Effectiveness of protected area networks in representing freshwater biodiversity: the case of a Mediterranean river basin (south-eastern Spain)

PEDRO ABELLÁN*, DAVID SÁNCHEZ-FERNÁNDEZ, JOSEFA VELASCO and ANDRÉS MILLÁN
Departamento de Ecología e Hidrología, Universidad de Murcia, Campus de Espinardo, Murcia, Spain

ABSTRACT

1. Biodiversity is probably at greater risk in freshwater systems than in other ecosystems. Although protected areas (PAs) play a vital role in the protection of biodiversity and are the mainstay of most conservation polices, the coverage of biodiversity by existing PA networks is often inadequate and few reserves are created that take into consideration freshwater biota.

2. In this paper an attempt is made to address the performance of protected areas in the context of freshwater biodiversity conservation using data records for water beetles in a Mediterranean river basin.

3. Although the present PAs in the study area cover a relatively high number of water beetle species, the distribution and extent of reserves is still inadequate or insufficient to protect freshwater biodiversity, especially species of conservation concern.

4. Alternative area-selection methods (hotspots and complementary) were more efficient than PAs for representing water beetles. Within these, complementarity was the most efficient approach, and was able to represent all species in a significantly lower area than the current PA network. On the other hand, the future Natura 2000 Network will result in a great increase in the total area of protected land as well as in the biodiversity represented.

5. Unfortunately, the occurrence of a species within a protected area is not a guarantee of long-term survival because the extent of PAs is often insufficient and disturbances occur outside park boundaries. Thus, whole-catchment management and natural-flow maintenance are indispensable strategies for freshwater biodiversity conservation.

Received 19 August 2005; Accepted 11 February 2006

KEY WORDS: freshwater biodiversity; protected areas; gap analysis; representation; Mediterranean river basin; water beetles

*Correspondence to: P. Abellán, Departamento de Ecología e Hidrología, Universidad de Murcia, Campus de Espinardo, 30100 Murcia, Spain. E-mail: pabellan@um.es
INTRODUCTION

Biodiversity is at greater risk in freshwater systems than in other ecosystems (Allan and Flecker, 1993; Master et al., 1998; Ricciardi and Rasmussen, 1999; Saunders et al., 2002). For example, of more than 200 freshwater, wetland and water margin vertebrate species, most species were found to be in decline (WCMC, 1998). This is particularly important in the Mediterranean Basin, which is considered as one of Earth’s hotspot areas for biodiversity (Quézel, 1995; Mittermeier et al., 1998; Myers et al., 2000), and where landscapes have been subject to strong human influence for millennia (Naveh and Lieberman, 1984). The transformation of agricultural landscapes, moving from extensive to intensive farming, has accelerated during this century, leading to the progressive loss of island water habitats (Hollis, 1995; Stoate et al., 2001). One example of this rapid transformation is the south east of the Iberian Peninsula. Because the scarcity of surface water is a distinguishing feature of this region, aquatic ecosystems are especially important, some of them being particularly rich in rare or endemic species (Moreno et al., 1997; Gómez et al., 2005).

A common approach to prevent the loss of biodiversity is the establishment of protected area systems. Protected areas (PAs) play a vital role in the protection of biodiversity and are the mainstay of most conservation policies. However, socio-economic and aesthetic criteria usually predominate in the choice of PA locations, and reserve selection has traditionally been opportunistic, depending on areas becoming available for conservation, political circumstances and local goodwill (Pressey, 1994). This process is likely to be sub-optimal from the point of view of protecting as many species as possible (Prendergast et al., 1999). In fact, a number of authors have noted that the coverage of biodiversity by existing protected areas is inadequate in several regions throughout the world and at different geographic scales (e.g. Bruner et al., 2000; Hopkinson et al., 2000; Powell et al., 2000; Scott et al., 2001; Rodrigues et al., 2004). Nevertheless, very few assessments of protected area networks based specifically on their capacity to protect freshwater biodiversity have been carried out (e.g. Keith, 2000), despite the fact that species losses in freshwater habitats are alarmingly high.

Because there is a general paucity of inventory data for freshwater systems, and complete inventories in many river basins cannot be expected within the near future, solutions are likely to lie in indirect approaches for evaluating the efficiency of the protected area networks in areas where these data are not available. A common approach to estimating biodiversity in data-poor situations is based on indicator taxa, which uses species distribution data of one or a small group of taxa to predict total biodiversity (Noss, 1990). This approach is based on the general idea of matching species richness patterns between different taxa.

In this paper, an attempt is made to address the performance of protected areas in the context of freshwater biodiversity conservation using data records for water beetles. The group of water beetles is a potentially ideal indicator of aquatic ecosystem biodiversity and meets most of the criteria proposed in the literature for such purposes (Noss, 1990; Pearson, 1994). Their taxonomy is well known and they have a worldwide distribution. Beetles occupy the complete range of aquatic habitats, inhabiting virtually every kind of fresh and brackish water body from headwaters to salt-marshes and coastal rock pools, from the smallest puddles up to large lakes and swamps, and from streams to irrigation ditches and reservoirs. Furthermore, they show individual species specialization within habitats. They are present all the year round, sometimes in large numbers. Most species have ecological demands that are sufficiently limited to allow useful predictions to be made about changes in quality and land-use history or simply for characterizing the community and the habitat (Foster, 1987, 1996; Ribera and Foster, 1993). In the Iberian Peninsula, water beetles are a well-known group (e.g. Ribera et al., 1998; Ribera, 2000) with a high species richness. They also are one of the best-studied groups of aquatic insects in the south east of the Iberian Peninsula (e.g. Míllan et al., 2002, and in press; Sánchez-Fernández et al., 2003) and they have already been used as biodiversity indicators for identifying priority areas in this region (Sánchez-Fernández et al., 2004b).
MATERIAL AND METHODS

Study area

The area considered in this analysis is the Segura river basin, located in the south east of the Iberian Peninsula and encompassing an area of 18,815 km² (Figure 1). This basin has a Mediterranean climate, with annual average rainfall of around 375 mm, and frequent and alternating prolonged droughts and major floods. The lithology and geology of the area are very complex, with a predominance of marls and chalk. There are many temporary streams with an irregular flow, usually with highly mineralized water, many of them also eutrophic (Vidal-Abarca et al., 1992). A very important feature of the area in recent times is the high demand for water for irrigation purposes (Martínez-Fernández et al., 2000), 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 (Millán et al., 2002; Sánchez-Fernández et al., 2003; Gómez et al., 2005). All these factors combine to produce a situation of high environmental stress.

Water beetle data

All families of water beetles (sensu Jáeh, 1998) present in the study area were included in this project, together with well-established subspecies. In order to minimize uncertainty, some species were not included owing to insufficient knowledge of their distribution and/or taxonomy (see Abellán et al., 2005c). Data on species were obtained from the literature and from fieldwork. As far as possible, all published and unpublished data presently known were included. The database included more than 5800 available records (species/site/date records) for 209 aquatic beetle species. Because of the lack of complete and extensive inventory data for other aquatic taxa in the Segura river basin, the water beetle records used in the analysis represent the most comprehensible freshwater biodiversity data currently available for the study area.

Figure 1. (a) Map of the study area showing the main watercourses. Locations of sampling localities are indicated with a black solid dot and current PA system is represented as shaded areas. (b) Future Natura 2000 network in the Segura river basin (SCI: proposed Sites of Community Importance; SPA: Special Protection Areas).
Field data were collected between 1981 and 2004 at 423 sites (Figure 1). Most sites were sampled at least twice. The sites selected represent the total diversity of water body types present within the study area. Following Millán et al. (2002), these sampling sites were associated with 18 habitat types according to environmental and ecological parameters (Table 1).

Three groups of target species were distinguished (hereafter called species of conservation concern): rare species, Iberian endemics and vulnerable species. A threshold criterion of one UTM 10 x 10 km grid cell occupied within the study area was used to define locally rare species. A total of 33 Iberian endemics were considered following Ribera et al. (1998). To identify vulnerable species, the 209 species recorded in the study area were ranked according to their conservation priority at the regional level under the vulnerability categorization proposed by Abellán et al. (2005b) for water beetles, which take into consideration a set of six variables (general distribution, endemity, rarity, persistence, habitat rarity and habitat loss). Thus, seven species were considered to be ‘vulnerable’ (those belonging to the high vulnerability and very high vulnerability categories; see Abellán et al. (2005b)).

Protected area data

The protected areas considered were: (1) current PAs (protected areas classified under the legislation of the different Spanish autonomous regions) and (2) future Natura 2000 sites within the Segura river basin.

In Spain, many of the nature conservation responsibilities belong to autonomous governments. However, regional laws differ in the types of designation for protected areas which result in different degrees of protection. Because the Segura basin involves, at least partially, four autonomous regions of Spain, different protected areas designated under the different regional laws fall within the study area. In the present paper, all of them were considered as ‘protected areas’. Thus, several GIS data layers, supplied by regional conservation agencies, were edited and combined to produce a single layer of current protected areas.

On the other hand, the Natura 2000 network forms the core of measures to protect biodiversity in Europe. Under the EC Habitats Directive (EU Council Directive 92/43/EEC), Member States are required to prepare and propose to the European Commission a national list of sites of community importance (pSCIs). These will eventually be designated by the Member States as special areas of conservation (SACs) (Article 4.4). These SACs, together with Special Protection Areas (SPAs) designated under the Birds Directive (79/409/EEC), will collectively form the future Natura 2000 network (Article 3.1 of the Habitats Directive).

Effectiveness assessment

The effectiveness of the current PA system and the future Natura 2000 network at capturing freshwater biodiversity was examined, by spatial overlay of the 209 water beetle species-location records and the protected area data layers in the GIS software Arcview 3.1 (ESRI inc.). The effectiveness of each network of protected areas in the representation of water beetle species (all species, rare species, Iberian endemics and vulnerable species) was evaluated using two different measures. First, a species was considered as protected when at least one of its capture records fell within the boundaries of a protected area. This is the most traditional measure of effectiveness (Rodrigues et al., 1999), but may be misleading if the species are only represented at sites that are inadequate to ensure their persistence (Gaston et al., 2001). As a second measure of effectiveness, viability was taken into account by determining the number of species with two or more capture records (site/date) in the protected area system. The underlying assumption is that the repeated occurrence of a species on different sampling dates within a given protected area and/or the occurrence of a species in at least two protected areas of the network provides a better measure of the effectiveness in retaining species over time. For this, species with only one capture record in the data set (11 species) were removed from the analysis.
<table>
<thead>
<tr>
<th>Habitat type</th>
<th>No. of localities</th>
<th>PA system</th>
<th>Natura 2000</th>
<th>Representation</th>
<th>Complementary areas</th>
<th>Complementary areas (full representation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headwater streams</td>
<td>64</td>
<td>19 (29.7%)</td>
<td>51 (79.7%)</td>
<td>24 (37.5%)</td>
<td>10 (15.6%)</td>
<td>10 (15.6%)</td>
</tr>
<tr>
<td>Middle-reach streams</td>
<td>75</td>
<td>16 (21.3%)</td>
<td>51 (68%)</td>
<td>16 (21.3%)</td>
<td>4 (5.3%)</td>
<td>7 (9.3%)</td>
</tr>
<tr>
<td>Middle course of rivers</td>
<td>23</td>
<td>3 (13%)</td>
<td>16 (69.6%)</td>
<td>4 (16%)</td>
<td>1 (4.3%)</td>
<td>1 (4.3%)</td>
</tr>
<tr>
<td>Rivers influenced by dams</td>
<td>11</td>
<td>—</td>
<td>7 (63.6%)</td>
<td>1 (9.1%)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Eutrophic streams</td>
<td>12</td>
<td>—</td>
<td>3 (25%)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Saline streams</td>
<td>57</td>
<td>5 (8.8%)</td>
<td>14 (25%)</td>
<td>2 (3.5%)</td>
<td>2 (3.5%)</td>
<td>2 (3.5%)</td>
</tr>
<tr>
<td>Springs</td>
<td>25</td>
<td>6 (24%)</td>
<td>14 (56%)</td>
<td>1 (4%)</td>
<td>4 (16%)</td>
<td>4 (16%)</td>
</tr>
<tr>
<td>Irrigation channels</td>
<td>7</td>
<td>2 (28.6%)</td>
<td>2 (28.6%)</td>
<td>—</td>
<td>2 (28.6%)</td>
<td>2 (28.6%)</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>12</td>
<td>2 (16.7%)</td>
<td>8 (66.7%)</td>
<td>2 (16.7%)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Irrigation pools</td>
<td>44</td>
<td>1 (2.3%)</td>
<td>3 (6.8%)</td>
<td>—</td>
<td>3 (6.8%)</td>
<td>1 (2.3%)</td>
</tr>
<tr>
<td>Karstic lagoons</td>
<td>1</td>
<td>1 (100%)</td>
<td>1 (100%)</td>
<td>—</td>
<td>1 (100%)</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>Endorheic lagoons</td>
<td>6</td>
<td>1 (16.7%)</td>
<td>4 (66.7%)</td>
<td>1 (16.7%)</td>
<td>3 (50%)</td>
<td>2 (33.3%)</td>
</tr>
<tr>
<td>Pools, ponds and other wetlands</td>
<td>44</td>
<td>16 (36.4%)</td>
<td>19 (43.2%)</td>
<td>2 (4.5%)</td>
<td>14 (31.8%)</td>
<td>14 (31.8%)</td>
</tr>
<tr>
<td>Continental salt-pans</td>
<td>6</td>
<td>2 (33.3%)</td>
<td>3 (42.9%)</td>
<td>—</td>
<td>—</td>
<td>1 (16.7%)</td>
</tr>
<tr>
<td>Channelized rivers</td>
<td>26</td>
<td>—</td>
<td>1 (3.8%)</td>
<td>—</td>
<td>1 (3.8%)</td>
<td>—</td>
</tr>
<tr>
<td>Rice-fields</td>
<td>2</td>
<td>—</td>
<td>2 (100%)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Coastal salt-pans</td>
<td>6</td>
<td>4 (66.7%)</td>
<td>5 (83.3%)</td>
<td>—</td>
<td>3 (50%)</td>
<td>3 (50%)</td>
</tr>
<tr>
<td>Rock pools</td>
<td>2</td>
<td>1 (50%)</td>
<td>1 (50%)</td>
<td>—</td>
<td>2 (100%)</td>
<td>2 (100%)</td>
</tr>
</tbody>
</table>
Furthermore, the performance of protected area systems was compared with hypothetical networks selected by alternative methods. First, a number of UTM 5 × 5 km grid cells representing an equivalent area (i.e. 74 cells for the current PA system and 216 cells for the Natura 2000 network) were chosen at random. This network of random areas was taken as a guide to the maximum number of species that might be expected to be represented by chance and was achieved through Monte Carlo randomizations (1000 times) with EstimateS software (Colwell, 2005). Furthermore, 20 of the 213 5 × 5 km grid-cells where species have been recorded were selected by different area-selection methods: hotspots and complementary areas. This number is arbitrary but convenient for comparing the results of the area selection methods with the PA system. The area represented by 20 cells is about 3% of the total area of the Segura basin and about 10% of the area surveyed.

Hotspots were calculated for richness (sum of species occurrence records in each grid cell) and range-size rarity hotspots (see Abellán et al. (2005c) for details). Complementarity refers to the degree to which an area contributes otherwise unrepresented attributes (e.g. species) to a set of areas (Vane-Wright et al., 1991) and it is used to seek sets of areas that, in combination, show the highest representation of diversity. Complementarity was used to maximize the number of species represented within a given number of areas (20 grid cells in this case). The complementarity analysis was performed using the ResNet software package (Aggarwal et al., 2000; see also Sarkar and Margules, 2002), which uses a heuristic technique and is a variation of one originally proposed by Margules et al. (1988) (see Abellán et al. (2005c) for details).

In addition, the complementarity approach was used to investigate the minimum set of cells that represents all species, and to identify the priority areas for eliminating gaps in the representation of freshwater biodiversity. For this last purpose, the cells with protection (i.e. those cells whose sampling localities fall within the boundaries of protected areas) were preselected and the species they contain removed from the analysis.

RESULTS

The present network of protected areas in the Segura basin covers more than 1850 km² or 9.7% of the total area through 26 reserves with different types of protection (Figure 1). Of these, only six should be considered as created specifically for the conservation of inland water biota. Another six PAs should be considered as ‘mixed reserves’, created to protect both freshwater and forest or both marine and inland water biodiversity at the same time. Forest reserves are the most abundant, and also cover the largest area. Similarly, coastal reserves are very abundant.

A total of 169 (80.9%) species were found within the current protected area system, of which 12 (50%) are rare, 27 (81.81%) are Iberian endemics and 5 (71.43%) are vulnerable (Table 2). However, when viability was taken into account the number of species within the PA system decreased considerably (Table 3). In both cases, most of the under-represented taxa were restricted-range species (i.e. species that occur in five or fewer 5 × 5 grid cells in the dataset). Nevertheless, the PA network included a significantly greater number of species than the randomly chosen areas (Tables 2 and 3).

The most poorly represented habitats were saline streams (excluding some artificial habitats such as irrigation pools or rice-fields) and middle courses of rivers (Table 1). On the other hand, high and medium altitude water bodies (such as headwater streams and springs), coastal and continental salt-pans and wetlands were the best-represented habitat types. However, most of the under-represented species occur principally in headwater streams, indicating that the representation of this habitat within the PA system is still insufficient.

Tables 2 and 3 show the number and percentage of total species, rare species, Iberian endemics and vulnerable species included in the priority sets (20 grid cells) identified according to each one of the three methods applied. In both measures of effectiveness, alternative area-selection methods (hotspots and
complementarity) were more efficient than PAs at representing overall species richness as well as at covering species of conservation concern. Although richness hotspots were more effective in covering overall species richness than rarity hotspots, the latter generally took in a larger number of species of conservation concern. Nevertheless, the complementarity analysis was the most effective method for representing species. The species-richest areas are located almost exclusively in the north-west half of the basin, in many cases associated with headwater systems at medium–high altitudes (Table 1).

Table 2. Numbers and percentages of total species, rare species, Iberian endemics and vulnerable species included in the protected areas (current PA system and future Natura 2000 network) and area sets identified according to alternative selection methods. The area (and percentage) of the Segura river basin covered by the different area sets is also indicated.

<table>
<thead>
<tr>
<th>Area (km²)</th>
<th>Total species (209)</th>
<th>Rare species (24)</th>
<th>Iberian endemics (33)</th>
<th>Vulnerable species (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current PAs</td>
<td>1850 (9.7%)</td>
<td>169 (80.9%)</td>
<td>12 (50.0%)</td>
<td>27 (81.8%)</td>
</tr>
<tr>
<td>Natura 2000</td>
<td>5397 (28.4%)</td>
<td>207 (99.0%)</td>
<td>22 (91.7%)</td>
<td>33 (100%)</td>
</tr>
<tr>
<td>Random areas a</td>
<td>1850 (9.7%)</td>
<td>114 (54.5%)</td>
<td>2 (8.3%)</td>
<td>14 (42.4%)</td>
</tr>
<tr>
<td>Random areas b</td>
<td>5400 (28.4%)</td>
<td>163 (78.0%)</td>
<td>7 (29.2%)</td>
<td>23 (69.7%)</td>
</tr>
<tr>
<td>Richness hotspots</td>
<td>500 (2.6%)</td>
<td>182 (87.1%)</td>
<td>14 (58.3%)</td>
<td>29 (87.9%)</td>
</tr>
<tr>
<td>Rarity hotspots</td>
<td>500 (2.6%)</td>
<td>181 (86.6%)</td>
<td>19 (79.2%)</td>
<td>30 (90.9%)</td>
</tr>
<tr>
<td>Complementary areas</td>
<td>500 (2.6%)</td>
<td>201 (96.2%)</td>
<td>23 (95.8%)</td>
<td>33 (100%)</td>
</tr>
<tr>
<td>Complementary areas (full representation)</td>
<td>625 (3.2%)</td>
<td>209 (100%)</td>
<td>24 (100%)</td>
<td>33 (100%)</td>
</tr>
</tbody>
</table>

a Random set of 5 × 5 km grid cells representing an equivalent area to current PAs system (i.e. 74 cells).
b Random set of 5 × 5 km grid cells representing an equivalent area to Natura 2000 network (i.e. 216 cells).

Table 3. Numbers and percentages of total species, rare species, Iberian endemics and vulnerable species included in the protected areas (current PA system and future Natura 2000 network) and area sets identified according to alternative selection methods taking viability consideration into account (see ‘Methods’). The area (and percentage) of the Segura river basin covered by the different area sets is also indicated.

<table>
<thead>
<tr>
<th>Area (km²)</th>
<th>Total species (198)</th>
<th>Rare species (13)</th>
<th>Iberian endemics (29)</th>
<th>Vulnerable species (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current PAs</td>
<td>1850 (9.7%)</td>
<td>139 (70.2%)</td>
<td>7 (53.8%)</td>
<td>23 (79.3%)</td>
</tr>
<tr>
<td>Natura 2000</td>
<td>5397 (28.4%)</td>
<td>187 (94.4%)</td>
<td>11 (84.6%)</td>
<td>29 (100%)</td>
</tr>
<tr>
<td>Random areas a</td>
<td>1850 (9.7%)</td>
<td>113 (50.1%)</td>
<td>1 (7.7%)</td>
<td>14 (48.3%)</td>
</tr>
<tr>
<td>Random areas b</td>
<td>5400 (28.6%)</td>
<td>161 (81.3%)</td>
<td>4 (30.8%)</td>
<td>22 (75.9%)</td>
</tr>
<tr>
<td>Richness hotspots</td>
<td>500 (2.6%)</td>
<td>158 (79.8%)</td>
<td>6 (46.2%)</td>
<td>25 (86.2%)</td>
</tr>
<tr>
<td>Rarity hotspots</td>
<td>500 (2.6%)</td>
<td>147 (74.2%)</td>
<td>9 (69.2%)</td>
<td>24 (82.8%)</td>
</tr>
<tr>
<td>Complementary areas</td>
<td>500 (2.6%)</td>
<td>165 (83.3%)</td>
<td>10 (76.9%)</td>
<td>26 (89.7%)</td>
</tr>
<tr>
<td>Complementary areas (full representation)</td>
<td>925 (4.9%)</td>
<td>198 (100%)</td>
<td>13 (100%)</td>
<td>29 (100%)</td>
</tr>
</tbody>
</table>

a Random set of 5 × 5 km grid cells representing an equivalent area to current PA system (i.e. 74 cells).
b Random set of 5 × 5 km grid cells representing an equivalent area to Natura 2000 network (i.e. 216 cells).
or 625 km² (Table 2 and Figure 2). This represents a third of the area covered by the PA system. On the other hand, 37 grid cells (925 km²) were necessary to cover all species with at least two capture records using complementarity (Table 3), which represents half of the current PA system area.

When the contribution of existing protected areas (by preselecting cells with protection) are considered, nine extra 5 × 5 grid cells needed to represent all species. Nevertheless, when we took viability considerations into account, 19 grid cells were necessary to cover all species with at least two capture records (Figure 3). These cells should be considered as priority areas for eliminating gaps in the representation of freshwater biodiversity in protected areas, which include some headwater streams of special biodiversity value not covered by the current PA system as well as habitats under-represented such as endorheic lagoons and saline streams.

To date, the Natura 2000 network in the study area (excluding marine environments) is composed of 67 pSCIs covering more than 4600 km² (23% of the basin) and 22 SPAs covering more than 2772 km² (14.6% of the territory). As sites belonging to different categories (pSCIs or SPAs) may overlap totally or partially,
the real extent of the whole network is around 5397 km$^2$ (Figure 1(b)). This represents about 28.4% of the Segura basin and an increase of about 192% of the protected land area. In terms of biodiversity representation, a high percentage of species fell within this reserve system, all Iberian endemics and vulnerable species being covered (Tables 2 and 3). These values are also significantly greater than those obtained for a number of grid cells representing an equivalent area and randomly chosen (Table 3). Nevertheless, this species representation can only be achieved through the pSCIs, and the incorporation of SPAs in the analysis, despite increasing the extent of the whole network, did not include more species. On the other hand, the Natura 2000 network will include a more complete representation of habitat types than the current PA system, better covering habitats currently under-represented such as middle courses of rivers, endorheic lagoons and saline streams.

**DISCUSSION**

Although the current PA network in the Segura river basin covers a relatively large number of water beetle species, the distribution and extent of reserves is still inadequate or insufficient to protect freshwater biodiversity, since many of the species of conservation concern (rare, endemic and vulnerable species) remain under-represented. This is underlined when viability considerations are taken into account to consider a species as represented in the PA system. This lack of efficiency is related to the criteria used to designate reserves. The establishment of the first PAs in the study area was mainly carried out using criteria other than biodiversity (sublime landscapes, wildernesses, etc.) (Morillo and Gómez-Campo, 2000), though such reference sets may not be repositories of high biodiversity (Pressey, 1994). Over the past decade, as a response to the growing awareness of the need to conserve biodiversity, regional governments started to fill in gaps in the types of habitat that were covered, and issues such as high levels of endemism and the conservation of rare or threatened habitats and species have been given greater consideration. Nevertheless, PA designation has been biased towards particular groups of organisms, such as terrestrial vertebrates (especially charismatic or threatened birds and mammals) and higher plants.
Thus, efforts to conserve freshwater biodiversity (except waterbirds) have often been lacking or ineffective and protected areas have usually been created with little consideration for the needs of aquatic species (Saunders et al., 2002). This is highlighted by the low number of PAs created specifically for the conservation of inland water biodiversity within the study area. Similarly, the higher representation of water bodies typical of forest systems (headwater streams and springs) with respect to other habitats such as saline streams or middle courses of rivers emphasize this polarization towards terrestrial systems in the establishment of reserves. Similarly, the high representation of some coastal habitats is really a consequence of the efforts to conserve some waterbirds or marine habitats rather than the inland water systems included.

Not surprisingly, methods explicitly tailored to deal with representation problems (hotspots and complementary) were more efficient than PAs and the Natura network to represent the taxa in a smaller area. Within these, complementarity was the most efficient approach (see Kiester et al. (1996), Williams et al. (1996) and Araujo (1999) for similar results) and was able to represent all species in a significantly smaller area than the current PA system. In fact, complementarity approaches have been regarded as the most efficient methods to represent conservation targets using water beetle data (Abellán et al., 2005c).

The effectiveness of the different area sets in representing biodiversity was related to the diversity and quality of the habitats. Certainly, PAs tend to include more different and pristine habitats than randomly chosen areas. Similarly, complementary areas and rarity hotspots encompassed a greater habitat diversity than richness hotspots, which included almost exclusively headwaters and middle-reach streams (see Table 1). Thus, the incorporation of less species-rich systems such as saline streams, ponds or coastal habitats resulted in an increase in species representation (see also Abellán et al., 2005c). The fact that the Natura network (which represented more species than PAs) included some artificial habitats that were lacking in the PAs system might suggest that an ideal area set to represent the greatest amount of species should encompass all kinds of habitats from those that are near-natural to those that are heavily degraded. However, species inhabiting artificial habitats also occur in natural systems, which is corroborated by the fact that alternative area sets (such as complementary areas) which did not include these artificial environments were able to include all species (Table 1).

Besides the efficiency of complementarity in species representation, the size of reserves may have a bearing on these results. It has been demonstrated that an atomization of small reserves would contain more species than a single large reserve of equal area (Simberloff and Abele, 1982) and that the minimum percentage of total area needed to represent all species decreases with the decreasing size of the unit (Rodrigues and Gaston, 2001). However, in order to ensure that the reserve networks selected fulfil their role of maintaining biodiversity over time, the size of selection units must be one at which the populations of species are likely to persist, and these small areas, defined by 5 \times 5 \text{ km} grid cells, would be inadequate for the conservation of their freshwater biodiversity. Thus, caution should be exercised when interpreting and implementing the results obtained when selecting minimum complementary sets (Rodrigues and Gaston, 2001). Despite this, results obtained with the complementarity approach may be particularly useful when used to identify gaps in the PA systems and as post hoc procedures to evaluate the efficiency of current selections (Araujo, 1999). The analysis here therefore provides conservationists and managers with some interesting insights for freshwater biodiversity conservation in the study area.

The future Natura 2000 network will result in a large increase in the amount of protected land as well as in the species represented. Since the species representation achieved does not only seem to be a consequence of the considerable increases in the extent of protected land (compared with random areas), these results may be related to designation criteria. Sites proposed as SACs have been selected on the basis of priority habitats and species listed in Annex I (habitats) and Annex II (species) of the Habitats Directive (EU Council Directive 92/43/EEC 1992). Thus, site designation is based on a combination of habitat and species representation, rarity, conservation status, potential for restoration, and ‘ecological value’ at the global scale.
Unfortunately, the role of Natura 2000 in biodiversity conservation is still unclear, since protection measures for these reserves have not been explicitly established. SAC designation requires Member States to establish conservation measures which correspond to the ecological requirements of Annex I habitats and Annex II species present in the site (Article 6.1; Directive 92/43/EEC 1992), and to take appropriate steps to avoid deterioration of the natural habitats and the habitats of species, as well as significant disturbance of species, for which the site is designated. Thus, only if these measures take into consideration freshwater biodiversity will the designation of SACs really be effective. However, species considered for SAC designation are still mostly terrestrial vertebrates and few aquatic invertebrates have been listed in Annex II of the Habitats Directive.

Nevertheless, the Natura 2000 network offers a good opportunity to avoid the dramatic loss of freshwater biodiversity in the study area. At the same time, recent regional initiatives are increasing efforts for freshwater biodiversity preservation. New conservation areas (such as Pétrola and Salobrejalo lagoons) have been proposed as protected areas under the autonomous legislation in Castilla-La Mancha region, which could cover most of the species not represented within the current PA system.

The results here illustrate that the effectiveness of species representation for the different network schemes is very sensitive to the threshold defined for considering a species as covered. So, although the simple occurrence analysis might suggest a successful species representation, the second measure of effectiveness casts doubts on species viability in the protected areas and chosen sites. Some protected areas, especially if they are species-rich, can also have a high number of ‘tourist’ species, but this does not mean that protecting these areas will be of any use for the species within them. Therefore, reserve planning should take viability considerations into account (e.g. Rodrigues et al., 2000; Gaston et al., 2001).

It is important to note that the occurrence of a species within a protected area (even with multiple capture records) is not per se a guarantee of long-term survival. PAs often fail to address important aquatic concerns such as whole-catchment integrity, hydrology, and introduction of non-native species (Lake, 1980; Skelton et al., 1995; Moyle and Randall, 1998). Many activities, such as dam building, diverting water for agriculture, land-use disturbances in the catchment, or the introduction of alien species (Saunders et al., 2002), may occur outside park boundaries yet still have negative consequences for freshwater habitats within the park.

These limitations can be seen in most of the current and future protected areas in the Segura river basin designated to protect inland water habitats. The extent of the present freshwater PAs often includes only the bed, banks and riverside space of reaches of rivers and streams (e.g. Sotos y bosque de ribera de Cañaverosa, Cañón de Amadenes and Rambla Salada), or the inundation space of lagoons and wetlands (e.g. El Hondo, La Mata and Laguna de Alboraj). This is also the case of some of the sSCIIs within the study area (e.g. Rio Quípar, Río Alharabe and Río Pliego). In fact, many of these PAs are currently altered by flow regulation, the introduction of non-native species and land-use disturbances taking place upstream or in the surrounding area (Sánchez-Fernández et al., 2004a). Therefore, occurrence in a protected area is not sufficient to consider a species safe. One example is Ochthebius glaber, a species that is globally threatened (Abellán et al., 2005b), with a distribution restricted to hypersaline streams in the south of the Iberian Peninsula. Despite its occurrence in a protected area (Humedal de Ajauque y Rambla Salada), the populations in this park have decreased drastically in the last decade owing to the land-use changes in the catchment area, which have led to non-point-source pollution and decreases in salinity (Abellán et al., 2005a).

In the Segura river basin, as in other Mediterranean river basins, increased sediment and nutrient loads from agriculture and the alteration of hydrological regimes are the most important threats to inland water species and habitats (Hollis, 1995; Millán et al., 2002; Gómez et al., 2005). Therefore, whole-catchment management and natural-flow maintenance are indispensable strategies for freshwater biodiversity conservation and should be taken into consideration in reserve designation for the adequate protection of freshwater biodiversity.
ACKNOWLEDGEMENTS

We would like to thank I. Ribera for valuable comments and suggestions. We also thank T. Ferreira and an anonymous referee for their useful comments on a previous version of the paper. This work was supported in part by a predoctoral grant from the Caja de Ahorros del Mediterráneo (CAM).

REFERENCES


