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ORIGINAL PAPER

Assessing the quality and usefulness of different taxonomic groups inventories in a semiarid Mediterranean region

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Abstract Extensive biological databases are valuables ecological research tools that form the basis of biodiversity studies. However, it is essential to perform an assessment of the inventories' completeness for their use in ecological and conservational research, and this is especially true for non-emblematic groups. Using four exhaustive databases compiled for four taxonomic groups (aquatic beetles, aquatic bugs, bryophytes and orchids), in a semiarid Mediterranean region, the aim of this study was to estimate the degree of completeness for the inventory of each taxa and to identify those spatial units that could be considered to be sufficiently-surveyed (UTM 10 × 10 km squares). Then, the degree of environmental representativeness of the databases was assessed, as well as those factors that could have caused biased sampling efforts. Lastly, the usefulness of each database for conservational purposes was discussed. The results of the present study highlighted the lack of complete and extensive inventory data; as the best sampled group did not even reach 25% of sufficiently-surveyed squares in the territory (in the case of aquatic bugs) and none of the squares presented reliable inventories in the case of bryophytes. Although these results suggested that recording was skewed by relatively simple climatic variables, the sufficiently-surveyed squares were evenly distributed across physioclimatic subregions, what enables their use in further ecological studies. The authors would like to emphasise the potential of these procedures to locate areas in need of further sampling as well as to aid in the design of more effective regional conservation schemes.

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Introduction

Compiling taxonomic information and distribution data forms the basis for most biodiversity studies. These extensive biological databases are extremely valuable tools in ecological research (Soberón et al. 2000, 2007) and only high quality inventories are able to produce more reliable distribution maps based on adequate sampling efforts (Dennis 2001; Kadmon et al. 2004). However, this is not the case in Mediterranean countries where inventories of many taxa, particularly non-charismatic groups, are incomplete or non-existent (Ramos et al. 2001). The lack of comprehensive information on survey efforts makes it difficult to determine which territories have reliable species inventories and which still need to be surveyed (Santos et al. 2010). These inventories refer to the species richness in a given geographic scale, and their quality depends on the survey effort carried out. A number of papers have pointed out that most of the biodiversity data currently available are scarce and biased, according to spatial, environmental or other variables related to accessibility or attractiveness (Dennis et al. 1999; Lobo and Martín-Piera 2002, Kadmon et al. 2004; Sánchez-Fernández et al. 2008).

In this sense, even when all the available information is exhaustively compiled for a determined taxonomic group, some caveats can hinder the usefulness of the database in describing biodiversity patterns accurately. Hortal et al. (2007) highlighted two of these drawbacks associated with the use of biodiversity databases: (1) lack of survey-effort assessments (and lack of exhaustiveness in compiling data on survey efforts), and (2) incomplete coverage of the geographical and environmental diversity that may affect the distribution of the organisms.

A number of studies have assessed congruency in the distribution of species richness between different species groups (Kati et al. 2004; Rey-Benayas and De la Montaña 2003). Other studies have assessed the sampling efforts carried out for specific taxa (Romo et al. 2006; Sánchez-Fernández et al. 2008; Aranda et al. 2010; Santos et al. 2010), in order to assess how complete or unbiased comprehensive databases are so that more reliable diversity estimations can be provided. Nevertheless, analyzing both the species richness and the sampling effort congruence between different taxa for a particular geographical scale has received less attention (Mora et al. 2008). This procedure enables one to know whether there are areas where sampling efforts have been focused upon, and if these areas are characterised by any particular conditions. In this sense, the number of the database-records can be used as a surrogate of the sampling effort carried out (Lobo 2008). It allows standardizing the sampling results between different collectors, protocols or field methodologies. All of these questions are key conservational issues, since the analysis of the records distribution as a surrogate of sampling effort reveals not only sampling gaps, but also identifies if abundance, richness and diversity data could be reflecting the sampling effort patterns carried out, rather than actual abundance, richness or diversity.

The rapid and irreversible decline of biodiversity, mainly caused by habitat fragmentation and alteration (Pimm and Raven 2000) makes it imperative to find the most effective way to gather the information yet to be described regarding species diversity and distribution. This is particularly important in the Mediterranean Basin, which is considered to be one of the Earth's biodiversity hotspot (Myers et al. 2000), and where landscapes have been subject to strong human influences for millennia (Naveh and Lieberman 1984). Using four exhaustive databases compiled for four taxonomic groups (aquatic beetles, aquatic bugs, bryophytes and orchids) in a semiarid Mediterranean region, the present study aimed to assess the congruence in both the intensity and distribution of sampling efforts carried out in the area. Specifically, the objectives were (1) to estimate the degree of completeness for the inventory of each group (i.e. observed species/estimated species, Soberón et al. 2000) identifying those spatial units that could be considered to be sufficiently-surveyed; (2) to assess the degree of environmental representativeness of the databases, checking if database records and squares that are sufficiently-surveyed are evenly distributed by the pre-established physioclimatic subregions (climatic and topographic variables); (3) to identify factors that biased sampling efforts, i.e., to identify what (spatial, topographic, climatic, land use and attractiveness) variables differed significantly between SSS (sufficiently-surveyed squares) and the remaining squares; and (4) to assess the usefulness of each database for conservational purposes.

Methodology

Study area

The study area in the Region of Murcia is a semi-arid Mediterranean zone located in the south-eastern Iberian Peninsula that encompasses a surface of 11,137 km^2 (Fig. 1). It is part of the Mediterranean Basin's hotspot of biodiversity as defined at the international level (Médail and Quézel 1999; Myers et al. 2000).

This region has an annual average rainfall of approximately 300 mm and annual average temperature of 16°C. In the European context, it is an area of high environmental heterogeneity and singularity. It includes a high diversity of bioclimatic stages, orography, lithology and geology and consequently supports a wide range of ecosystems (Calvo-Sendín et al. 2000; Esteve-Selma et al. 2003; Millán et al. 2006), that could explain the high biodiversity values (Abellán et al. 2005; Achurra and Rodríguez 2008; Mendoza-Fernández

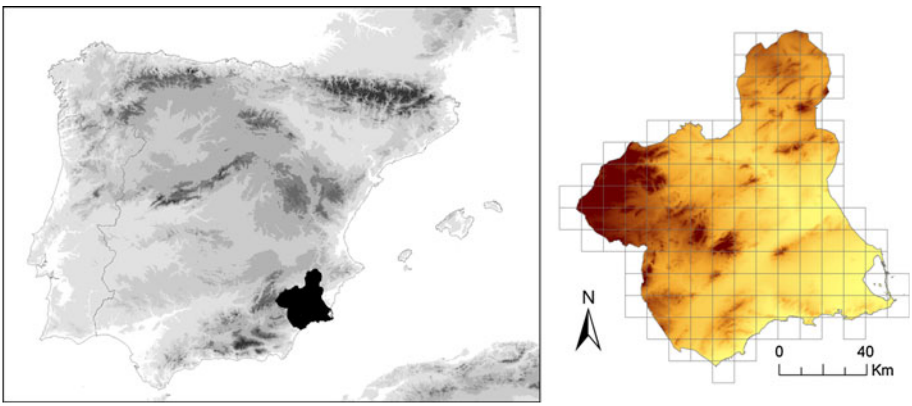


Fig. 1 Geographic location of the study area (Region of Murcia) in the Iberian Peninsula. The 10 × 10 km UTM-squares ($n = 143$) that were used to georeference the biological data are also shown. *Light tones* indicate lower elevations, and *dark tones* indicate higher elevations

et al. 2010; Puissant and Sueur 2010). This region is characterised by a climatic and topographic gradient (NW–SE), from the high (2,000 m), wet (600 mm of mean annual precipitation) and cold (12°C of mean annual temperature) northwest to the low (0 m), dry (220 mm) and hot (20°C) southeast.

Source of biological data

Target groups' selection criteria were based on accessible regional information; only those taxa with available exhaustive databases (aquatic beetles and bugs, bryophytes and orchids) were used. These four databases contained all of the available biological spatially referenced records from literature up to 2009, also including data from museum and private collections, PhD theses, field surveys carried out in the last years and other unpublished sources. All of this information was georreferenced at the same spatial resolution (10 × 10 km UTM-squares) to make the analyses comparable. The study area overlaps with 143 operational spatial units (see Fig. 1). Although the level of precision may vary between groups of different ecological preferences, the used resolution seems to be suitable for the size of the study area and the proposed objectives. We used Spearman rank correlations to assess the concordance between species richness and number of records for each taxonomic group.

The database of water beetles and bugs was compiled by the 'Aquatic Ecology' group at the University of Murcia. This database contained 3,825 records for 162 water beetle species (see Figures S1a and S2a in supplementary material) and 1,476 records for 33 water bug species (see Figures S1b and S2b in supplementary material). The Murcian orchid database (mainly included in López-Espinosa and Sánchez-Gómez 2006) was compiled by the 'Biology, Ecology and Evolution of Bryophytes and Spermatophytes' and contained 902 records for 31 orchid species in the Region of Murcia (see Figures S1c and S2c in supplementary material). The Murcian bryophyte database was developed by the 'Systematic, Molecular, Phylogeography and Bryophyte conservation' group at the University of Murcia. It included 3307 records for 230 bryophyte species (see Figures S1d and S2d in supplementary material).

Assessing sampling efforts and identifying sufficiently-surveyed squares (SSS)

As a first step to evaluate the sampling effort congruency carried out in the study area, we correlated the number of database records by square among the four taxonomic groups using Spearman rank correlations. We also checked if the median number of records per square differs significantly between taxa. Both analyses give an idea of the congruence in sampling effort in terms of distribution and intensity. Secondly, the inventory completeness is analyzed for each group. A variety of statistical techniques (Gotelli and Colwell 2001; Rosenzweig et al. 2003; Koellner et al. 2004; Hortal et al. 2006) were traditionally used to estimate the degree to which the biological data obtained from field sampling or bibliographic compilation represented reliable inventories on a given scale (Petersen and Meier 2003). This completeness value can be calculated based on different estimations of the theoretical maximum richness i.e., an area is usually considered to be adequately sampled when the ratio between the number of recorded species against those predicted (its completeness) is above a specific arbitrary threshold (see Nakamura and Soberón 2009).

Collector's curves have been frequently used to determine the exhaustiveness of the compiled information (Moreno and Halffter 2000; Willott 2001). These curves assume that there is a high probability of adding new species during the first stages of a prospection; however, this likelihood decreases over time as the number of species yet to be discovered decreases. Different equations based on collector's curves have been proposed to estimate the theoretical value of species richness (e.g. Soberón and Llorente 1993; Walther and Moore 2005; Hortal et al. 2006). One of the most applied equations is currently the Clench function (Díaz-Francés and Soberón 2005; Romo et al. 2006; Jiménez-Valverde and Lobo 2007; Picazo et al. 2010). On the other hand, non-parametric estimators have also begun to be used extensively in the recent years (Hortal et al. 2006; Williams et al. 2007; Coddington et al. 2009; Unterseher et al. 2011) due to their easier applicability and effectiveness, being less time-consumers. Their estimations are made by focusing on the rare species (whose that appear in one or two samples) (Colwell and Coddington 1994; Moreno and Halffter 2001) and they require a less amount of data to make a reliable prediction (Brose 2002). Thus, in the present study, two different estimators were used to identify sufficiently surveyed squares (SSS): the previously metioned Clench function (Clench 1979) and Jackknife 1 (see Colwell and Coddington 1994), a non-parametric estimator recommended for incidence (presence/absence) data in small grains that enables the comparison of different taxonomic groups inventories (Hortal et al. 2006). As the shape of these relationships depends on the order in which samples were recorded, the order was randomized 1000 times to obtain a smoothed accumulation curve (using the EstimateS 8.0 software package; Colwell 2006).

The evident scarcity and paucity of non-charismatic hyperdiverse group data in Mediterranean countries (Ramos et al. 2001) and especially in freshwater systems (Lévêque et al. 2005) make difficult to find areas with reliable inventories. In this sense, different completeness thresholds were initially considered, but taking into account (i) the lack of general consensus and (ii) the two complementary approaches used that make the selection more cautious, we consider those squares that display a completeness value above 65% in both approaches to be sufficiently-surveyed (SSS) to reach the proposed objectives.

Assessing biases in sampling effort distribution

With the objective of discriminating among the different environmental conditions that could have shaped the distribution of the sampling efforts, we used three pre-established physioclimatic subregions in the study area (northwest, coastal and interior) that were defined by multivariate analysis using a set of 28 climatic and topographic variables (see Bruno et al. in press a for detail). Firstly, the number of database records for each physioclimatic subregion was calculated. Then, the Kruskal–Wallis test was used with post hoc paired comparisons to investigate if there were differences among the number of database records in the three subregions.

Taking into account the importance of identifying SSS for their multiple usages in biogeography and conservation (e.g. designing effective survey campaigns or to forecast the distribution of biodiversity attributes or individual species distributions in the remaining, poorly-surveyed territory), the environmental coverage provided by the SSS identified for each group was examined. A Chi-square test was performed to assess the proportion of 10 × 10 km SSS for each one of the different physioclimatic subregions.

As an alternative way to analyze the potential biases using the physioclimatic regions, it has been additionally studied the influence of other variables related not only to climate. For this, a Mann–Whitney *U* test was used to identify variables that differed significantly between SSS and the remainder. A total of 34 variables divided into five categories were initially considered: spatial, topographic, climatic, land use and variables related to the attractiveness of the sites (see Table S1 in supplementary material). Spearman rank correlations were applied to reduce the number of variables, removing those ones that showed

$r_s \geq 0.9$; $p < 0.01$, keeping the variables (18 according to the test) that showed a greater number of statistically significant correlations. In case of draw the variable with greater number of $r_s \geq 0.9$ was kept. The Statistica package 8.0. (StatSoft 2007) was used for all computations.

Results

Sampling efforts and completeness values

The observed species richness distribution patterns varied considerably among the groups (see Figure S1 in supplementary material), although in general, it seemed that the north of the study area was richer than the south, with the exception of a few well preserved coastal squares. On the one hand, the Spearman correlation showed a high statistically significant concordance between the richness and record distribution patterns for all of the groups: aquatic beetles ($r_s = 0.993$; $p < 0.05$), aquatic bugs ($r_s = 0.966$; $p < 0.05$), orchids ($r_s = 0.976$; $p < 0.05$) and bryophytes ($r_s = 0.996$; $p < 0.05$) (see Figures S1 and S2 in supplementary material). On the other hand, a significant congruence was found between the distribution of database records for aquatic beetles and bugs ($r_s = 0.860$; $p < 0.05$). The distribution pattern of bryophyte records was also significantly correlated with the distribution pattern of records for the other three groups: aquatic beetles ($r_s = 0.421$; $p < 0.05$), aquatic bugs ($r_s = 0.389$; $p < 0.05$) and orchids ($r_s = 0.460$; $p < 0.05$). Complementarily, we found little variation in the median number of records per square among the taxa: 2 ± 26.64 (median deviation) for aquatic beetles, 1 ± 10.31 for aquatic bugs, 2 ± 5.99 for orquids and 6 ± 22.37 for bryophytes. Additionally, the number of squares with no data varies among aquatic beetles (65 squares), aquatic bugs (74 squares), orquids (49 squares) and bryophytes (50 squares).

There are sensible differences among the results of inventory completeness given by both estimators (see Table 1). Although it seems that species accumulation curves tend to overpredict the real species richness as compared to non-parametric estimators (Walther and Martin 2001), according to the proposed objectives we have chosen to select as SSS those squares that reach an inventory completeness value above the 65% (the maximum completeness value able to provide a minimum number of grid-cells for subsequent analyses) with both estimators (Figures S3 and S4 in supplementary material). The application of Clench function was the method that gave the most restrictive estimation, and in our case, the set of SSS selected using both methods match up with the set using just the Clench function method. Thus, the degree of inventory completeness varied notably among groups (see Figure S3 in supplementary material). Concretely, the number of SSS

Table 1 Number of squares that reach the greater degree of inventory completeness according to the results of the different estimators

Inventory completeness	>65%		>80%		>90%	
Estimator	Clench	Jackknife 1	Clench	Jackknife 1	Clench	Jackknife 1
Aquatic beetles	18	34	3	3	0	0
Aquatic bugs	31	52	8	27	0	10
Orchids	25	43	12	21	4	5
Bryophytes	0	8	0	1	0	0

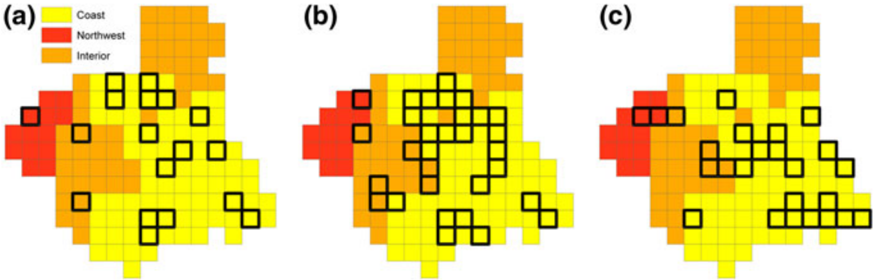


Fig. 2 Distribution of sufficiently surveyed squares (SSS) (*red squares*) on the defined physioclimatic subregions of (**a**) aquatic beetles (**b**) aquatic bugs and (**c**) orchids. (Color figure online)

ranged from 31 squares (21.7% of the whole study area) for aquatic bugs, 25 (17.5% of the study area) for orchids, 18 (13% of the study area) for water beetles, to 0 in the case of bryophytes. In terms of congruence, if we exclude bryophytes, only four squares can be considered as SSS for all the groups at the same time. As completeness values given by Clench function for bryophytes were below the considered threshold in all of the squares, they were not considered for further analyses.

Distribution and sampling effort biases

The Kruskal–Wallis tests point to the fact that none of the taxonomic groups showed differences in the number of records among the three physioclimatic subregions (aquatic beetles: $H = 3.322$, $p = 0.190$; aquatic bugs: $H = 1.221$, $p = 0.543$; orchids: $H = 0.660$, $p = 0.719$; bryophytes: $H = 0.283$, $p = 0.868$). Furthermore, the distribution of the SSS in these three physioclimatic subregions (Fig. 2) was balanced (Chi-square test; $p \leq 0.05$ and 999 permutations) for aquatic beetles ($\chi^2 = 5.109$; $p = 0.078$; d.f. $= 2$), aquatic bugs ($\chi^2 = 5.081$; $p = 0.079$; d.f. $= 2$) and orchid data ($\chi^2 = 4.024$; $p = 0.134$; d.f. $= 2$).

The Mann–Whitney U-test allowed to select the variables that differed significantly ($p \leq 0.05$) between squares considered to be sufficiently-surveyed and the rest ones (see Table 2). Thus, it was found that SSS for orchids were characterised by a lower monthly mean solar radiation than the remaining squares. In the case of aquatic bugs and beetles, a number of variables were significantly different between SSS and the remaining squares, but in general, the SSS were warmer and drier than the rest of squares.

Discussion

How complete are target groups inventories?

Assessing the quality of biodiversity databases could bridge the gap between the need for biodiversity distribution data and limited resources in taxonomic and inventory work. The results of the present study highlight a lack of complete and extensive inventory data; as the best-sampled group did not even reach 25% of SSS in the territory (in the case of aquatic bugs) and none of the squares presented reliable inventories for bryophytes. Approximately a half of the territory remains characterised by a remarkable shortage of records (with <50% of the predicted species recorded). This drawback, the so-called "Wallacean shortfall" (Lomolino 2004), is quite frequent (Whittaker et al. 2005; Bini et al.

Table 2 Variables with significant differences between sufficiently-surveyed squares (SSS) and remaining squares by using a Mann–Whitney *U* test

	Aquatic beetles			Aquatic bugs			Orchids		
	U	p	SSS	U	p	SSS	U	p	SSS
Monthly mean solar radiation	ns	ns	ns	ns	ns	ns	701	<0.001	−
Max temperature of warmest month	598	0.001	+	1126.5	0.002	+	ns	ns	ns
Precipitation of wettest quarter	686	0.007	−	1197	0.005	−	ns	ns	ns
Dryland (%)	751	0.02	−	ns	ns	ns	ns	ns	ns
Irrigated land (%)	751	0.02	+	ns	ns	ns	ns	ns	ns
Aridity	773	0.03	+	ns	ns	ns	ns	ns	ns
Distance to the main research centre	ns	ns	ns	1201	0.005	−	ns	ns	ns
Mean altitude	792	0.04	−	ns	ns	ns	ns	ns	ns

SSS column represents if the median score of each one of these variables is higher (+) or lower (−) for the group of sufficiently surveyed square (SSS)

2006; Kozlowski 2008), and shows that the distribution data of most species are incomplete and biased being this limitation even higher in hyperdiverse groups, such as invertebrates and bryophytes. Moreover, the species richness and record distribution patterns showed high concordance; apparently, the observed richness patterns were a consequence of the sampling efforts applied in the study area. In general, the median number of records per square was low and the dispersion of the data was considerable.

The results have shown that although the databases for bryophytes and water beetles contained more records (and a wider record distribution in the case of bryophytes) than those for aquatic bugs and orchids (see Table S2 in supplementary material), these databases were also the least complete. It could be due to the special nature of these groups, which includes a high number of species and rare species having many of them narrow ecological niches (Hylander et al. 2002; Millán et al. 2006; Stewart and Mallik 2006; Picazo et al. in press). So, the degree of inventory completeness depends on both the sampling effort carried out and the intrinsic nature of the species-abundance distribution: at the same sampling effort applied in a given geographic scale, the groups that hold a greater richness and higher number of rare species will show lower completeness values. Another evidence is the fact that despite bugs had the lowest median number of records per square, they displayed much higher completeness values than aquatic beetles with a similar sampling effort. It has been probably caused by the low number of species and their ubiquitous nature (Polhemus and Polhemus 2008; Carbonell et al. 2011). The orchids, a group with low specific richness in the study area but a high dependence on the microenvironmental conditions exposed moderately high completeness rates. Overall, it is also possible that the spatial resolution (100 km^2) could have influenced the general values of the inventory completeness because there are probably many local rarities for some of the groups not yet discovered. Additionally, the absence of aquatic environments in some particular areas could have caused an underestimation in the inventory completeness of the aquatic groups.

Are there biases in sampling efforts?

Several studies of other taxonomic groups and territories (Dennis et al. 1999; Romo et al. 2006; Hortal et al. 2007, 2008; Aranda et al. 2010), found geographical and environmental biases in the distribution of sampling efforts. Traditionally, biologists have generally been attracted to mountainous landscapes and protected areas with interesting species (endemics, rare species, species with conservation interest, etc.), and/or easy accessibility to the sampling sites (distance from main research centres) (Dennis and Thomas 2000; Romo et al. 2006; Sánchez-Fernández et al. 2008; Aranda et al. 2010). In this study, some individual variables differed between SSS and the remaining squares of the study area. This was especially true for aquatic insect groups whose areas that displayed the greatest sampling efforts were, in general, mainly characterised by higher temperatures and lower precipitation. Additionally, areas that displayed the greatest sampling efforts were closer to the main research centre for aquatic bugs and with a higher irrigated land surface for aquatic beetles. Despite these slight differences, their importance was limited since neither of the taxonomic groups showed differences in the number of records and SSS among the three physioclimatic subregions, what raises the value of the inventories. One possible explanation for this equilibrium and consequent lack of clear biases could be that mountainous and forested areas, although likely more interesting from a conservational perspective, are far from the main research centres. In this sense, the attractiveness of the north western area could be compensated by easier accessibility in the coastal and interior areas.

Checking the utility of biological databases

There are a number of examples using databases in ecological or conservation studies (e.g. Flather 1996; Fagan and Kareiva 1997; Médail and Quézel 1999; Myers et al. 2000; Ferrier 2002; Rey-Benayas and de la Montaña 2003; Rodrigues et al. 2004; Sánchez-Fernández et al. 2004), however the major part of them without a previous assessment of the quality and completeness of the database. On the other hand, the studies that have incorporated this kind of assessment have shown certain bias, lack of completeness or absence of environmental representativeness (e.g. Soberón et al. 2000; Hortal et al. 2007; Mora et al. 2008; Sánchez-Fernández et al. 2008).

In this context, one of the main purposes of the applied methodology was to check whether a relatively reliable predicted distribution based upon limited information could be obtained. According to Hortal et al. (2007) and their schematised protocol to obtain reliable biodiversity maps from biodiversity databases, the applicability of the target group data (at this grain size) varied significantly. On one hand, additional surveys will be required to fill the gaps in existing information of bryophytes so that they will be usable in further ecological studies. On the other hand, although the databases from the rest of the target groups (aquatic beetles, aquatic bugs and orchids) also showed a generalised lack of complete and extensive inventory, the inventories for these groups displayed enough sufficiently-surveyed squares to be used in further ecological studies, although some analyses might be needed prior to their use. For these groups, extra efforts must be directed towards two aims. Firstly, in the short term, predictive modelling will be desirable to provide a picture of the biodiversity distribution that could be closer to reality. Although these databases displayed a low number of SSS, they were representative of the environmental heterogeneity of the study area, they were evenly distributed in the three physioclimatic subregions and harbour an important fraction of the total number of species, which substantially increase their usefulness in predictive ecology (Lobo and Martín-Piera 2002; Hortal et al. 2004). Secondly, more survey efforts will be necessary over time to increase the degree of inventory completeness in general and the number of SSS in particular. These new samples should be located mainly in areas of high precipitation and low temperature for aquatic insects in the study area (i.e. the amount of sampling in the northwest should be slightly higher than in the remaining areas).

Some conservation implications

The discrimination and recognition of poorly surveyed areas as well as the study of the biases associated with the available information are key tasks necessary for the design of more efficient survey strategies (Sánchez-Fernández et al. 2011). In this sense, these results provide a basis for the design of future sampling efforts by enabling the identification of under-sampled regions.

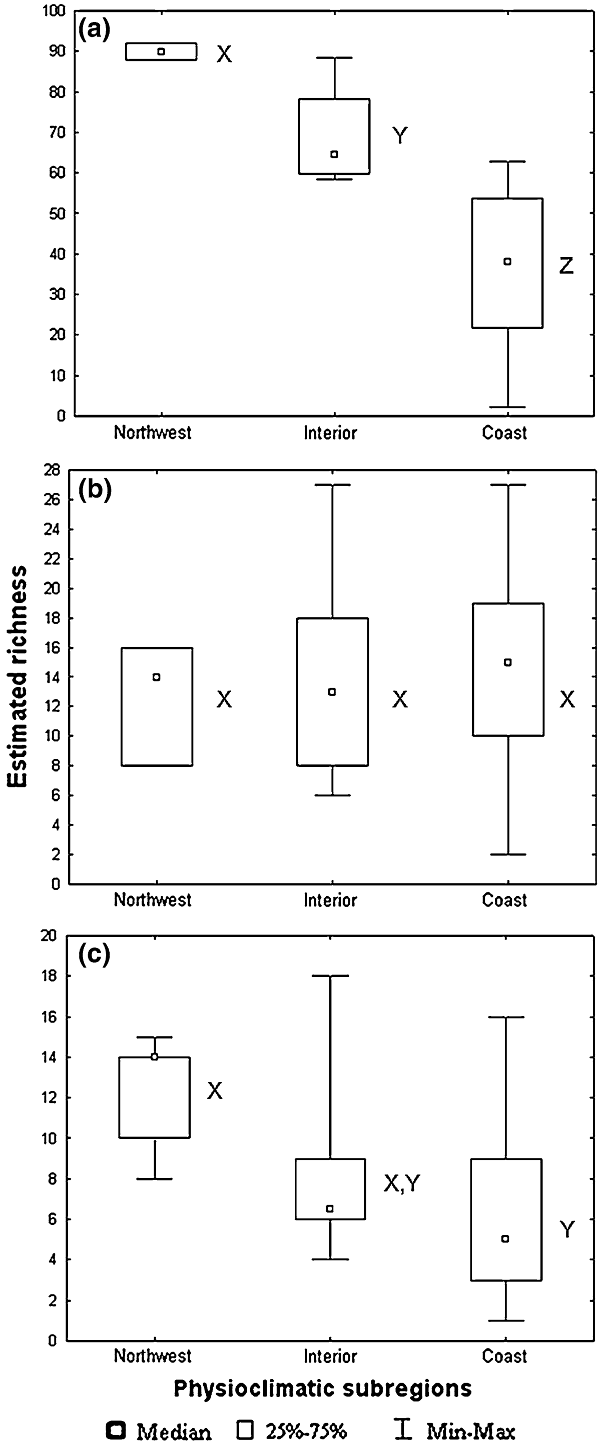
The proportion of severely transformed surface (urban and irrigated land use) in the areas that remain under-sampled is high (24.7% for aquatic beetles, 24.8% for bugs and 26.8% for orchids). In general, the regional southeast (except some well preserved squares in the coast) and some interior areas (close to the main cities) show a high percentage of anthropic land use (sometimes above the 75%). This high rate of anthropization undoubtedly diminishes their interest in order to prioritize the location of further sampling programs since they correspond to highly modified zones where the inclusion of new species is unlikely for all the taxonomic groups studied.

On the other hand, the detection of potentially species-rich regions combined with the results obtained from the sampling effort assessment would also improve efficiency in gathering the remaining information. Considering that observed richness was strongly influenced by sampling effort distribution patterns, the use of estimated richness by Clench function would provide researchers a picture of the richness that could be closer to reality. The estimated richness values of those squares that showed a completeness value above 50% were calculated. Although we are aware of the fact that their use may overpredict the theoretical maximum species richness (especially in completeness values near 50%), the results could be more realistic than those obtained by using the observed richness. Figure 3 shows clear differences regarding the estimated richness among physioclimatic subregions for two of the three studied groups. Following Kruskal–Wallis with post hoc paired comparison, the northwest seems to be a regional hotspot for aquatic beetle ($H = 11.763$, $p = 0.003$) and orchid ($H = 9.009$, $p = 0.011$), existing a decreasing gradient to the coast for aquatic beetle (Fig. 3a) whereas no trend is visible in aquatic bug richness distribution ($H = 0.515$, $p = 0.773$) (Fig. 3b), probably due to the ubiquitous behaviour of this last group (Carbonell et al. 2011).

Finally, the comparison between the distributions of both estimated richness and records of the three physioclimatic regions indicated that the richest areas (those located in the northwest) are not rich because they have been surveyed more intensively than the rest of the region. In fact, the regional northwest has been considered in several studies as the most diverse area for a wide range of taxonomic groups (Carrión-Vilches et al. 2000; De la Calle et al. 2000; Sánchez-Gómez et al. 2002; Sánchez-Fernández et al. 2004; Torralva et al. 2005; Egea-Serrano et al. 2006, Bruno et al. in press b). Consequently, despite its unquestionable diversity, the northwest (both observed and estimated richness point to this area as the more diverse for most groups) requires extra surveys in order to determine to what extent the estimated species richness may approach the real value of maximum species richness.

In conclusion, although it should be noted that the databases used here are the most complete source of information available for non-charismatic groups in the SE of the Iberian Peninsula, the obtained results highlight the necessity of improving their inventories and demonstrate the importance of incorporating sampling bias estimates in

Fig. 3 Distribution of the estimated richness (only calculated for squares with a completeness value ≥50%) among the different physioclimatic subregions for (**a**) aquatic beetles (**b**) aquatic bugs and (**c**) orchids



biodiversity studies. In particular, this combination of methods should be required as a preliminary step in biodiversity and ecological studies, in order to evaluate not only the degree of geographic and environmental coverage of existing faunistic and floristic data, but also the amount, nature and significance of the field work bias.

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