Area selection for the conservation of butterflies in the Iberian Peninsula and Balearic Islands

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Abstract

Area selection for the conservation of butterflies in the Iberian Peninsula and Balearic Islands.— Coverage provided by the network of protected areas in the Iberian Peninsula and Balearic Islands was tested by measuring the coincidence between the squares protected by the network and the butterfly species recorded for such UTM grid squares. Five species were found to be absent in the network. The protected areas with the highest numbers of butterfly species were Ordesa National Park and Monte Perdido and the Posets–Maladeta Natural Park. Priority areas were selected using WORLDMAP software and showed that the all species of butterflies in the Iberian Peninsula and Balearic Islands can be found within 16 squares of 10 x 10 km (nine of them not within the network of protected areas). More specific area selections were also carried out: eight squares supported the total number of threatened species, five hosted all the Iberian endemisms and 13 harboured the rare butterfly species. This study detected 16 squares that are not currently protected but are important for butterfly conservation in the Iberian Peninsula and Balearic Islands.

Key words: Conservation, Butterflies, Gap analysis, Protected areas, Iberian Peninsula, Balearic Islands.

Resumen

Selección de áreas para la conservación de las mariposas diurnas de la Península Ibérica e Islas Baleares.— Se ha analizado el nivel de cobertura que proporciona la red de espacios protegidos en la Península Ibérica e Islas Baleares comprobando la coincidencia entre éstos y el número de especies de mariposas registrado. Cinco especies quedan excluidas de la red. Los espacios protegidos con mayor número de especies fueron el Parque Nacional de Ordesa y Monte Perdido y el Parque Natural de Posets–Maladeta. Se realizó también una selección de áreas utilizando el programa WORLDMAP en la que 16 cuadrículas de 10 km de lado albergan a la totalidad de mariposas de la Península Ibérica y Baleares (nueve de ellas no se encuentran dentro de la red de espacios protegidos). También se realizaron selecciones de áreas más específicas: ocho cuadrículas fueron suficientes para albergar la totalidad de especies amenazadas, cinco para los endemismos ibéricos y 13 para las especies de mariposas raras. Basándonos en estos resultados se seleccionaron 16 cuadrículas en el área de estudio que son importantes para la conservación de mariposas y que actualmente no están protegidas.

Palabras clave: Conservación, Mariposas diurnas, Análisis de huecos, Espacios protegidos, Península Ibérica, Islas Baleares.

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Introduction

The Lepidoptera is the third most diverse insect order (following Coleoptera and Diptera: Gullan & Cranston, 2000), with ca. 70 families and 140,000 species, 20,000 of which are butterflies (Heppner, 1991). Butterflies are strongly climate–dependent (e.g. Dennis, 1993; Stefanescu et al., 2003), and their phytophagous larvae favor specific plant taxa. Hence, they are generally believed to be good environmental indicators (New, 1991; Kremen, 1992; Cleary, 2004).

A remarkable decline in butterfly diversity is becoming increasingly evident, especially in central western Europe (Konvicka et al., 2006). Local or regional losses are largely caused by human activity (e.g. Warren et al., 2001; Hill et al., 2002; Pullin, 2002; Pennisi, 2004; Thomas et al., 2004; Pounds et al., 2006). For instance, the distribution range of some British species has decreased by 46% in recent times (Asher et al., 2001), and 21% of the Dutch species vanished during the last century (Van Swaay, 1990). There is some evidence that changes in elevational limits associated with climate warming might be occurring in Central Spain (Wilson et al., 2005).

Spanish policy for the preservation of biodiversity includes the creation of four main categories of natural preserved areas (*Ley 4/89 de Conservación de los Espacios Naturales y de la Flora y Fauna Silvestres,* artículo 12), i.e.: "Parques" (National and Natural Parks), "Reservas Naturales" (Nature Reserves), "Monumentos Naturales" (Natural Monuments) and "Paisajes Protegidos" (Protected Landscapes). These categories are also applicable in Portugal (ICN–Instituto da Conservação da Natureza, http://www.icn.pt/). On a more communitarian level, there is an additional array of legally protected sites and areas. These areas co–exist with the Natura 2000 Network which includes the Sites of Community Importance (SCIs) and the Special Protection Areas (SPAs) (Múgica de la Guerra & Gómez–Limón, 2002; Múgica de la Guerra et al., 2005).

The conservation status of Iberian species and evaluations of the coverage offered by the network of protected areas have been dealt with in some detail for the flora (Castro et al., 1996; Araújo, 1999; Martínez et al., 2001; Cerrillo et al., 2002; Moreno et al., 2003) and the vertebrate fauna (Araújo, 1999; Carrascal et al., 2002; De la Montaña & Rey Benayas, 2002; Carrascal & Lobo, 2003; Lobo & Araújo, 2003; Rey Benayas & De la Montaña, 2003; Filipe et al., 2004; Carrascal et al., 2006; Egea–Serrano et al., 2006; Razola et al., 2006; Rey Benayas et al., 2006). Invertebrates have been far less profusely dealt with (e.g. Rosas et al., 1992; Ribera, 2000). Red Books available include those by Gómez Campo (1987), Palomo & Gisbert (2002), Pleguezuelos et al. (2002), and Verdú & Galante (2006).

An "economy" criterion to design networks of protected areas would require the selection of a minimal number of area units with a maximal number of species. This can be done in several ways (Cabeza & Moilanen, 2001). One technique is Gap Analysis (Burley, 1988; De la Montaña & Rey Benayas, 2002; Méndez, 2003), which first involves setting a hierarchy of area units (e.g. land squares) ordered by decreasing species richness until the set of geographic units hosts the full set of species considered. The selection is then contrasted with the network of preserved areas (using the same geographic units), to detect the squares not included in the protected network ("gaps"; see e.g. Burley, 1988; Pullin, 2002). Gap analysis has been applied to Iberian plants (Castro et al., 1996) and vertebrate animals (Williams et al., 1996; De la Montaña & Rey Benayas, 2002; Rey Benayas & De la Montaña, 2003; Rodrigues et al., 2004a; Rodrigues et al., 2004b; Wall et al., 2004). Several quantitative analyses have been used for the selection of priority areas for conservation (hotspots of rarity, hotspots of richness, random selection and area complementarity: Williams et al., 1996; Araújo, 1999; Ramírez, 2000; Cerrillo et al., 2002; Lobo & Araújo, 2003). Area complementarity seems to be best suited to maximise the full representation of species and to supplement pre–existing networks of protected spaces (Williams et al., 1996; Balmford & Gaston, 1999; Méndez, 2003). Accordingly, complementarity–based approaches have been applied in several geographic contexts (e.g. Ando et al., 1998; Howard et al., 1998; Rodrigues & Gaston, 2002a; Gaston & Rodrigues, 2003; Roig–Juñent & Debandi, 2004) including the Iberian Peninsula (Araújo, 1999; Martín–Piera, 2001; Carrascal & Lobo, 2003; Lobo & Araújo, 2003). Although the outputs obtained by different methods were tested in the present study, we chose area complementarity using richness because this method has proven to be more suitable in butterfly studies.

Analyses of the Iberian butterfly fauna intended for conservation purposes have concentrated either on analysing the species status, or on qualifying land cells by means of species diversity at a regional scale (Viejo et al., 1989; Moreno, 1991; García–Barros et al., 1998), for the Spanish territory (De Viedma & Gómez–Bustillo, 1976, 1985; Munguira & Martín, 1993; Carrión & Munguira, 2001, 2002), Portugal (Garcia–Pereira, 2003) or the whole of the Iberian Peninsula (Munguira, 1989; Munguira et al., 1991, 2003). A preliminary gap–analysis based on selected species was attempted by Carrión & Munguira (2002) for the Spanish butterflies. However, none of these works has used a detailed and extensive database from the whole Iberian butterfly fauna. Comprehensive faunistic information on the Ibero–Balearic butterflies has recently been compiled (García–Barros et al., 2004), allowing an exhaustive evaluation based on updated data. Thus the main aim of this study was to provide, for the first time, a test for the coverage of the Spanish–Portuguese network of protected areas in terms of butterfly species richness. For the reasons mentioned above, this was primarily attempted using richness–based complementarity (although alternative options are

briefly discussed). More specifically, our objectives were: 1) to determine how many and which species are not represented within the network of protected areas, 2) to estimate how much land surface and what sites should be added to the set of preserved areas so that the network provide coverage to all the butterfly species, 3) to identify the most outstanding protected areas from two points of view: for their species diversity or for hosting relevant (threatened, rare, endemic) butterfly species, 4) to select the best subsets of squares for the rare, endemic and threatened Iberian and Balearic species, and finally, 5) based on the former results, to determine which area units (among those not currently protected) should be considered for inclusion in the present network of protected areas.

Material and methods

Study area

The study area was the Iberian Peninsula and the Balearic Islands. The total area is of 584,192 km^2, of which 49,900 km^2 (8.5%) are formally protected by law. The operative geographic units were the UTM (Universal Transverse Mercator) 10 x 10 km grid squares, a system which has previously been used in conservation studies (Viejo et al., 1989; Munguira et al., 1991; Rey Benayas & De la Montaña, 2003). As an operative criterion, the number of the UTM grid squares that totally or partially include a protected area of any extent was calculated.

Species, occurrence data and rarity

We used an updated version of the data described by García–Barros et al. (2004), consisting of 290,329 records assigned to 10 x 10 km UTM grid squares for 223 species of butterflies (Lepidoptera, superfamilies Papilionoidea & Hesperioidea). The number of species present in the protected areas was determined by compiling all the species present in the 10 x 10 km squares that had some part of their area within the boundaries of the protected areas. The status and list of threatened species follows Verdú & Galante (2006), endemicity status is taken from García–Barros et al. (2000, 2002) and both lists are shown in table 1. Species rarity was calculated as (1 / n), where n is the number of 10 km grid squares where the species has been recorded (table 1). Species with an estimated rarity 15% below the maximum value were treated as "rare" in the analyses (e.g. Rey Benayas & De la Montaña, 2003).

Network of protected areas

Information on the limits and extent of the Spanish natural protected areas was gathered from the Ministerio de Medio Ambiente (www.mma.es) and Europarc (www.europarc–es.org) and from the Instituto da Conservação da Natureza (http://www.icn.pt/) and Garcia–Pereira (2003) in the case of Portugal. We took into account 205 Natural Monuments, 10 National Parks, 130 Natural Parks and 209 Nature Reserves. Overall, this network comprised 1,282 10 km squares, which represents roughly 20% of the total number of squares in the study area. An analysis of the most outstanding protected areas was carried out, i.e. those that hosted the highest number of species or threatened species.

Data analysis

The package WORLDMAP 4.17.08 (Williams, 1997) was used. This application was developed to estimate and represent patterns of diversity, rarity and species richness and to facilitate the area selection for management and conservation purposes (Ghillean, 2000). It performs analyses based in complementarity criteria (Méndez, 2003) and has been applied to a wide range of organisms at varied locations and geographic scales (Castro et al., 1996; Araújo, 1999; Williams & Araújo, 2000; Balmford et al., 2001; Lobo et al., 2001; Lobo & Araújo, 2003). Some of the cartographic results were represented using MapInfo software (MapInfo, 1994); and AutoCAD (AutoCAD, 2004) was used for complementary estimates of area and coverage.

Priority area selection and Gap Analysis

To define the minimum number of squares that are necessary to host the total number of butterfly species in the Iberian Peninsula and Balearic Islands, an area selection was performed with the automatic option and using richness as criteria with the function *Greedy area set* of the WORLDMAP program (Williams, 1997), which uses the algorithm designed by Kirkpatrick (1983). This procedure uses a complementarity criterion, with a species richness map as a starting point and adding new squares according to their contribution to the total number of species already included in the previous selection. When there is a conflict between two squares adding the same number of species the program chooses the option with higher richness value. The squares are added until the selected squares are representative of the total number of species.

The selected areas were then matched with the protected areas map to spot which squares were outside the current network of protected areas. This protocol (Gap Analysis; Pullin, 2002) identified the priority squares for butterfly conservation in the studied area and their possible interest as new conservation areas.

As a validation for our method, we tested whether random area selections (made ten times with 1,000 replicas each) produced a better performance as far as the number of species hosted by the same number of squares is concerned. We also identified

Table 1. List of threatened, endemic (E) and rare (R) species considered in this work. Threatened species follow the Red Data Book of the Spanish Invertebrates (RDB, Verdú & Galante, 2006: EN. Endangered; VU. Vulnerable; NT. Near threatened; LC. Least concern), European Red Data Book (ERDB, Van Swaay & Warren, 1999: SPEC 1. Species of global conservation concern; SPEC 3. Species threatened in Europe, but with headquarters both within and outside Europe; SPEC 4a. Global distribution restricted to Europe, but no threatened; SPEC 4b. Global distribution concentrated in Europe, but no threatened) and the Bern Convention (BC) and Habitats Directive (HD) annexes II and IV are also given. *P. apollo* is protected by CITES Convention; and *M. nausithous* (VU) and *P. golgus* (EN) are protected by the Spanish National Catalogue of Threatened Species. Endemic species are shown with a cross (X). If the distribution of endemic species comprises the North of Pyrenees, this is indicated by an asterisk (*). The last column details the number of 10 x 10 km UTM grid squares in which the rare species are present.

Tabla 1. Lista de las especies consideradas como amenazadas, endémicas (E) y raras (R) en este trabajo. Se muestran las especies consideradas amenazadas según el Libro Rojo de los Invertebrados de España (RDB, Verdú & Galante, 2006: EN. En peligro; VU. Vulnerable; NT. Casi amenzada; LC. Preocupación menor), las categorías SPEC del European Red Data Book (ERDB, Van Swaay & Warren, 1999: SPEC 1. Especies amenazadas a escala mundial; SPEC 3. Especies amenazadas en Europa, cuyas poblaciones no se encuentran mayoritariamente en este continente; SPEC 4a. Especies cuya distribución se encuentra restringida a Europa pero no se encuentran amenazadas; SPEC 4b. Especies no amenazadas en Europa que presentan una distribución global aunque concentrada en este continente), y las mariposas protegidas en los anexos II y IV del Convenio de Berna (BC) y la Directiva de Hábitats (HD). P. apollo *además se encuentra dentro del convenio de CITES y* M. nausithous *(VU) y* P. golgus *(EN) dentro del Catálogo Nacional de Especies Amenazadas de España. Los endemismos aparecen representados con una cruz (X). En el caso de que el endemismo se encuentre en el Norte de los Pirineos se representa con un asterisco (*). Se muestra el número de cuadrículas de 10 km de lado en las que se encuentran las especies consideradas raras.*

Threatened species	RDB	ERDB	BC	HD	E	R
Agriades glandon (Prunner, 1798)		SPEC 4a				36
Agriades pyrenaicus (Boisduval, 1840)		SPEC 4a			*	19
Agriades zullichi Hemming, 1933	EN				X	6
Aricia morronensis Ribbe, 1910		SPEC 4a			*	
Aricia nicias (Meigen, 1829)		SPEC 4a				16
Azanus jesous (Guérin, 1849)						1
Boloria eunomia (Esper, 1799)						15
Boloria napaea (Hoffmannsegg, 1804)						8
Borbo borbonica (Boisduval, 1833)						9
Carterocephalus palaemon (Pallas, 1771)						34
Carchadorus tripolinus (Esper, [1780])						6
Chazara prieuri (Pierret, 1837)	VU	SPEC 4b				
Erebia epistygne (Hübner, [1824])	LC	SPEC 1 VU				
Erebia gorgone (Boisduval, [1833])		SPEC 4a			*	
Erebia hispania Butler, 1868		SPEC 4a			*	
Erebia lefebvrei (Boisduval, 1828)		SPEC 4a			*	
Erebia manto (Denis & Schiffermüller, 1775)		SPEC 4a				22
Erebia oeme (Hübner, [1804])		SPEC 4a				19
Erebia palarica Chapman, 1903					X	
Erebia pandrose (Borkhausen, 1788)						9
Erebia pronoe (Esper, [1780])		SPEC 4a				25
Erebia sthennyo (Graslin, 1850)		SPEC 4a			*	28
Erebia zapateri Oberthür, 1875		SPEC 4a			X	30

Table 1. (Cont.)

Threatened species	RDB	ERDB	BC	HD	E	R
Euchloe charlonia (Donzel, 1842)	NT					7
Gegenes pumilio (Hoffmannsegg, 1804)						3
Lasiommata petropolitana (Fabricius, 1787)						13
Lopinga achine (Scopoli, 1763)	VU	SPEC 3 VU	II	IV		6
Lycaena bleusei Oberthür, 1884					X	
Lycaena helle (Denis & Schiffermüller, 1775)	EN	SPEC 3 VU				4
Maculinea nausithous (Bergsträsser, [1779])	VU	SPEC 3 VU	II	II, IV		17
Maculinea rebeli (Hirschke, 1904)	VU	SPEC 1 VU				
Melitaea aetherie (Hübner, [1826])	NT	SPEC 3 EN				
Parnassius apollo (Linnaeus, 1758)	LC	SPEC 3 VU	II	IV		
Parnassius mnemosyne (Linnaeus, 1758)	LC		II	IV		
Plebejus hespericus (Rambur, 1839)	VU	SPEC 1 VU			X	
Polyommatus fabressei (Oberthür, 1910)		SPEC 4a			X	
Polyommatus fulgens (Sagarra, 1925)					X	14
Polyommatus golgus (Hübner, [1813])	EN	SPEC 4a	II	II, IV	X	3
Polyommatus nivescens (Keferstein, 1851)		SPEC 4a			*	
Pseudochazara hippolyte (Esper, 1784)	NT					22
Pseudophilotes panoptes (Hübner, [1813])					X	
Pyrgus andromedae (Wallengren, 1853)		SPEC 4a				21
Pyrgus bellieri (Oberthür, 1910)		SPEC 4a				29
Pyrgus cacaliae (Rambur, [1840])		SPEC 4a				8
Pyrgus cinarae (Rambur, [1840])	VU	SPEC 4a NT				8
Pyrgus sidae (Esper, [1782])	VU					4
Satyrium pruni (Linnaeus, 1758)						12
Satyrus ferula (Fabricius, 1793)						29
Tarucus theophrastus (Fabricius, 1793)						23

the 16 squares with higher species richness (hotspots of richness), the 16 with higher rarity (hotspots of rarity) and made an area selection using complementarity based on rarity (*Near minimum area set, NMS*). The latter uses a rarity algorithm that is based on Margules et al. (1988), that gives priority to squares that have the highest number of rare species. Then it adds the squares that host the largest amount of rare species to the previous set, until the total number of species is represented. When two squares add the same number of new rare species, the program selects that with the highest number of overall rare species, and if even these are similar it makes a random selection choosing the square with the lowest label number. The same set of analyses was performed using only the data with threatened, endemic or rare species.

Species not included in the network of protected areas

To spot the species that were completely excluded from the current network of protected areas a map with these areas was superimposed with the distribution map for each species (depicted with data of the ATLAMAR database). Each species was then tested for presence in the network of protected areas and the species with no representation in this network were selected. The distribution of these excluded species was then represented in a map and an area selection with these species was performed. This selection resulted in areas that needed to be added to the network of protected areas. Conservation of such areas would assure that all the species have at least one population within the network of protected areas.

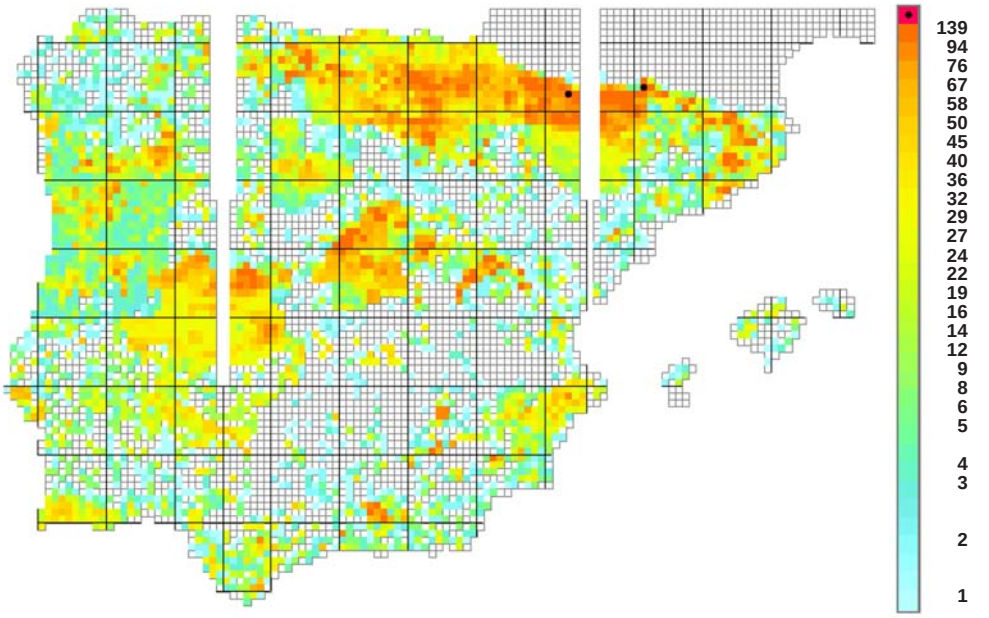

Fig. 1. Geographic distribution of butterfly species richness in the Iberian Peninsula and Balearic Islands obtained with the use of the WORLDMAP program. The highest number of species in each 10 x 10 km UTM square is shown in darker grey tones.

Fig. 1. Mapa de riqueza de especies de mariposas de la Península Ibérica e Islas Baleares obtenido mediante la aplicación del programa WORLDMAP. El mayor número de especies diferentes por cuadrícula UTM de 10 km de lado se muestra con tonalidades de gris más oscuras.

Results

Species richness

The maximum species richness (139 species, 62.33% of the total) was detected in the squares in the National Park of Ordesa y Monte Perdido (Huesca Province) and in Viella (Lérida) (fig. 1; table 2). Highest species numbers concentrate in mountain ranges. The Portuguese territory is overall dominated by a high proportion of low–richness squares.

Selection of priority areas

The use of WORLDMAP with the species richness criterion resulted in a selection of 16 squares (fig. 2A) which altogether would host the whole set of Iberian butterflies, with each species represented in at least one square (table 3). Only seven of these squares (43.8%) belong to the present network of protected areas (fig. 2A), although one of them includes a Protected Landscape. If the Sites of Community Importance (SCIs) were considered as an effective figure for butterfly conservation, the figure would rise to 13 squares; similarly, 12 squares are included in Special Protection Areas (SPAs). In the best of these combinations, three squares (i.e. 29SNB70, 29TNF25, 31SDD68) would still not fall within any protected area.

Alternative selections of squares based on random selection, hotspots of richness, hotspots of rarity, or complementary areas based on rarity were compared with complementary areas based on richness (table 4). The selection based on rarity criterion generally pointed out similar squares that were used as alternatives to the 16 formerly identified. The most relevant difference was the square in Sierra de Baza instead of the formerly selected one in Los Monegros, both supported by the presence of *Euchloe charlonia.*

Species not included in the network of protected areas

The number of species present in each of the main protected areas is summarised in table 5. Five species are not represented in any of the actual protected areas, i.e.: *Gegenes pumilio* (rare), *Pyrgus cinarae* (vulnerable, rare), *Euchloe charlonia* (near threatened, rare), *Boloria napaea* (rare) and *Satyrium pruni* (rare) (details and conservation status in table 1). These five butterflies have been recorded from different (non–coincident) subsets of a total of 38 squares; a selection of areas based solely on these species is given in table 6.

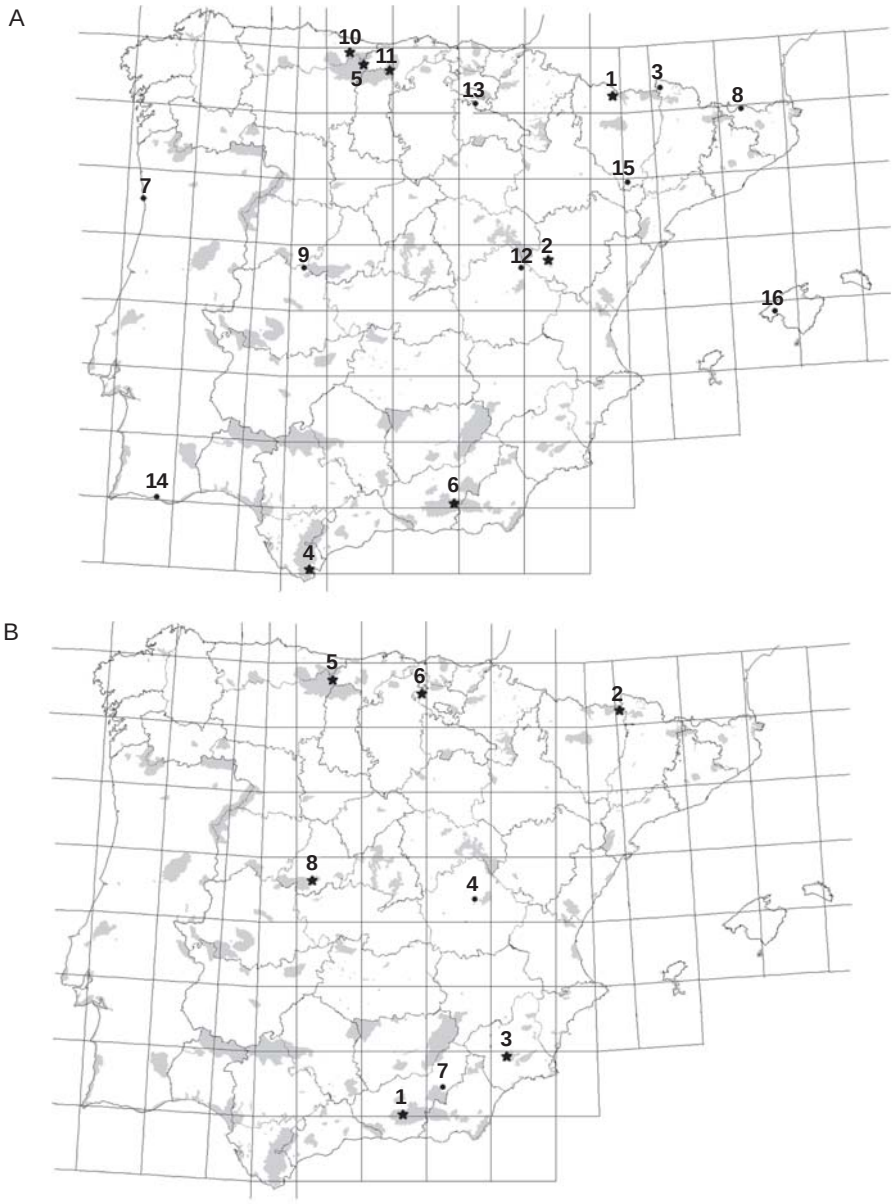

Fig. 2. Selection of high–priority squares for the conservation of butterfly species in the Iberian Peninsula and Balearic Islands, using the complementarity criteria based on richness with the WORLDMAP program. The numbers show the hierarchical position of the areas. The network of protected areas is shown in grey. Stars represent the coincidence between the priority areas selected by the program and the network of protected areas. Circles show the gaps where this selection does not match the network: A. Selection with all the species, the 16 selected squares together host all the Peninsular and Balearic butterfly species; B. The eight selected squares jointly host the total number of threatened species in the study area.

Fig. 2. Selección de cuadrículas prioritarias para la conservación de mariposas en la Península Ibérica e Islas Baleares, utilizando el criterio de complementariedad basado en la riqueza con el programa WORLDMAP. Las selecciones se presentan de forma jerárquica indicada por la numeración. En gris se representa la red de espacios protegidos. Las estrellas muestran la coincidencia de las áreas seleccionadas por el programa con la red de espacios naturales protegidos. Los círculos indican los huecos donde la selección no coincide con la red de espacios: A. Selección con todas las especies, las 16 cuadrículas, consideradas en conjunto, contienen la totalidad de especies de mariposas iberobaleares; B. Selección con las especies amenazadas, ocho cuadrículas UTM de 10 km de lado presentan, en conjunto, la totalidad de especies de mariposas diurnas amenazadas en el área de estudio.

Table 2. Analysis of butterfly species richness in the Iberian Peninsula and Balearic Islands performed using the WORLDMAP program. Values of relative richness (in percentage) referring to the total (223) species are given. Six of these 10 x 10 km UTM grid squares are listed with their respective localities. They account for the highest values in the number of different species (N).

Tabla 2. Análisis de riqueza de especies de mariposas en la Península Ibérica e Islas Baleares realizada con el programa WORLDMAP, en el que se obtienen los valores de riqueza relativa (en porcentaje) respecto al total (223 especies). Se muestran las seis cuadrículas UTM de 10 km de lado, con sus respectivas localidades, que presentan los valores más altos de número de especies (N) diferentes que albergan.

N	Richness (%)	UTM square	Locality	Province
139	61.78%	30TYN32	P. N. Ordesa	Huesca
139	61.78%	31TCH13	Viella	Lérida
136	60.44%	30TXK37	Albarracín	Teruel
132	58.67%	30TUN57	Fuente De	Cantabria
132	58.67%	30TYN23	Panticosa	Huesca
131	58.22%	30TWM92	Sierra del Moncayo	Zaragoza

Table 3. Results obtained in the selection (S) of high–priority squares for the conservation of butterfly species in the Iberian Peninsula and Balearic Islands, using the complementarity criteria based on richness with the WORLDMAP program. Localities are shown according to the hierarchical selection order. The number of species registered in each square (SR), the number of new species added in the selection (SA) and their presence (yes) or absence (no) in the network of protected areas (PA) are also shown.

Tabla 3. Resultados obtenidos en la selección de cuadrículas prioritarias para la conservación de mariposas en la Península Ibérica e Islas Baleares, utilizando el criterio de complementariedad basado en la riqueza con el programa WORLDMAP. Se muestran: las localidades según el orden de selección, el número de especies citadas en esa cuadrícula (SR), el número de especies nuevas que añaden en la selección (SA) y su presencia (yes) o ausencia (no) en la red de espacios naturales protegidos (PA).

S	UTM square	Locality	SR	SA	PA
1	30TYN32	P. N. Ordesa (Huesca)	139	139	Yes
2	30TXK37	Albarracín (Teruel)	136	34	Yes
3	31TCH13	Viella (Lérida)	139	13	No
4	30STF70	Algeciras (Cádiz)	60	8	Yes
5	30TUN57	Fuente De (Cantabria)	132	6	Yes
6	30SVG90	Puerto de la Ragua (Granada)	62	5	Yes
7	29TNF25	Porto (Douro Litoral)	60	4	No
8	31TDG39	Nuria (Gerona)	82	3	No
9	30TTK66	La Garganta (Cáceres)	102	2	No
10	30TUN39	Covadonga (Asturias)	94	2	Yes
11	30TVN06	Reinosa (Cantabria)	52	2	Yes
12	30TWK96	Tragacete (Cuenca)	127	1	No
13	30TWN21	Montoria (Álava)	115	1	No
14	29SNB70	Faro (Algarve)	32	1	No
15	31TBF59	Los Monegros (Huesca)	32	1	No
16	31SDD68	Son Espanyolet (Mallorca)	30	1	No

Table 4. Assessment of the efficiency of the current network of protected areas (regarding UTM squares with any percentage of protected surface, or UTM grid squares with more than 15% of their surface protected). We compared the number of threatened, endemic, rare species and the total of butterfly species in the Iberian Peninsula and Balearic Islands by several area selections based on different criteria (random selection, hotspots of richness and rarity, and complementarity). The number of UTM squares considered for each selection, the number of species recorded in these squares and the relative percentage in relation to the total in each case are shown. The asterisk (*) represents average ± standard deviation.

Tabla 4. Valoración de la efectividad de la red de espacios protegidos actualmente existente (considerando las cuadrículas UTM con cualquier porcentaje de espacio protegido, y aquellas cuadrículas UTM que tengan más del 15% de su superficie protegida) y comparación con la representatividad que ofrecen las selecciones de áreas aleatorias, los puntos de máxima riqueza y rareza y las selecciones de áreas complementarias a las especies amenazadas, endémicas, raras y a la totalidad de las especies de mariposas de la Península Ibérica e Islas Baleares. Se muestra el número de cuadrículas UTM de 10 km de lado consideradas en cada caso, el número de especies que reúnen y el porcentaje de estas especies respecto al total de especies consideradas en el área de estudio en cada caso. El asterisco (*) indica la media ± la desviación estándar.

		No. of squares	Species	% Species
All species	Protected areas	1,282	218	97.76
	Protected areas (> 15%)	718	211	94.62
	Hotspots of richness	16	197	88.34
	Hotspots of rarity	16	202	90.58
	Complementarity (1 representation)	16	223	100
	Complementarity with rarity (NMS)	16	223	100
	Random selection*	16	133 ± 0,9	59.64
Threatened	Protected areas	1,282	14	87.5
	Protected areas (> 15%)	718	11	68.75
	Hotspots of richness	8	10	62.50
	Hotspots of rarity	8	10	62.50
	Complementarity (1 representation)	8	16	100
	Complementarity with rarity (NMS)	8	16	100
	Random selection*	8	6 ± 0,5	37.5
Endemic	Protected areas	1,282	16	100
	Protected areas (> 15%)	718	14	87.5
	Hotspots of richness	5	12	75
	Hotspots of rarity	5	7	43.75
	Complementarity (1 representation)	5	16	100
	Complementarity with rarity (NMS)	6	16	100
	Random selection*	5	5 ± 0	31.25
Rare	Protected areas	1,282	27	81.82
	Protected areas (> 15%)	718	21	63.64
	Hotspots of richness	13	19	57.58
	Hotspots of rarity	13	23	69.70
	Complementarity (1 representation)	13	33	100
	Complementarity with rarity (NMS)	12	33	100
	Random selection*	13	12 ± 0	36.36

Table 5. Number of different butterfly species (N) present in the richest protected areas in the Iberian Peninsula and Balearic Islands. The percentage shows the species present in the protected areas with regard to the total number of diurnal butterflies in the study area (223). The protected areas with percentages above 50% are those included in the table.

Tabla 5. Número de especies diferentes de mariposas (N) que presentan los espacios protegidos de mayor riqueza en la Península Ibérica e Islas Baleares. El porcentaje indica las especies que están presentes en el espacio protegido respecto al número total de especies de mariposas diurnas del área de estudio (223). Las áreas protegidas con porcentajes mayores del 50% son las incluidas en la tabla.

Protected area	N	%
Ordesa y Monte Perdido	160	71.7
Posets–Maladeta	159	71.3
Parque Regional de los Picos de Europa	152	68.2
Parque Nacional de los Picos de Europa	148	66.4
Massís del Montseny	144	64.6
Cadí–Moixeró	144	64.6
La Sierra y Cañones de Guara	138	61.9
Fuentes Carrionas y Fuente Cobre	137	61.4
Moncayo	132	59.2
Urbasa y Andia	132	59.2
Cuenca Alta del Manzanares	130	58.3
Zona Volcánica de La Garrotxa	129	57.8
Gorbeia	126	56.5
Sierra de Cebollera	125	56.1
Sierras de Cazorla, Segura y Las Villas	122	54.7
Cumbre, Circo y Lagunas de Peñalara	121	54.3
Sierra Nevada	120	53.8
Alto Tajo	119	53.4

Table 6. Results of the square selection (S) using the richness criteria, performed with the WORLDMAP program for the butterfly species that are not present within the network of protected areas in the Iberian Peninsula and Balearic Islands. The selected localities and the name of the species added in the selection are shown.

Tabla 6. Resultados de la selección de cuadrículas (S) realizada con criterio de riqueza, con el programa WORLDMAP para las especies de mariposas que se encuentran fuera de la red de espacios protegidos en la Península Ibérica e Islas Baleares. Se muestran las localidades seleccionadas y el nombre de las especies que se añaden en la selección.

S	UTM square	Locality	Species registered
1	30SWG24	Baza (Granada)	*Euchloe charlonia*
2	31SDD67	Cas Catalá (Mallorca)	*Gegenes pumilio*
3	30TWK73	Cuenca	*Pyrgus cinarae*
4	30TXM48	Sadaba (Zaragoza)	*Satyrium pruni*
5	31TDG49	Setcases (Gerona)	*Boloria napaea*

Table 7. Protected areas with the highest number of threatened butterfly species (T) in the Iberian Peninsula and Balearic Islands and the number of these species in each area.

Tabla 7. Espacios naturales protegidos que presentan el mayor número de especies de mariposas amenazadas (T) en la Península Ibérica e Islas Baleares y el número de estas especies en cada área.

Protected area	T
Sierra Nevada	5
Posets–Maladeta	5
Picos de Europa	4
Alto Tajo	4
Sierra de María–Los Velez	3
Sierra de Baza	3
Sierra Espuna	3
Oodesa y Monte Perdido	3
Dehesa del Moncayo	3
Cadí–Moixeró	3
Aigüestortes i Estany de Sant Maurici	3

Threatened species, area selection and Gap Analysis

The distribution of threatened species was compared with the network of protected areas (tables 4, 7). Only 46.8% of the records of threatened species and 34.5% of the squares hosting any of the threatened species fell within the protected network. Two squares (31TCH02 in the Pyrenees and 30SVG60 in Sierra Nevada) represented the top hotspots from the point of view of threatened species, with five of these species per square. Comparatively important numbers of threatened species were concentrated in parts of the Iberian System, Cantabrian Mountains and the Sierra del Moncayo. The minimum selection needed to cover the threatened species would be eight squares (fig. 2B, table 8), six of which are within the protected network. The remaining two are those selected by the presence of *Pyrgus cinarae* and *Euchloe charlonia* (i.e.: Cuenca in Central and Baza in Southern Spain).

The complementarity selection based on rarity pointed out several alternative sites such as Los Monegros (NE Spain, instead of Sierra de Baza); Béjar (not protected, instead of the presently protected Navarredonda, both in Western Spain) based on the presence of *Pyrgus sidae*; and Cacém (Estremadura, Portugal, not protected) instead of Sierra Espuña (SE Spain protected), due to the occurrence of *Melitaea aetherie* (tables 4, 9).

Endemic species, area selection and Gap Analysis

Richness analysis showed three squares with seven Iberian endemic species each (30TYN04, 31TCH02, 30SVG60). The results showed a similar pattern with threatened species, although in this case the Central System was detected for its endemic species richness.

Five squares together hosted the 16 Iberian endemic butterflies (fig. 3A, table 8). Three of these squares were within the network of protected areas. The complementarity selection based on rarity resulted in one additional square (Puerto del Escudo, Burgos, N Spain) chosen for the presence of *Polyommatus fulgens* (table 4). The main differences encountered using this selection were the square for Sierra del Moncayo (Zaragoza) instead of Navacerrada (Central Spain, both squares outside the network of protected areas) as a result of the presence of *Lycaena bleusei*; and the selection of Candanchú (Pyrenees, not protected) instead of Benasque (Pyrenees, protected) due to the occurrence of several species of the genus *Erebia* (table 9).

Rare species, area selection and Gap Analysis

The highest number of rare species (11 species) was concentrated in the square 31TCH02 (Pyrenees). The areas with higher number of these species were Sierra Nevada and Cádiz in Southern Spain, the Cantabrian Range and the Iberian System. An area selection resulted in 13 squares which altogether hosted all the rare species (fig. 3B, table 8). Seven of these squares were within the network of protected areas. Complementarity selection based on rarity analysis resulted in one square less in the Pyrenees than that based on richness (table 4); one square in Los Monegros replaced that in Sierra de Baza as a consequence of the presence of *Euchloe charlonia* (table 9).

Summary of analyses

The results show that 16 squares are important for the conservation of diurnal butterflies and are not represented in the existing network of protected areas (fig. 4). Nine further squares may be worth considering because of the relevance of the species recorded therein (table 9).

Discussion

Species richness and protected areas in the Iberian Peninsula and Balearic Islands

The 223 butterfly species considered showed differences in their conservation status, abundance and distribution in the study area. According to Rey Benayas & De la Montaña (2003), rarity can be defined as the inverse value of the number of squares in which a species is present (1 / n). There

Table 8. Selection of high–priority squares (S) for the conservation of butterfly species in the Iberian Peninsula and Balearic Islands, using the complementarity criteria based on richness with the WORLDMAP program with the threatened, endemic and rare species (present in less than 37 UTM grid squares). Localities are shown according to the hierarchical selection order, the number of threatened, endemic and rare species registered in that grid (SR), the number of new species added in the selection (SA) and their presence (yes) or absence (no) in the network of protected areas (PA).

Tabla 8. Selección de cuadrículas prioritarias (S) para la conservación de mariposas en la Península Ibérica e Islas Baleares, utilizando el criterio de complementariedad basado en la riqueza con el programa WORLDMAP con las especies amenazadas, endémicas y raras (presentes en menos de 37 cuadrículas UTM). Se muestran: las localidades según el orden de selección, el número de especies amenazadas, endémicas o raras citadas en esa cuadrícula (SR), así como el número de especies nuevas que se añaden en la selección (SA) y su presencia (yes) o ausencia (no) en la red de espacios naturales protegidos (PA).

	S	UTM square	Locality	SR	SA	PA
Threatened	1	30SVG60	Veleta (Granada)	5	5	Yes
	2	31TCH02	Benasque (Huesca)	5	4	Yes
	3	30SXG29	Sierra Espuña (Murcia)	3	2	Yes
	4	30TWK73	Cuenca	3	1	No
	5	30TUN57	Fuente De (Cantabria)	3	1	Yes
	6	30TVN95	Puerto de Orduña (Burgos)	2	1	Yes
	7	30SWG24	Baza (Granada)	1	1	No
	8	30TUK26	Navarredonda (Ávila)	1	1	Yes
Endemic	1	30SVG60	Veleta (Granada)	7	7	Yes
	2	31TCH02	Benasque (Huesca)	7	4	Yes
	3	30TXK64	Sierra de Javalambre (Teruel)	5	2	No
	4	30TUN47	Puerto de Pandetrave (León)	5	2	Yes
	5	30TVL10	Navacerrada (Madrid)	4	1	No
Rare	1	31TCH02	Benasque (Huesca)	11	11	Yes
	2	31TCH23	Salardú (Lérida)	9	3	No
	3	30STF70	Algeciras (Cádiz)	3	3	Yes
	4	30SVG90	Puerto de la Ragua (Granada)	3	3	Yes
	5	31TDG39	Nuria (Gerona)	7	2	No
	6	30TUN57	Fuente De (Cantabria)	4	2	Yes
	7	30TWK84	Valdecabras (Cuenca)	2	2	No
	8	30TUN96	Puerto de Palombrera (Cantabria)	2	2	Yes
	9	31TCH14	Les (Lérida)	6	1	No
	10	30TUN48	Cordiñanes (León)	3	1	Yes
	11	30SWG24	Baza (Granada)	1	1	No
	12	31SDD67	Cas Catalá (Mallorca)	1	1	No
	13	30TUK26	Navarredonda (Ávila)	1	1	Yes

is, however, no generalized criterion in the classification of Spanish species through the use of their geographic ranges.

The percentage of squares that can be designed as relevant for having at least some part of their surface as a protected area is relatively low (20%). However, this figure is larger than the 15% considered in the European Union as a guideline for nature conservation (79/409/ECC Bird Directive and 92/43/ECC Habitat Directive) (European Commission, 1996;

Table 9. Selection of important squares for butterfly conservation, taken from the analyses of all area selections based on richness with the WORLDMAP program. These squares are not present within the current network of protected areas. The asterisk (*) indicates squares that are alternative to previous proposals, as a result of the area selection based on rarity (*Near Minimum Area Set*) performed with the WORLDMAP program. Localities are shown together with the species responsible for the selection of the squares: VU. Vulnerable; NT. Near threatened; R. Rare; E. Endemic; LC. Least concern.

*Tabla 9. Selección de cuadrículas importantes para la conservación de las mariposas obtenidas a partir de los resultados de todos los análisis de selecciones de áreas basados en riqueza realizados con el programa WORLDMAP y que no se encuentran dentro de la red de espacios protegidos existente. Con un asterisco (*) se marcan las cuadrículas obtenidas con el programa WORLDMAP basado en rareza (*Near Minimum Area Set*), consideradas como cuadrículas alternativas a las propuestas. Se muestran las localidades y las especies por las que esas cuadrículas son elegidas en la selección de áreas: VU. Vulnerable; NT. Casi amenazada; R. Rara; E. Endémica; LC. Preocupación menor.*

UTM square	Locality	Species
30SWG24 31TBF59	Hoya de Baza (Granada) Los Monegros (Huesca)	*Euchloe charlonia* (NT, R)
30TWK73 30TWK96	Cuenca Serranía de Cuenca	*Pyrgus cinarae* (VU, R) *Erebia epistygne* (LC) *Chazara prieuri* (VU)
30TXM48 31TCH14	Sadaba (Zaragoza) Les (Lérida	*Satyrium pruni* (R)
31TDG49 31TDG39	Setcases (Gerona) Nuria (Gerona)	*Boloria napaea* (R)
31SDD67 31SDD68 31SDD79*	Cas Catalá (Mallorca) Son Espanyolet (Mallorca) Bunyola (Mallorca)	*Gegenes pumilio* (R)
29TNF25	Porto (Douro Litoral)	*Pseudophilotes panoptes* (E)
29SNB70	Faro (Algarve)	*Melitaea aetherie* (NT) *Carchadorus tripolinus* (R)
29SMC89*	Cacém (Estremadura)	*Melitaea aetherie* (NT)
31TCH13	Viella (Lérida)	139 species
30TTK66	La Garganta (Cáceres)	*Pyrgus sidae* (VU, R) *Lycaena bleusei* (E)
30TTK67*	Béjar (Salamanca)	*Pyrgus sidae* (VU, R)
30TXM03*	Sierra del Moncayo (Zaragoza)	*Lycaena bleusei* (E)
30TXK64	Sierra de Javalambre (Teruel)	*Erebia zapateri* (E, R) *Plebejus hespericus* (VU, E) *Polyommatus fabressei* (E) *Polyommatus nivescens* (E) *Pseudophilotes panoptes* (E)
30TVL10	Navacerrada (Madrid)	*Aricia morronensis* (E) *Lycaena bleusei* (E) *Polyommatus nivescens* (E) *Pseudophilotes panoptes* (E)
30TUP41*	Nueva (Asturias)	*Maculinea alcon*
30TVN36*	Puerto del Escudo (Burgos)	*Polyommatus fulgens* (E, R)
30TWN14*	Nanclares de la Oca (Álava)	*Callophrys avis*
30TYN04*	Candanchú (Huesca)	*Erebia gorgone* (E) *Erebia lefebvrei* (E) *Erebia sthennyo* (E, R)
31TCH81*	Encamp Cortals (Andorra)	*Aricia nicias* (R) *Boloria eunomia* (R)

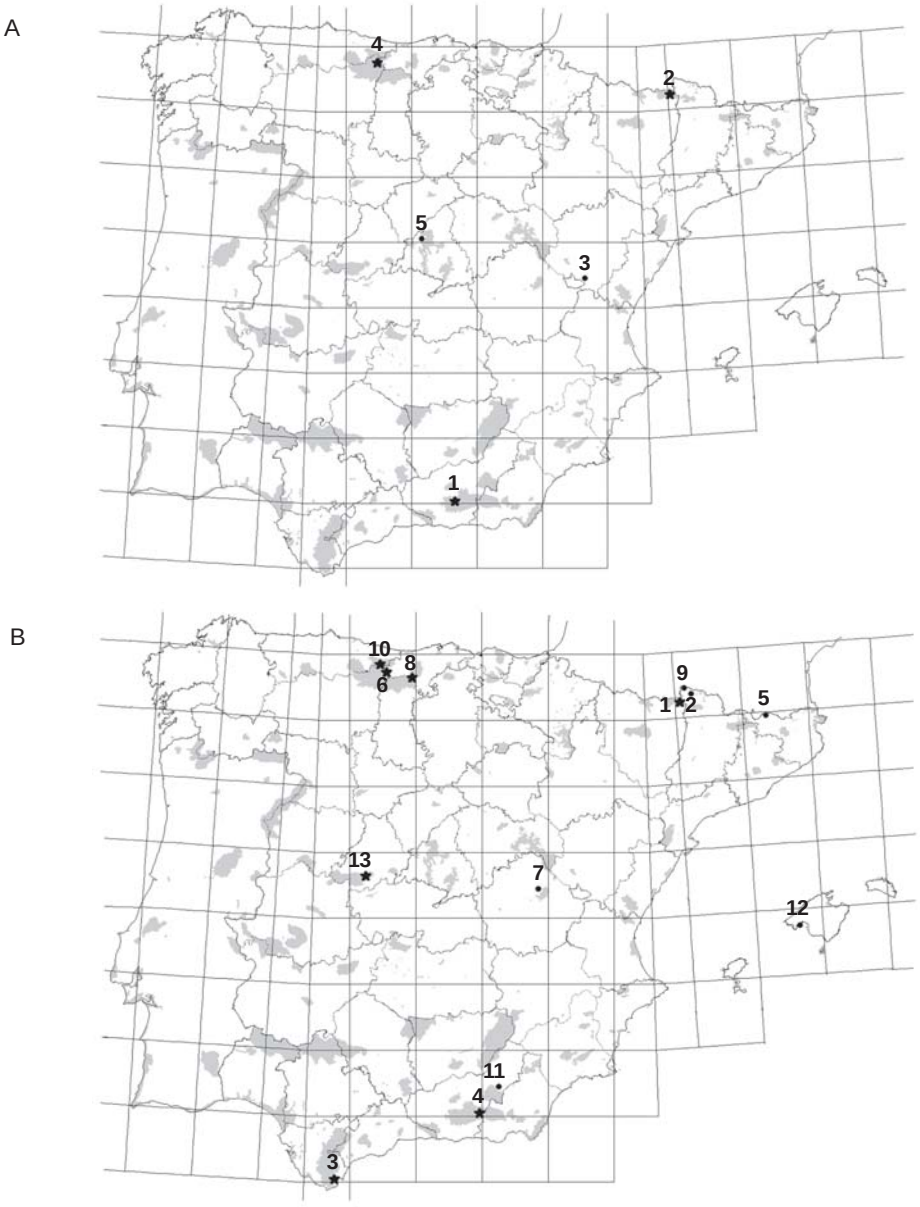

Fig. 3. Selection of high–priority squares for the conservation of butterfly species in the Iberian Peninsula and Balearic Islands, using the complementarity criteria based on richness with the WORLDMAP program. The numbers show the hierarchical position of the areas. The network of protected areas is shown in grey. The stars indicate the coincidence between the priority areas selected by the program and the network of protected areas. The circles show the gaps where this selection does not match the network: A. The five UTM grid squares selected jointly host the total number of endemic species in the study area; B. The 13 UTM grid squares selected together contain all the rare species (present in less than 37 100 km^2 UTM grid squares) in the study area.

Fig. 3. Selección de cuadrículas prioritarias para la conservación de mariposas en la Península Ibérica e Islas Baleares, utilizando el criterio de complementariedad basado en la riqueza con el programa WORLDMAP. Las selecciones se presentan de forma jerárquica indicada por la numeración. En gris se representa la red de espacios protegidos. Las estrellas indican la coincidencia de las cuadrículas seleccionadas por el programa con la red de espacios naturales protegidos. Los círculos indican los huecos donde no coincide la selección con la red de espacios: A. Se presentan las cinco cuadrículas UTM que, en conjunto, albergan a la totalidad de especies endémicas en el área de estudio; B. Se presentan las 13 cuadrículas UTM que albergan, en conjunto, la totalidad de especies raras (presentes en menos de 37 cuadrículas UTM de 100 km^2) en el área de estudio.

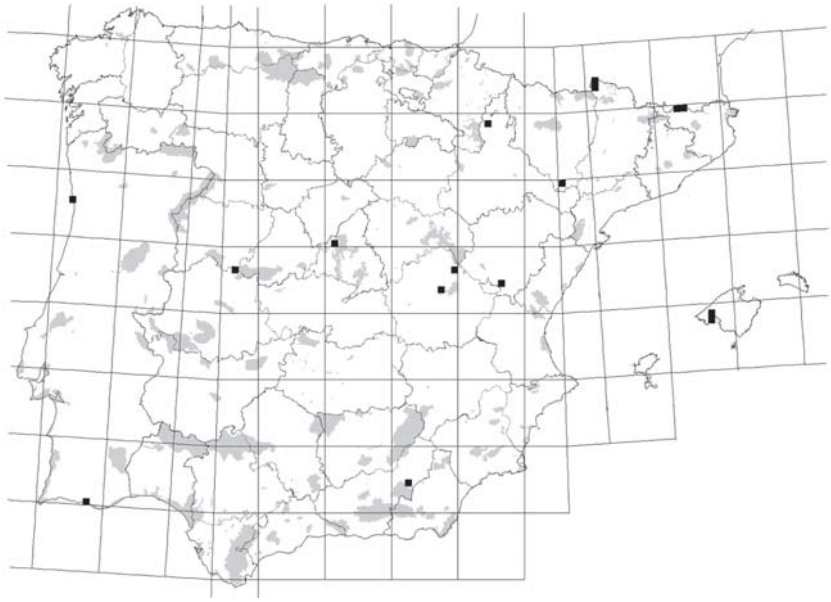

Fig. 4. Selection of the important UTM grid squares for butterfly conservation in the Iberian Peninsula and Balearic Islands obtained in the different analyses in this paper. The network of protected areas is represented in grey. The selected squares are shown in black.

Fig. 4. Selección de cuadrículas UTM importantes para la conservación de las especies de mariposas diurnas a la luz de los resultados obtenidos en los diferentes análisis. En gris se representa la red de espacios protegidos. Los cuadrados negros indican las cuadrículas seleccionadas.

Rey Benayas & De la Montaña, 2003). The use of 10 km grid squares can nevertheless bias this percentage, giving a higher value than the real percentage of protected areas (8.5%). It has also been suggested that it is not appropriate to favour a universal basis for the proportion of conserved land, because this percentage should depend on the faunistic composition of the considered territory (Rodrigues & Gaston, 2001).

Species richness is higher in the Central Pyrenees, the Cantabrian Mountains, the Central System, Sierra Nevada, Sierras Béticas and the Serra de Gerês. These results are highly consistent with previous studies carried out with butterflies (García–Barros et al., 2000) and with other plant or animal groups (Castro et al., 1996; Lobo & Araújo, 2003; Rey Benayas & De la Montaña, 2003; Rey Benayas et al., 2006). The Pyrenees are a typical area for lepidopterological studies due to the ample knowledge of their important species richness (García–Barros & Munguira, 1999). Sierra Nevada is also a relevant site for its diversity and the number of threatened and endemic species it hosts (Carrión & Munguira, 2002; Munguira et al., 2003). The altitudinal gradient has a major influence on butterfly diversity in a given area (Martín & Gurrea, 1990), and our results clearly show higher diversities in mountains. The fact that most protected areas in the Iberian Peninsula have been declared in mountain ranges produces a coincidence between hotspots for butterflies and nature reserves that is favourable for conservation purposes. This is the case in regions like Andalusia, the Oriental Pyrenees, Cantabrian Mountains, part of the Central System and the mountains in Northern and Central Portugal.

The richness of threatened, endemic and rare species regularly follows similar patterns: the Pyrenees and Sierra Nevada show the highest values and are followed by the Cantabrian Mountains and the Southern part of the Iberian System. For the endemic species the Central System is also important. This geographic pattern is very similar to that previously obtained with endemic vascular plants (Castro et al., 1996) and with endemic butterflies using 100 km grid squares (Martín et al., 2000). As far as butterflies are concerned, it was already known that the number of endemic species is correlated with the total number of species (García–Barros et al., 2000).

Selection of priority areas

Gap Analysis is an efficient tool that can be used as a first step in the selection of priority areas for conservation purposes (Scott et al., 1993). The

areas selected by this procedure need to be analysed carefully in order to obtain detailed knowledge of the fauna they can preserve and its conservation needs.

Using the presence of a species in at least one 10 km square as a basis for the Iberian Peninsula and Balearic Islands, the minimum number of squares to cover all the species would be 16. This figure is rather low and in other animal groups the necessary area is larger with 13 (50 km) squares necessary to protect the 252 Spanish bird species (Carrascal & Lobo, 2003), five 50 km squares for amphibians, and nine for all the reptiles (Lobo & Araújo, 2003; note the scale difference). In Portugal, 27 squares (10 km) are necessary to cover a population of all the amphibians and reptiles and lower plants (Araújo, 1999). The selected squares are scattered right throughout the Iberian Peninsula and Mallorca but at the same time they are concentrated in areas with diversity hotspots or areas with larger numbers of endemic species. The selection thus covers areas such as the Pyrenees, the Cantabrian Mountains and the Iberian System, as well as areas in Portugal, the South of Andalusia and Balearic Islands.

Three squares in the selection are not protected in the network of protected areas or in the Natura 2000 Network (SCIs and SPAs) and have species of interest such as *Melitaea aetherie* (NT, see table 1), *Pseudophilotes panoptes* (endemic species) and *Gegenes pumilio* (rare following the criteria used in this analysis). Some squares have been selected in the different analyses because they host species whose records need to be confirmed, such as *Azanus jesous* that has not been recorded again since its discovery and can be considered a casual immigrant. The square selected for this species is also interesting, however, for hosting other butterflies, and in fact adds eight new species in the selection process. The species *Gegenes pumilio* has not been found in the Balearic Islands (its distribution area) since its last record in 1978.

Species not covered by protected areas and fauna in these areas

The species that are excluded from the protected area network are different to those pointed out by Carrión & Munguira (2002). *Euchloe charlonia, Satyrium pruni,* and *Pyrgus cinarae* were detected in both studies as excluded from the network, and *Gegenes pumilio* and *Boloria napaea* are only excluded in our analysis. The reasons for this are that the present study considers a larger amount of protected areas than that of Carrión & Munguira (2002) and also the database from which data come is more detailed. Besides, the threatened species considered for both analyses differ slightly because the Red Data Book of the Spanish Invertebrates (Libro Rojo de los Invertebrados de España, Verdú & Galante, 2006) had not been published when the first study was performed and the status of these species has now been better assessed.

The protected parks that show the largest number of species are concentrated in the Pyrenees and the Cantabrian Mountains. This confirms the altitudinal effect in butterfly richness described by Martín & Gurrea (1990). The protected areas with the largest number of species in our study are consistent with those in the literature (Carrión & Munguira, 2001, 2002), stressing the importance of some traditional and relevant areas for the conservation of butterflies in the study region.

Area selection with threatened, endemic and rare species

The areas selected for hosting all the threatened, endemic or rare species show a very similar pattern, with squares scattered all throughout the Peninsula with the exception of Portugal. Sierra Nevada is the first selected area for both threatened and endemic butterfly species as it is for vascular plants (Castro et al., 1996). On the other hand, the first square selected for rare species is in the Pyrenees. The second selected area for all these species is also in the Pyrenees.

The area selection for threatened species has an overall similarity with that in the proposal of Prime Butterfly Areas (PBAs) with the exception of Portugal, where the number of PBAs was five (Van Swaay & Warren, 2006), while our analysis did not select priority areas for threatened species in Portugal. Threatened species are concentrated in mountain areas, a pattern different that contrasts with other groups such as amphibians (concentrated in the Northern coast and Balearic Islands) and reptiles (South and East of the Peninsula) (Rey Benayas & De la Montaña, 2003; Razola et al., 2006). Threatened birds and mammals are, on the other hand, mainly found in the centre of the Peninsula and are not abundant in mountain areas as butterflies are (Rey Benayas & De la Montaña, 2003).

It is well known that mountain areas are important for endemic butterfly species (Balleto, 1995; Martín et al., 2000; García–Barros, 2003). Our results show similar patterns to those made with 50 km UTM squares (García–Barros et al., 2000), although there were some differences with some areas in the Pyrenees that were not relevant for their endemicity in other studies (Martín et al., 2000). It is also interesting to note that the butterfly pattern is similar to that of endemic collembolan, with the exception of Sierra Nevada (Martín et al., 2000).

Rare species of butterflies follow a similar pattern to other animal groups (amphibians, reptiles, birds and mammals), with a high priority for the Pyrenees and Cantabrian Mountains (Rey Benayas & De la Montaña, 2003). The areas selected in this analysis that are not otherwise protected should be considered in further conservation plans due to their important rare species accumulation (table 8).

A problem that should not be overlooked is the difference between the size of the squares in which the data were taken compared with the size of the squares from the network of protected areas that is usually in the range of one or more orders of magnitude (Hopkinson et al., 2000). Another drawback is the fact that we only have butterfly data from 4,114 (10 km) of the total of 6,395 squares for the Iberian Peninsula and only between 6.8% and 9.8% have been properly sampled (Romo & García–Barros, 2005). This could affect the conclusions of this study, but it is also true that most areas that are rich in butterfly species are well studied and sampled.

Squares selected in different analyses

Because the networks of protected areas designed using criteria for other animal groups might not be efficient in protecting insect species (Araújo, 1999; Rodrigues & Gaston, 2001), it is important to take into account the information gathered from the latter. Nevertheless, the protected areas in the Iberian Peninsula provide coverage for the majority of butterfly species. The figures are more favourable than for other taxa such as plant species, in which a gap analysis needed 97 new 10 km squares to achieve a total coverage of the species in the Iberian Peninsula (Castro et al., 1996).

In all the analyses performed for the conservation of the near threatened (NT) and rare (R) species *E. charlonia,* two squares are highlighted: Hoya de Baza (Granada, 30SWG24, table 9) and Los Monegros (Huesca, 31TBF59). The former results in four different selections (the area selection with species not covered by protected areas, with threatened and rare species and with the complementarity analysis based on rarity); this square was previously suggested for the conservation of *E. charlonia* by Carrión & Munguira (2002). Area selections based on species richness (taking into account all the butterfly species) and those based on rarity with rare and threatened species highlight an area in Los Monegros for the same species. The conservation of both areas would be necessary for this threatened species because its distribution range within Europe is restricted to Spain. Regarding the squares from Cas Catalá (31SDD67) and Son Espanyolet (31SDD68) in Mallorca, selected for *G. pumilio*, it would be necessary to review the distribution and species' status because the records are rather old and from isolated populations. Finally, Viella (31TCH13) in the Pyrenees is one of the locations with highest species richness in the study area (139). It is not within any protected area and is selected in the third position in the area selection process.

Species richness has been used as a criterion for the selection of conservation areas, although not all authors consider it is the most efficient method (Viejo et al., 1989; Williams et al., 1996; Araújo, 1999; Balmford & Gaston, 1999; Reyers et al., 2000; Méndez, 2003; Rey Benayas & De la Montaña, 2003). Threatened and endemic species are also important targets in conservation proposals, but they do not always warrant the representation of the total number of species (Bonn et al., 2002). Our results show that the richest areas are also those with most endemic and threatened species, a conclusion verified in previous studies (Williams et al., 1996; Cofré & Marquet, 1999; Bonn et al., 2002). Therefore, a selection based on species richness and a complementarity criterion can be considered a reasonable preliminary approach. It is also true that this preliminary analysis could be improved with other more complex techniques such as linear programming, which allows the assignation of a specific conservation value for each species. This would result in an optimization of the design of a protected area network (Carrascal & Lobo, 2003; Rodrigues & Gaston, 2002b) through the elaboration of more realistic selections among all the used methods.

Although some authors have shown with other taxa that complementarity selections based on rarity (*NMS*) are more effective (Csuti et al., 1997), in the case of butterflies the selections based on richness provide an interesting alternative in the set of squares that host the total fauna under consideration. Selection based on rarity showed a tendency to aggregate the squares in particular areas, while the richness selection produced a more scattered pattern. Thus the richness option seems to be more adequate when considering the minimization of extinction risk, because it spreads the localities in wider areas and therefore makes them less vulnerable to any given impacts. However, in some cases the rarity selection is useful, because it detects squares outside the protected areas, while richness selection chooses a protected square for the same species. In these cases we have proposed both options as the best conservation strategy (see table 9).

Random selections have in all cases produced a lower percentage of total considered species than the complementarity area selections or the already existing network of protected areas. The latter options are thus more suitable than random selections for conservation strategies. Rarity and richness hotspots also showed low percentage of species and tended to aggregate the selected squares in the Pyrenees and Sierra Nevada and in the Iberian System or Central System in some analyses. They are not thus a good strategy for conservation because concentrating all efforts in the same area is not the best alternative if there are other possible choices.

With the analysis of the information available we can say that the conservation status of Iberian and Balearic butterflies is relatively good, particularly when compared with the countries in our geographical vicinity. Comparisons with the number of species now extinct in other European countries (Konvicka et al., 2006) and the number of threatened species per country (Van Swaay & Warren, 1999) seem to support this statement. In our study,

a high percentage of the butterfly species is within the network of protected areas, and a few UTM squares hosts all the butterfly species, but full protection of these insects in the Iberian Peninsula and Balearic Islands is not guaranteed. Our study highlights the necessity to add new areas to the currently existing network and suggests a first approach in complementing this network.

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