes, 1999).

Water beetles are generally considered a suitable group to assess the environmental and conservation value of wetland sites and habitats (Davis *et al.*, 1987; Foster, 1987, 1999; Eyre and Rushton, 1989; Foster *et al.*, 1990, 1992; Eyre *et al.*, 1992, 1993; Ribera and Foster, 1992). The detailed study of the autoecology of aquatic insects, specially water beetles, has revealed the existence of many species with narrow ecological requirements including adaptations to saline environments (Foster, 2000; Greenwood and Wood, 2002). Assemblages of aquatic Hemipterans are generally poorer in species than are water beetles, and seem to be more resilient to environmental change (Roback, 1974; Vierssen and Verhoeven, 1983; Broering and Niedringhaus, 1988; Eyre and Foster, 1989; Tuly *et al.*, 1991; Savage, 1996).

The objectives of the present study were to describe and analyse the composition and structure of aquatic Coleoptera and Hemiptera assemblages in three coastal lagoons during a one year cycle, in order to evaluate their relative adequacy to provide information about the conservation value of lagoonal habitats and sites. More precisely, the following questions were addressed: (a) Were the assemblages of aquatic Coleoptera and Hemiptera rich in species? (b) Were they composed of rare species at the regional (Iberian

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Peninsula) scale? (c) Were they composed of coastal species? (d) Were they composed of species tolerant to high salinity?

STUDY AREA

The study area comprised three coastal lagoons in the south of Galicia (north-west Spain): Bodeira, Xuño and Vixán (Figure 1). Although each of the lagoons selected was completely separated from the sea by a barrier of sand dunes, seawater can enter by filtration or when sea storms break through the sand barrier. Fresh water is provided by one or two small streams. The extent of standing water ranged from 0.96 ha in Bodeira, to 3.94 ha in Vixán and 6.7 ha in Xuño. The bottoms of all the water bodies were almost totally covered by submerged vegetation and Vixán has a relatively large (5.9 ha) reed (*Phragmites australis*) bed.

The three lagoons are located within areas proposed as Special Areas of Conservation (SAC) under the European Union Habitats Directive (Directive 92/43/EEC). Vixán and Bodeira are also protected by the Ramsar Agreement (Ramsar sites no. 598 and 452, respectively).

The climate of the study area is mild and wet, with annual average temperatures around 14°C and annual rainfall between 1200 and 1800 mm. The landscape consists of a mosaic of farmland, heather (*Erica* spp.) and gorse (*Ulex* spp.) heathlands and pine (*Pinus pinaster*) forests in a densely populated rural setting.

METHODS

Sampling

The three lagoons were sampled on a seasonal basis (March, June, September, December) in 1998. Two sampling points were selected for each lagoon to include the main microhabitats. At every sampling point fauna was collected by sweeping a semicircular net (0.40 m in diameter and 0.25 mm mesh size) three times across a 10 m transect running parallel to the margin. A fine mesh sieve was used to collect specimens

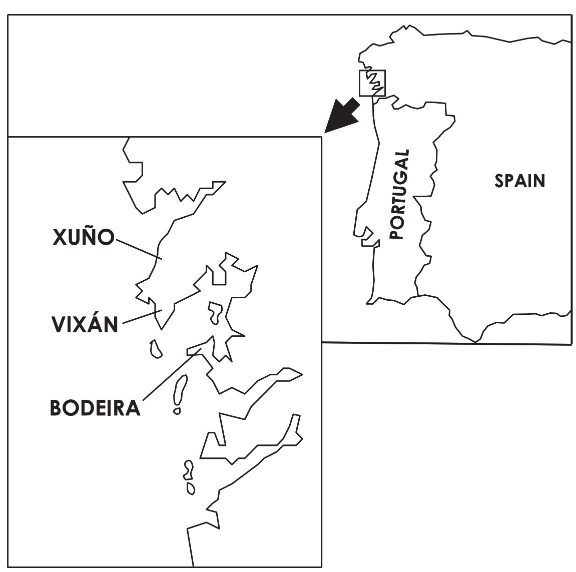

Figure 1. Maps of north-west Iberia showing the location of the lagoons under study.

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floating on the water surface after the bottom had been swept. This semi-quantitative method allows for direct comparisons across sites or seasons because sampling effort can be assumed equivalent. Water temperature, pH, conductivity, salinity and dissolved oxygen were measured in triplicate at each sampling point at the same time as the fauna was sampled.

Species richness

Species richness refers to the number of species of Coleoptera and Hemiptera collected and no corrections for lagoon size were made. It should be noted that sampling efficiency generally decreases with increasing area thus species richness could be comparatively underestimated in the larger lagoons.

Assessment of rarity

Rarity at the local scale was assessed by comparing the degree of similarity in the identity and relative abundance of species between the assemblages of the three lagoons using Kendall's coefficient of concordance (W). Species represented by just a single individual were excluded from the calculations and ties were corrected when necessary (Zar, 1999). W-values were transformed to chi-square values to test for statistical significance of concordances (Zar, 1999). Unlike other measures of similarity or affinity, concordance indexes take into account the relative abundances of the taxa that comprise the sets that are being compared.

To assess the rarity of individual species in the Iberian Peninsula, information on the number of provinces in which each species is known to occur was used (i.e. the species had been recorded in that province at least once; the cut-off date was 2005) as provided in the appropriate checklists of aquatic Coleoptera and Heteroptera for Spain and Portugal (Nieser and Montes, 1984; Rico *et al*., 1990; Valladares and Montes, 1991; Valladares and Ribera, 1999). The number of provinces on the Iberian Peninsula is 57 (11 Portugal and 46 Spain). For every species recorded an index of rarity (R_i) was calculated as follows: $R_i = 1 - (n_i/n_{\max})$, where n_i is the number of provinces in which the species had been recorded and $n_{\max}$ the number of provinces in which the most widespread species occurs (Coleoptera: *Haliplus lineatocollis*, cited in 50 provinces; Hemiptera: *Hydrometra stagnorum*, cited in 38 provinces). The rarity index takes values between 0 (for species listed in the largest number of provinces; i.e. $n_i = n_{\max}$) and 1 (for species recorded for the first time in the Iberian Peninsula in the current study).

Relationship with environmental factors

Canonical correspondence analysis (CCA) was used to analyse species–environment relationships (Ter Braak and Van Tongeren, 1995) in order to identify environmental (abiotic) factors potentially influencing aquatic Coleoptera and Hemiptera assemblages. The factors analysed were dissolved oxygen, pH, temperature, conductivity and salinity. The statistical significance of the ordination axes 1 and 2 was determined using a Monte Carlo permutation test. Rare species (represented by just one individual) were not down-weighted, thus all occurrences were included in the analysis.

In addition, it was assumed that if the assemblages under study were characteristic of coastal habitats, they should be composed of species that were preferentially recorded in the coastal provinces of the Iberian Peninsula. To validate this, information on the number of littoral (25) and interior (32) provinces where the species had been recorded (as given in the same literature sources cited above) was used. Species were ranked along a littoral–interior gradient by simply subtracting the percentage of interior provinces from the percentage of littoral provinces where the species had been recorded. Hence, coastal (littoral) species will have positive scores and 'interior' species will have negative scores. The range of this 'coastal distribution index' is -1 to 1. Parametric statistics were used to test for differences in rarity and coastal distribution

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scores between Coleoptera and Hemiptera (*t* test) and lagoons (one-way ANOVA). Results are given as means $\pm$ SE.

RESULTS

Species richness

In total, 67 species (52 Coleoptera and 15 Hemiptera) and 6568 adult individuals (2664 Coleoptera and 3904 Hemiptera) were collected (Table 1). Of the aquatic Coleoptera, 29 species belonged to the family Hydradephaga (Gyrinidae, Haliplidae, Noteridae, Hygrobiidae and Dytiscidae) and the other 23 to the family Polyphaga (Hydrochidae, Helophoridae, Hydrophilidae, Hydraenidae, Dryopidae, and Elmidae). Most Hemiptera (six species) belonged to the family Corixidae of the infraorder Nepomorpha. Vixán was the lagoon with the highest richness of Coleoptera (42 species); followed by Xuño (38 species) and Bodeira (19 species). The richness of aquatic Hemiptera showed much less variation between sites and was also highest for Vixán (13 species) although, in this case, more species were recorded in Bodeira (11) than in Xuño (9).

Species rarity

In all pair-wise comparisons Kendall's coefficients of concordance between lagoons were higher for Hemiptera than for Coleoptera, indicating that Hemiptera assemblages were more similar across sites (Table 2). Of the 52 species of water beetle, only 14 species (26.9%) were common to the three lagoons, whereas for Hemiptera, the three lagoons shared a common pool of eight out of 15 species (53.3%). Overall, 13 species of Coleoptera (25%) and three species of Hemiptera (20%) were recorded on only one sampling occasion and were represented by just a single individual (Table 1).

Provincial rarity scores showed that, for both groups of aquatic invertebrates, the species collected in the current study were common throughout the Iberian Peninsula (Figure 2). Mean rarity scores for the two groups were very similar (Coleoptera: 0.48 ± 0.24; Hemiptera: 0.48 ± 0.60; $t = -0.045$; $P = 0.965$). The species with the highest rarity scores were *Hydrochus angusi* (0.94, cited in three provinces) and *Cymbiodyta marginella* (0.92, cited in four provinces) among Coleoptera, and *Sigara scotti* and *Notonecta glauca glauca* (0.84, both species were cited in six provinces) among Hemiptera. Mean rarity scores for Coleoptera (Bodeira: 0.476 ± 0.220; Vixán: 0.475 ± 0.229; Xuño: 0.468 ± 0.224) and Hemiptera (Bodeira: 0.507 ± 0.241; Vixán: 0.506 ± 0.288; Xuño: 0.553 ± 0.262) were very similar for the three lagoons ($F_2 = 0.013$; $P = 0.987$ and $F_2 = 0.100$; $P = 0.905$, respectively).

Relationship with environmental factors

Environmental variables behaved similarly in the three lagoons. Water temperatures were lower in winter and autumn (10.1–12.9°C) and peaked in summer (21.7–24.3°C). Dissolved oxygen values were lower in summer (2.4–4.2 mg L^{-1}) and were close to saturation in spring (10.3–11.6 mg L^{-1}), possibly as a result of photosynthetic activity of macrophytes enhanced by high water temperatures. pH values showed no seasonal trends and were very similar for the three lagoons. In fact, pH was omitted by CANOCO due to negligible variance (6.7 to 8.9). Salinity and conductivity were very highly correlated ($r = 0.994$) and also showed high correlation with Axis 1 ($r = 0.823$ and $r = 0.835$, respectively). Salinity levels were lower in winter and spring and peaked in summer, suggesting that over the year the influx of marine water was through underground filtration. Vixán consistently showed the highest salinity values, with a maximum of 24.8 g L^{-1} in the summer samples. Salinities in Bodeira and Xuño were very low (maximum 0.3 g L^{-1} in summer) (Figure 3).

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Table 1. Aquatic Coleoptera and Hemiptera recorded in the lagoons of Bodeira, Vixán and Xuño and overall seasonal occurrence. The total number of individuals collected is shown

Taxa recorded	Lagoon			Season				
	Bodeira	Vixán	Xuño	Winter	Spring	Summer	Autumn	Total
Coleoptera								
Gyrinidae Latreille, 1810								
Gyrinus (*Gyrinus*) *caspius* Ménétriés, 1832		+	+	+	+			11
Haliplidae Thomson, 1860								
Peltodyte caesus (*Duftschmid*, 1805)	+	+	+	+	+	+		13
Peltodyte rotundatus (*Aubé*, 1836)		+			+			1
Haliplus (*Neohaliplus*) *lineatocollis* (*Marshan*, 1802)		+			+	+	+	5
Haliplus (*Haliplus*) *heydeni Wehncke*, 1875		+			+			1
Noteridae Thomson, 1860								
Noterus laevis Sturm, 1834	+	+	+	+	+	+	+	67
Hygrobiidae Régimbart, 1878								
Hygrobia hermanni (*Fabricius*, 1775)	+		+	+	+	+	+	136
Dytiscidae Leach, 1815								
Copelatus haemorrhoidalis (*Fabricius*, 1787)		+	+	+		+	+	3
Laccophilus minutus (*Linnaeus*, 1758)	+	+	+	+	+	+		15
Hyphydrus aubei Ganglbauer, 1892	+	+	+	+	+	+	+	90
Bidessus goudotii (*Castelnau*, 1834)	+	+	+	+	+	+		155
Hydroglyphus geminus (*Fabricius*, 1792)		+				+		1
Hygrotus inaequalis (*Fabricius*, 1777)	+	+	+	+	+	+	+	316
Hygrotus lagari (*Fery*, 1992)		+	+	+			+	14
Hydroporus planus (*Fabricius*, 1781)			+	+				1
Hydroporus tessellatus Drapiez, 1819			+	+				1
Hydroporus vagepictus Fairmaire & Laboulbène, 1854		+	+	+	+			3
Hydroporus vespertinus Fery & Hendrich, 1988	+		+	+		+		19
Graptodytes aequalis Zimmermann, 1918		+			+	+		4
Graptodytes flavipes (*Olivier*, 1795)	+	+		+	+	+		17
Graptodytes ignotus (*Mulsant*, 1861)		+	+	+		+		109
Stictonectes lepidus (*Olivier*, 1795)		+			+	+		3
Stictotarsus griseostriatus (*De Geer*, 1774)			+	+				1
Agabus bipustulatus (*Linnaeus*, 1767)		+	+	+	+			9
Agabus nebulosus (*Forster*, 1771)			+	+				2
Rhantus (*Rhantus*) *suturalis* (*McLeay*, 1825)		+	+	+	+	+	+	81
Colymbetes fuscus (*Linnaeus*, 1758)			+	+				1
Dytiscus marginalis Linnaeus, 1758		+				+		1
Cybister (*Scaphinectes*) *lateralimarginalis* (*De Geer*, 1774)		+	+		+			4
Helophoridae Leach, 1815								
Helophorus (*Rhopalhelophorus*) *minutus Fabricius*, 1775	+	+	+	+	+	+		66
Hydrochidae Thomson, 1859								
Hydrochus angusi Valladares, 1988		+				+		1
Hydrochus angustatus Germar, 1824		+				+		1
Hydrophilidae Latreille, 1802								
Berosus (*Berosus*) *affinis Brullé*, 1835	+	+	+	+	+	+	+	589
Berosus (*Berosus*) *hispanicus Küster*, 1847		+	+	+		+	+	117
Berosus (*Berosus*) *signaticollis* (*Charpentier*, 1825)		+	+	+			+	4
Anacaena (*Anacaena*) *lutescens* (*Stephens*, 1829)	+	+	+	+	+		+	60
Helochares (*Helochares*) *lividus* (*Forster*, 1771)	+	+	+	+	+	+		56

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Table 1 (*continued*)

Taxa recorded	Lagoon			Season				
	Bodeira	Vixán	Xuño	Winter	Spring	Summer	Autumn	Total
Helochares (*Helochares*) *punctatus Sharp*, 1869	+		+	+				7
Enochrus (*Lumetus*) *halophilus* (*Bedel*, 1878)	+	+	+	+	+	+		102
Cymbiodyta marginella (*Fabricius*, 1792)		+		+		+		15
Hydrobius fuscipes (*Linnaeus*, 1758)			+	+				2
Limnoxenus niger (*Zschach*, 1788)		+	+	+	+	+	+	60
Hydrophilus (*Hydrophilus*) *pistaceus* (*Castelanau*, 1840)		+	+	+	+	+		4
Coelostoma (*Coelostoma*) *orbiculare* (*Fabricius*, 1775)		+		+				1
Hydraenidae Mulsant, 1844								
Hydraena testacea Curtis, 1830		+	+	+	+			3
Limnebius furcatus Baudi, 1872	+	+	+	+	+	+	+	210
Ochthebius (*Asiobates*) *dilatatus Stephens*, 1829		+			+			1
Ochthebius (*Ochthebius*) *nanus Stephens*, 1829	+	+	+	+	+			2
Ochthebius (*Ochthebius*) *viridis Peyron*, 1858	+	+	+	+	+	+		238
Elmidae Curtis, 1830								
Oulimnius rivularis (*Rosenhauer*, 1856)		+				+		1
Dryopidae Billberg, 1820								
Dryops algiricus (*Lucas*, 1849)	+	+	+	+	+			35
Dryops striatellus (*Fairmaire & Brisout de Barneville*, 1859)			+		+			5
Hemiptera								
Guerridae Leach, 1815								
Guerris (*Guerris*) *gibbifer Schummel*, 1832		+			+			1
Hydrometridae Billberg, 1820								
Hydrometra stagnorum Latreille, 1796		+		+	+			2
Veliidae Brullé, 1836								
Microvelia pygmaea (*Dufour*, 1833)	+	+		+	+			6
Notonectidae Latreille, 1802								
Notonecta glauca glauca Linnaeus, 1758		+	+		+		+	4
Notonecta glauca meridionalis Poisson, 1926	+	+	+	+	+		+	26
Notonecta viridis viridis Delcourt, 1909	+	+	+	+	+	+	+	14
Pleidae Fieber, 1851								
Plea minutissima Leach, 1818	+	+	+	+	+	+	+	753
Naucoridae Fallen, 1814								
Naucoris maculatus Fabricius, 1789	+	+	+	+	+	+	+	340
Nepidae Latreille, 1802								
Ranatra linearis (*Linnaeus*, 1758)	+				+			1
Corixidae Leach, 1815								
Corixa panzeri (*Fieber*, 1848)	+	+	+	+	+	+	+	541
Hesperocorixa linnei (*Fieber*, 1848)	+	+	+	+	+	+	+	1460
Hesperocorixa sahlbergi (*Fieber*, 1848)		+			+			4
Sigara (*Halicorixa*) *stagnalis* (*Leach*, 1818)	+	+	+	+	+	+	+	1
Sigara (*Subsigara*) *scotti Douglas & Scott*, 1868	+	+	+	+	+	+	+	34
Sigara (*Vermicorixa*) *lateralis* (*Leach*, 1818)	+						+	717

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Table 2. Kendall's coefficients of concordance (W) for Coleoptera and Hemiptera assemblages in three coastal lagoons of north-western Spain. Concordance coefficients were transformed to chi-square values to test for statistical significance

Pair-wise comparisons	Coleoptera				Hemiptera			
	W	χ^2	d.f.	P	W	χ^2	d.f.	P
Bodeira–Vixán	0.659	46.13	35	n.s.	0.840	18.49	11	n.s.
Bodeira–Xuño	0.769	52.27	34	0.05	0.824	14.83	9	n.s.
Xuño–Vixán	0.637	48.41	38	n.s.	0.904	19.89	11	n.s.

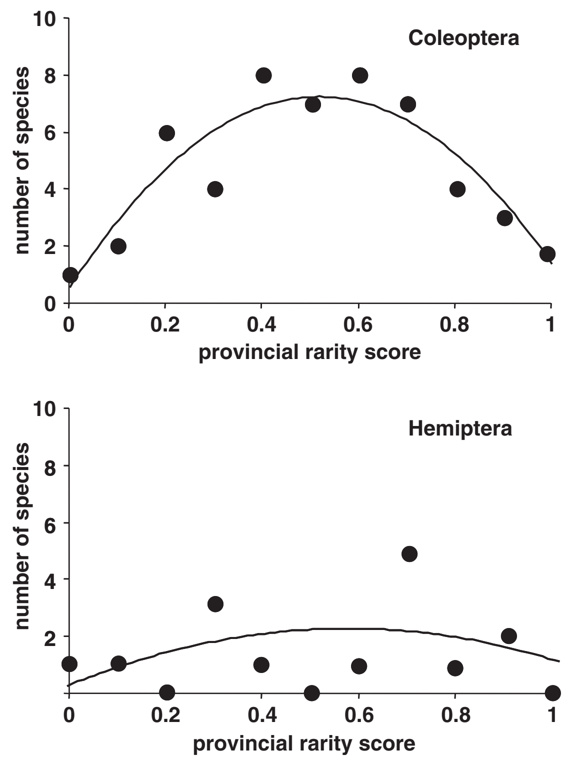

Figure 2. Distribution of provincial rarity scores for aquatic Coleoptera and Hemiptera species collected in three coastal lagoons of north-west Iberia.

CCA showed that the majority of species responded negatively to salinity (Figure 4). However, joint CCA of species and sites clearly separated a subset of 14 aquatic beetle species along the salinity environmental axis (Figure 4). That subset was further separated by CCA into five species that were represented by only a single individual collected in the summer sample from Vixán (*Hygroglyphus geminus*, *Dytiscus marginalis*, *Hydrochus angusi*, *Hydrochus angustatus*, *Oulimnius rivularis*) and nine species with a high frequency of occurrence (abundance) in that lagoon (Figure 4). The only Hemipteran distributed along the salinity axis was *Sigara stagnalis*. In Vixán, species richness of Hemiptera was reduced to just three species (*Sigara stagnalis*, *Naucoris maculatus* and *Plea minutissima*) in the summer and autumn samples, when the salinity values were highest.

Generally, the water beetle species collected had been recorded from interior provinces more frequently than expected by chance (Figure 3). It should be noted that the mean coastal distribution index for the

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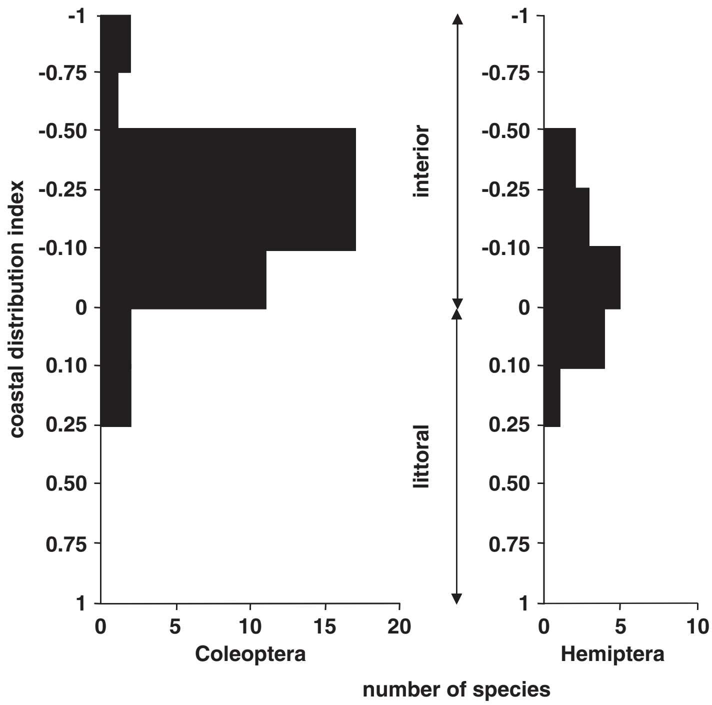

Figure 3. Coastal distribution scores for the aquatic Coleoptera and Hemiptera species sampled in three coastal lagoons of north-west Iberia.

Coleopterans that were distributed along the salinity axis was -0.238 ± 0.226. Hemipterans were more evenly distributed between interior and littoral provinces and their coastal distribution score was closer to 0 (-0.071 ± 0.134). Differences between the two groups were highly significant ($t = -2.690$; $P = 0.009$).

DISCUSSION

In the three lagoons, assemblages of aquatic Coleoptera were richer in species and were less similar in species composition across sites than assemblages of aquatic Hemiptera. When compared with other coastal stagnant water bodies of the Iberian Peninsula (Montes *et al.*, 1982; Garrido *et al.*, 1996, 1997; Ribera *et al.*, 1996; Moreno *et al.*, 1997) they had a similar number of Hemiptera species but were richer in Coleoptera species. Nevertheless, richer Coleoptera assemblages seems to be the rule in aquatic insect communities where the proportion of Coleoptera to Hemiptera usually varies from 3:1 to 4:1 (Eyre and Foster, 1989; Lancaster and Scudder, 1987; Millán *et al.*, 1997, 2001; Moreno *et al.*, 1997). This lends further support to the idea that, for coastal brackish-water systems, Coleoptera assemblages have more value than Hemiptera assemblages for characterizing water bodies and providing informating about their conservation status (Eyre and Foster, 1989; but see Hufnagel *et al.*, 1999). On the other hand, lower similarities in species composition among sites imply that a larger proportion of wetland sites will be needed to ensure the protection of entire assemblages (Margules *et al.*, 1988).

The assemblages of aquatic Coleoptera and Hemiptera in the lagoons studied were predominantly composed of species that were widely distributed at the regional scale. Most of the species of water beetle collected had a wide Palearctic distribution and only three species could be considered endemic to Iberia:

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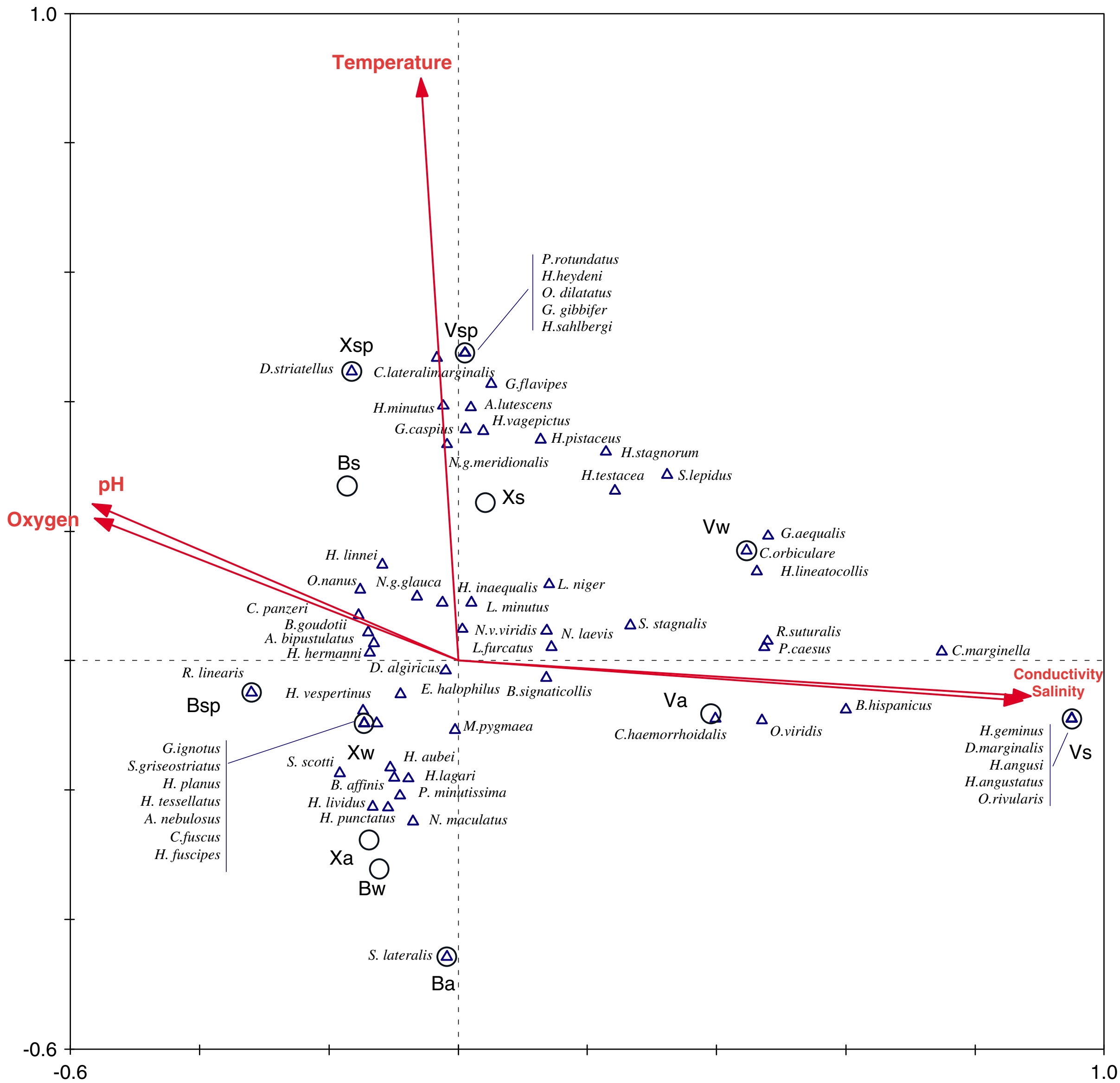

Figure 4. Ordination diagram of species and sites along axis of environmental variables as shown by a canonical correspondence analysis. This figure is available in colour online at www.interscience.wiley.com/journal/aqc

Hydroporus vagepictus, *Hydroporus vespertinus* and *Hydrochus angusi* (Valladares, 1988; Ribera *et al*., 1998; Ribera, 2003). The paucity of endemics among coastal water beetles has been attributed to the temporal dynamics of the lagoons and their recent origin in geological time, as most of the sites are 'temporary' on a scale of a few hundred years (Ribera *et al*., 1996) and this could also apply to aquatic Hemiptera. Similarly, rarity scores based on the number of provinces in Spain and Portugal in which the species were known to occur, suggested also a widespread distribution in Iberia for the majority of species in both groups. It should be noted that Vixán is one of the few localities where *Hydrochus angusi* and *Cymbiodyta marginella*

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have been recorded in the Iberian Peninsula (Sáinz-Cantero and Garrido, 1996). Regarding water bugs, *Sigara scotti* (collected in the three lagoons) and the subspecies *Notonecta glauca glauca* (collected in Vixán and Xuño) are thought to be distributed in the Iberian Peninsula as a few scattered populations (Nieser and Montes, 1984; Nieser *et al*., 1994). However, more than half of the species in the current study were not recorded in two previous comprehensive studies of littoral water bodies along the Mediterranean coast of the Iberian Peninsula (Ribera *et al*., 1996), and Doñana National Park, in south-western Spain (Garrido *et al*., 1996, 1997) suggesting a distinctive fauna for the coastal wetlands of northern Spain when compared to coastal Mediterranean environments (Ribera, 2000).

Ordination analysis showed that the assemblages of Hemipterans and Coleopterans differed greatly in their response to sudden increases in salinity (Barnes, 1999) that are characteristic of coastal lagoons. Assemblages of Hemipterans apparently were much more vulnerable and were reduced to a few species known to be tolerant to osmotic change (Macan, 1962; Montes *et al*., 1982; Millán, 1987; Savage, 1990, 1996; Nieser *et al*., 1994). Among Coleoptera a distinct set of 14 species clearly separated along the salinity gradient and many of them have been recorded in both interior and coastal saline environments (Valladares *et al*., 1994, 2002; Ribera *et al*., 1996; Castro *et al*., 2003; Millán *et al*., 2005). However, the species in this group have also been collected from a wide array of freshwater habitats in the Iberian Peninsula and elsewhere, thus, they are not restricted to saline conditions. Values of a 'coastal distribution index' based upon the number of littoral *vs*. interior Iberian provinces in which the species had been cited in the literature, further suggests that the assemblages of the lagoons under study were far from being composed of species restricted to coastal environments.

The study is limited by small sample size and the sampling regime may not adequately track variations in salinity. However, it suggests that, when compared with other (i.e. freshwater) lenitic water bodies, assemblages of aquatic Coleoptera and Hemiptera in coastal lagoons may not be outstanding in such important conservation attributes as species richness or rarity. In addition, reductions in the number of species related to marked increases in water salinity (i.e. the few tolerant to osmotic change), characteristic of lagoonal habitats, further reduced the value of species richness. Thus, the relative contribution of coastal lagoons to total catchment aquatic insect biodiversity is likely to be low. This calls for caution when selecting areas to protect aquatic ecosystems based on attributes such as species richness or rarity of aquatic insects. Environments with high variations in salinity as well as the species that inhabit them, are of high conservation interest since they show adaptive strategies of high ecological value (Greenwood and Wood, 2003; Sánchez-Fernández *et al*., 2004).

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