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Integrating habitat diversity into species conservation in the Mediterranean mosaic landscape

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Abstract

Biodiversity conservation requires strategies that encompass a variety of land uses and habitat diversity. In this study, we used sites of high ecological interest identified on the basis of the distribution of priority plant and vertebrate species to assess the implications of habitat diversity for conservation management in the Mediterranean mosaic landscape. 40% of the priority species occur in open habitats that depend on continued human presence and low-intensity land-use activities. Furthermore, 70% of the sites have more than one species habitat and 15% of sites contain more than four different species habitats. By explicitly integrating localized habitat variation, conservation planning can address the multiple conservation issues at stake in regions of high landscape diversity to provide clear and effective management objectives.

Keywords: biodiversity, conservation planning, Mediterranean, landscape mosaic

Introduction

Biodiversity conservation is undertaken in the face of social and economic constraints that require priority setting (Vimal, Pluvinet, et al., 2012) and the selection of key areas for their conservation (Margules & Pressey, 2000). A critical issue here is that conservation occurs in a matrix of alternative land-uses which can have highly variable ecological, social and economic value (Wilson et al., 2010). Hence, to be of any success, conservation strategy must go beyond the selection of protected areas in a binary landscape (contrasting conservation

areas with production areas) towards setting priorities for multiple conservation strategies in heterogeneous landscapes (Vimal, Pluvinet, et al., 2012; Vimal & Devictor, 2015).

The Mediterranean Basin provides a particularly illustrative example of such issues. Around the Mediterranean Basin, the contemporary landscape and its biodiversity have been greatly shaped by the complex geological and climatic history of the region in relation with historical human land-use patterns that have developed over several millennia (Cowling, Rundel, Lamont, Kalin Arroyo, & Arianoutsou, 1996; Lobo, Lumaret, & Jay-Robert, 2001). As a result, high levels of biodiversity occur in areas with a long history of traditional agriculture and pasture, forest and coppice activities, hunting and fishing and water resource management in wetlands. The distribution of this diversity is strongly marked by the local heterogeneity and mosaic of habitats in the landscape (Blondel, Aronson, Bodiou, & Boeuf, 2010; Thompson, 2005).

The aim of this paper is to quantify the habitat diversity associated with conservation issues in the Mediterranean region of southern France. To do so, we used sites of high ecological interest identified on the basis of the presence and distribution of high priority (locally rare or narrow range) plant and vertebrate species as part of the national inventory of such sites in a Mediterranean region of southern France. For each species, we identified its broad habitat of occurrence. We then developed various metrics to quantify the diversity of habitats per site, their association with taxonomic groups, their combination within sites and their spatial distribution across the considered region. We discuss the implications of habitat diversity for the implementation of conservation management strategies.

Material and methods

Study area

The Languedoc Roussillon region is an area of 27,376 km² situated in southern France, covering most of the French Mediterranean region west of the Rhône valley (Fig. 1). The main landscape types which occur in this region are coastal landscapes with lagoons, marshes, cliffs and dunes, lowland garrigues often in a mosaic with cultivated areas, extensive vineyards, extensive upland limestone plateau areas, and hilly or mountainous landscapes on granite and schist in the southern tip of the Massif Central and the south-eastern Pyrenees. During the last decades, two major types of modification to the landscape have occurred in the region. First, urbanization has increased extensively around towns and villages and tourist resorts have been developed along a large part of the coast. Second, human population decline in rural areas has been accompanied by the abandonment of vineyards, terraces and extensive grazing activity in many areas. These changes have set the scene for rapid reforestation as a result of a natural process of secondary succession (Debussche, Lepart, & Dervieux, 1999; IFEN, 2003). In the Languedoc-Roussillon, the forest increased by more than 100% during the last century, from 416000 ha in 1878 to 1041000 ha in 2009 (Ministère de l'agriculture, de l'agroalimentaire et de la forêt - Agreste - La statistique, l'évaluation et la prospective agricole, 2017).

Regional inventory

In order to identify sites of high ecological value in each region of France (*Zones Naturelles d'Intérêt Ecologique Faunistique et Floristique* or *ZNIEFF*), a list of key species of regional conservation interest (based on specific criteria, see below) has been compiled for each administrative region of France (INPN, 2006). Before publication, this inventory has been validated in each administrative region by its regional scientific council for natural heritage.

We used both the inventory of these sites and their associated key species in the Languedoc-Roussillon region as a basis for our study.

To identify the list of key species, regional specialists weighted and noted each species of a given taxonomic group according to two main criteria (DREAL, 2009). First, regional rarity was quantified as the number of distinct localities where a species had been recorded within the region (the fewer the localities the higher the score). Second, the degree of regional responsibility was quantified in relation to the number of other regions in France where the species occurs (the fewer the number of other regions where a species occurs, the higher the score). Species with an international, national or regional protection status were automatically included. A score of between 0 (low levels of regional rarity and responsibility) and 8 (high levels of rarity and responsibility) was attributed to each species. Species with a score between 2 and 8 for plants and between 3 and 8 for animals were selected as key species for the delimitation of sites in the regional inventory.

For the purpose of this study, we used taxonomic groups for which we had a reasonable knowledge of the regional distribution and abundance, namely 629 vascular plant species and 112 vertebrate species, *i.e.* fishes (n = 14); reptiles (n = 8) and amphibians (n = 6), birds (n = 61), and mammals (n = 23). Based on the distribution of these species, 793 sites (16.8% of the surface area of the study region) were designated in the regional inventory (Fig. 1). For animals, only species that reproduce in a site were considered to be present. In order to give a larger scope to our study, we also integrated 139 insect species (59 Coleopteridae, 19 Odonata, 30 Orthopteridea, and 31 Lepidoptera Rhopalocera). These species however were only used in the non-spatial part of our analysis (Table 1) since marked spatial biases in sampling precluded their full inclusion in this study.

Broad habitat identification

For each key species, we determined its broad habitat *via* expert consultation. Based on this information, each species was assigned to a broad habitat in which it is considered to occur in the study region. For most animal species, the breeding habitat is similar to the foraging habitat (except for raptors and bats); hence, we used the former in our study. For plants, species are mostly associated with one particular type of broad habitat; hence, only one habitat per species - the most frequent - was identified. In contrast, more than one broad habitat was identified for some animal species (*e.g.* the greater horseshoe bat *Rhinolophus ferrumequinum* can occur in villages and caves, the golden eagle *Aquila chrysaetos* can nest in either forest or rocky habitats in the study region). Seven broad habitats were designated.

(a) Coastal habitat: dunes, maritime cliffs, brackish wetlands, lagoons, beaches and salty meadows.

(b) Forest habitat: all the forest types in the region (deciduous, evergreen, conifers, and mixed forest).

(c) Open habitat: open scrubland, maquis, garrigues, dry grassland, and wet meadows.

(d) Wetland habitat: peat bogs, springs, rivers, lakes, ponds, reed beds, temporary marshes and pools and alluvial forests.

(e) Agricultural habitat: cultivated fields, vineyards, fallow lands, olive groves and orchards.

(f) Rocky habitat: cliffs, scree slopes, caves, snow or glaciers and rocks.

(g) Urban habitat: villages, towns and mountain and seaside resorts.

The classification and choice of these broad habitats was based on their general ecological characteristics, human presence and overall conservation management necessary for each of them. For these reasons, coastal habitats were kept distinct due to their specific human land use and vulnerability. Although the category “open” encompasses quite different types of

habitats, all of them are associated with traditional agricultural activities, mostly extensive pastoralism.

This method allowed us to assess the importance of habitats and their management based on the presence of priority species associated with them, whereas using the Corine Land Cover database to identify the habitat composition of each site would not have been as relevant. Indeed, some Corine Land Cover habitats may occur in a site without any of the species being associated with such habitat. Furthermore, some of the considered species (particularly plants) occur in very small patches of habitat which the Corine Land Cover resolution may not identify as being present in a site. The full list of species and their associated habitats is presented in Appendix A.

Analysis

We first analysed the number and proportion of species associated with each broad habitat (Table 1). We then determined the species' habitats present in each of the 793 sites. A habitat was considered present in a given site if at least one species associated with the habitat was inventoried. In this part of the analysis, we did not account for species that potentially occur in more than one habitat (10 birds, 9 mammals, 3 reptiles and 1 amphibian). Consequently, the habitats present remained undetermined for 13 sites. We do not present the results for urban habitats since only two species were concerned (lesser kestrel *Falco naumanni* and lesser horseshoe bat *Rhinolophus hipposideros*; other urban species such as bats are also associated with other habitats).

For each habitat type, we calculated the number of sites where they occurred, the mean surface area of sites in which they occurred, the mean number of associated species (across sites), and the mean number of sites in which species of a particular habitat occurred. We also calculated the mean number of habitats per site and the total mean number of species per site where a focal habitat occurred.

In order to analyse the statistical difference among habitats, we used the Kruskal-Wallis non-parametric test.

Results

The different broad habitats in the study region do not have equal importance in terms of the presence of different taxonomic groups (Table 1). Whereas two-thirds of the plant species occur in open and rocky habitats, wetlands are the most important habitat for amphibians (> 50%) and insects are more broadly distributed across open, wetland and forest habitats.. Birds show a generally more uniform distribution across the broad habitat classes. Taxonomic groups are all fairly well represented in coastal habitats (12 - 21% of species), except for mammals for which only one species occurs in coastal habitats (the European free-tailed bat *Tadarida teniotis*). Forest and rocky habitats are both characterized by marked variation in the presence of different taxonomic groups with an affinity of mammals to these contrasting situations. Although forest habitats contain only a small number of priority plant species, they are important for mammals (particularly bats). Agricultural land use is almost exclusively a habitat for birds and insects. Few species (mostly bats) are associated with an urban environment.

552 (70%) sites contain more than one broad habitat and 138 sites (15%) contain at least four broad habitats (Fig. 3). For instance, the site “Gorges de Pierre-Lys” situated in the Pyrenees contains as key species 7 mammals, 2 fishes, 2 birds and 5 plants which are associated with either wetland, open, forest or rocky habitats.

There is significant difference among broad habitat types in terms of the mean number of species they host ($\text{Chi}^2 = 164.1$, $\text{df}=5$, $p<0.001$), the total mean number of species ($\text{Chi}^2 = 42.3$, $\text{df}=5$, $p<0.001$), and the mean number of habitats per site ($\text{Chi}^2 = 74.08$, $\text{df}=5$, $p<0.001$), but not in terms of the mean number of sites ($\text{Chi}^2 = 9.76$, $\text{df}=5$, $p=0.08$). Due to the high number of

plant species (n=629) in this study and the fact that priority plant species occur primarily in open habitats, a total of 40% of species (44% of plants and 20% of vertebrates) occur in open habitats (Table 1). Indeed, 565 sites (71% of all sites) contain at least one open habitat species (Table 2). These sites are widely distributed across the region (Fig. 3) and their surface area is in the lower range of that observed in the different habitat types (Table 2).

The surface areas of the 143 sites with coastal species and the 439 sites with wetland species are the smallest, even though the mean number of coastal species in a given site is relatively high (5.5 species). The number of sites with wetland species is also relatively high (Table 2), no doubt because wetlands encompass a variety of habitat types (rivers, marshes and temporary pools) which are widespread across the study region. Despite the low number of species associated with forest habitats (n = 51), the surface area of sites where forest habitat species occur is higher than that of other habitat types (Table 2). Sites with a forest habitat have the largest total mean number of species per site (13.2) and mean number of habitats per site (3.3) but a relatively low density of forest species (2.1 forest species per site). The localization of sites with forest habitat reflects the diversity of forest types occurring in this region: from the eastern and southern limits of the Pyrenees to the forests of the southern rim of the Massif Central and a smaller number of sites in more lowland areas of the Mediterranean climate region (Fig. 3). Due to their small number, few species associated with agricultural land are present in each site, but the total number of species per site where agricultural habitats occur is similar to that for sites based on other habitats (Table 2). The sites concerned are localized in the south-western plain of the region, fairly close to the coast (Fig. 3).

Discussion

In this study, we describe the diversity of habitats associated with the conservation of high priority species as well as their distribution and interaction in a Mediterranean mosaic landscape. Such results have important implications for conservation management in heterogeneous landscapes where human activities are omnipresent.

The characterization of a reference habitat for priority species draws attention to the importance of focusing on the habitat for the maintenance of biodiversity. Our aim has not been to provide a precise definition of necessary management actions but to quantitatively illustrate the diversity of conservation issues at stake based on the broad habitats species occupy and the co-occurrence of different habitats in individual sites. The broad habitats we used in our study refer to general categories of habitat types and associated land use. This approach may enhance communication in planning and management (Hobbs & McIntyre, 2005). Furthermore, it also shows that, in human dominated landscapes, biodiversity conservation must consider the diversity of ecological systems and functions in association with very different socio-economic and cultural benefits, *e.g* tourism, agricultural production and private land-use (Jackson & Gaston, 2008; Newburn, Reed, Berck, & Merenlender, 2005)

In order to enhance the reproducibility of such approach in other contexts, several methodological issues should be mentioned here. First, our results must be considered in light of the taxonomic groups used. As previously mentioned, the inclusion of vascular plants in this study clearly highlighted the importance of open habitat. On the other hand, the possibility to integrate other taxonomic groups such as fungi, non-vascular plants and invertebrates could slightly change the results and illustrate the importance of other types of habitats. Furthermore, although this study focused on a pool of key species designated in the context of a national inventory, other biodiversity surrogates could be used. For instance, it would be interesting to analyse the importance of different habitats for common species and basic ecological functions. Finally, when available, analysing the habitat of reference for

locally extinct species could be promising in order to understand how land-use change have affected biodiversity (see also Hambler, Henderson, & Speight, 2011).

A primary result of this study is the identification of several habitats of species occurrence within sites of recognized high ecological interest; a total of 552 (71% of all sites) sites had species associated with more than one habitat type and more than 15% of sites contained a species pool associated with at least four different habitats. This localized habitat diversity testifies to the mosaic structure of the landscape in the region. Conservation action should therefore be developed not only to define appropriate management for each kind of habitat, but also to focus on the importance of the mosaic spatial structure of habitats in the landscape (Vimal, Pluvinet, et al., 2012).

In our study region, most priority species (40%) occur in open habitats (primarily because of a large number of priority plant species that occur in these habitats) and consequently two-thirds of the sites of ecological interest contain this kind of broad habitat type. In the Mediterranean region, open habitats are considered semi-natural and are, in most areas, intimately associated with traditional, low-intensity human activity (mostly grazing). Sites that have a species associated with this broad habitat type are widely distributed across the region (Fig. 4). This is illustrative of priority species in traditionally used agricultural areas such as meadows, dry grassland and garrigues, most of which are highly vulnerable to urbanization, infrastructures and tourism near the coast, or to the abandonment of traditional farming activities in the back country and low mountains (Fonderflick, Caplat, Lovaty, Thevenot, & Prodon, 2010).

Three major conservation issues can be distinguished here in relation to contrasting socio-economic interests. The first concerns biodiversity conservation in the different types of wetlands, coastal habitats and garrigues close to the coast and major towns in the lowland areas of our study region. Such areas are threatened by water pollution, urbanization, tourism

and infrastructure development (Vimal, Geniaux, Pluvinet, Napoleone, & Lepar, 2012). Although strict regulatory site protection may be necessary here, such measures may not be effective if their action is too spatially constrained. For example, the diffusion of fertilizers and pesticides in the agricultural areas of the lowland part of our study region can occur at a scale which affects the water quality in the complex of lagoons in coastal areas, many of which figure in our priority sites. The purchase of large areas of coastal sites by the national coastal conservation agency must thus be integrated with a strategy for more widespread modification of agricultural practices towards reduced fertilizer and pesticide use in the surrounding landscape.

A second situation concerns the co-occurrence of forest and rocky habitats in upland areas that together ensure the maintenance of many species in different taxonomic groups. Here, threats are often naturally limited by topographic conditions that preclude their exploitation or attendance (Lavergne, Thompson, Garnier, & Debussche, 2004).

A third situation relates to the case where biodiversity conservation cannot be based on strict protection measures of small areas but requires proactive management by woodcutting, grazing and burning of the mosaic landscape of open habitats, currently being rapidly overtaken by scrub and forest. In this setting it would be more judicious to instigate contractual management strategies for the habitat they contain. The conservation plans in different sites of the Natura 2000 network provide pertinent examples of the different management strategies required for these areas. The maintenance and sometimes redeployment of viable extensive pastoralism and other agricultural activities is a major issue here (Pullin et al., 2009).

A diversity of conservation actions will thus be necessary for effective and sustainable biodiversity conservation in the human-dominated landscape of our study region. The effective and sustainable management of what is ultimately an unprotected matrix should

become a key element of conservation objectives. In a region where the mosaic structure of the landscape has evolved in close interaction with traditional human activities, conservation strategies must focus on reconciling nature with human.

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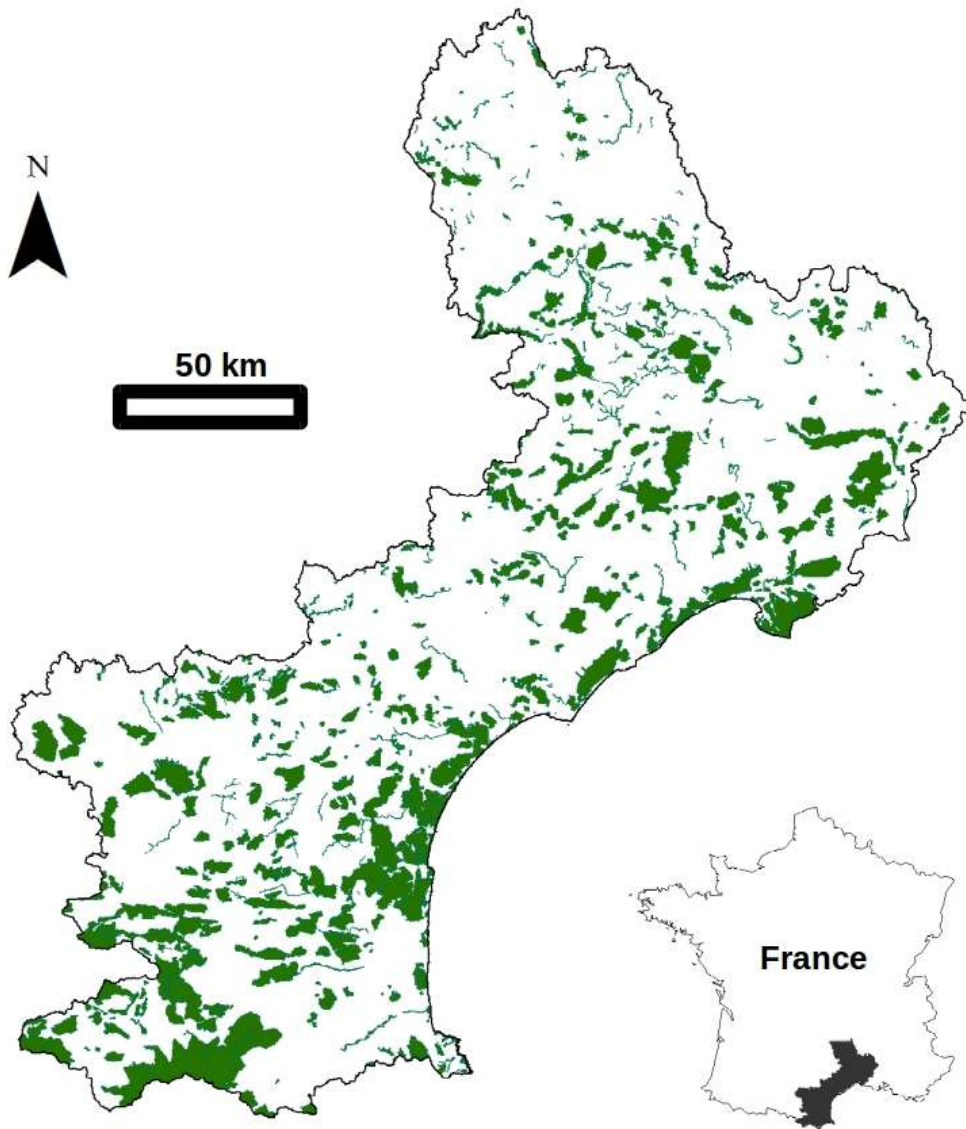
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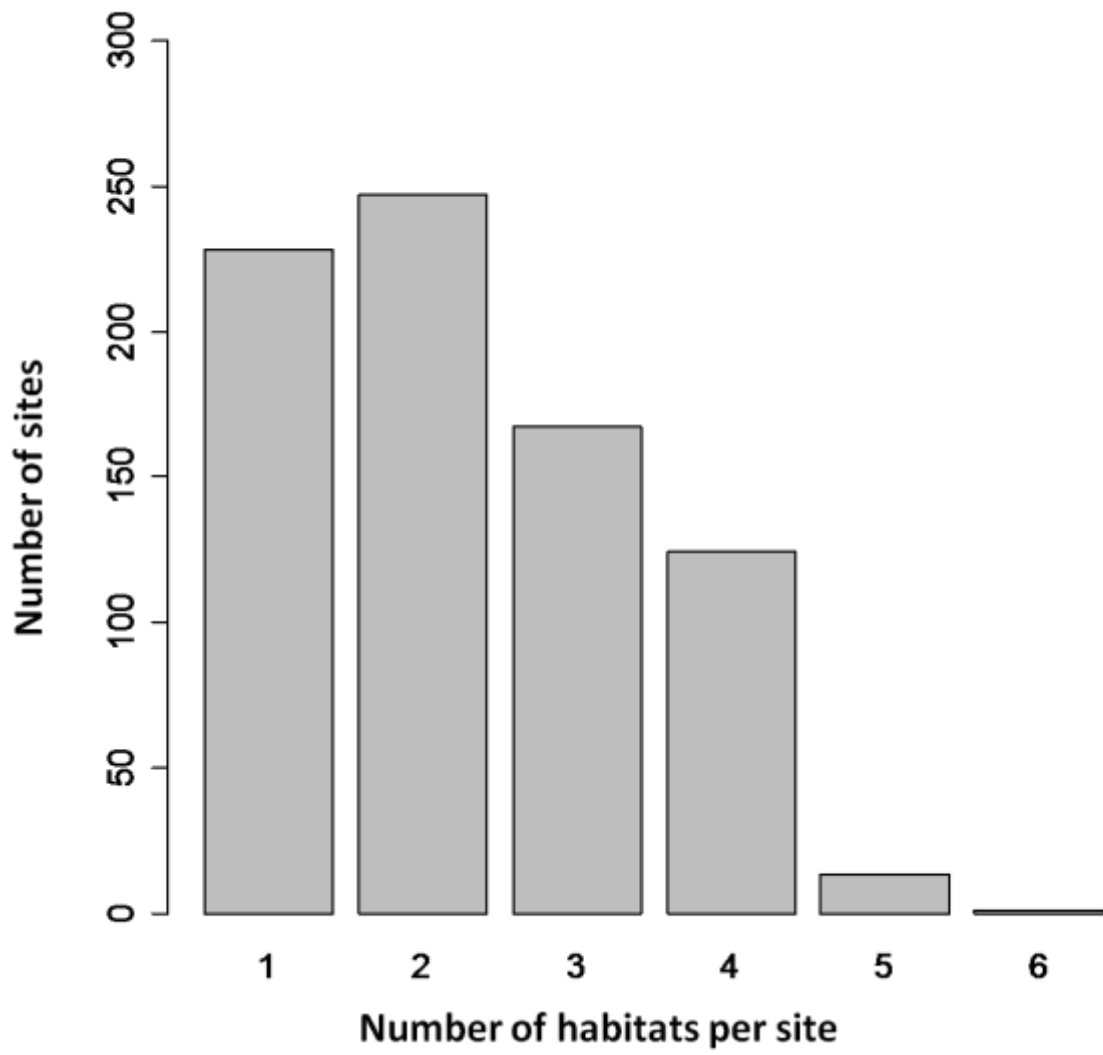
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Fig. 1. The study region (Languedoc Roussillon, France) and the localities of the 793 sites identified in the regional inventory of sites of high ecological interest.

Fig. 2. The frequency distribution of the number of broad habitats per site.

Fig. 3. The spatial distribution of the selected sites for each broad habitat (Languedoc Roussillon, France).





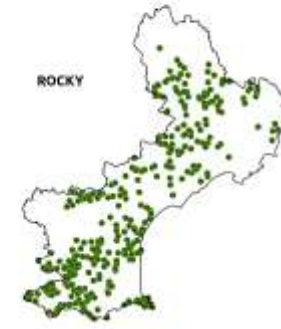


Table 1. Percentages and numbers (in parentheses) of species in different taxonomic groups associated with the broad habitats present in the 793 sites of high ecological interest in the study region (Languedoc Roussillon, France).

Percentages can sum up to more than 100 because some species occur in more than one habitat.

	Plants	Amphibians	Reptiles	Birds	Mammals	Fishes	Insects	Overall
Number of species	629	6	8	61	23	14	139	880
Mean number of species / site	7.4 ±0.3	1.1 ±0.0	1.2 ±0.0	3.3 ±0.1	2.2 ±0.1	1.5 ±0.0	-	-
Open	44 (275)	17 (1)	63 (5)	21 (13)	13 (3)	0 (0)	41 (57)	40 (351)
Coastal	15 (91)	17 (1)	25 (2)	21 (13)	4 (1)	0 (0)	12 (16)	14 (124)
Wetland	14 (85)	83 (5)	38 (3)	30 (18)	22 (5)	100 (14)	33 (46)	20 (176)
Forest	6 (42)	33 (2)	0 (0)	10 (6)	39 (9)	0 (0)	33 (46)	12 (105)
Rocky	20 (128)	0 (0)	13 (1)	16 (10)	43 (10)	0 (0)	5 (7)	18 (156)
Agricultural	1 (8)	0 (0)	0 (0)	18 (11)	0 (0)	0 (0)	16 (22)	5 (41)
Urban	0 (0)	0 (0)	13 (1)	3 (2)	26 (6)	0 (0)	4 (5)	2 (14.7)

Table
1

Table 2. Frequency of each broad habitat in the 793 sites of ecological interest inventoried in the study region (Languedoc Roussillon, France).

The “Mean number of species per habitat” refers to the mean number of species related to the considered broad habitat and the “mean number of habitats per site” is the mean number of habitats per site where a given broad habitat occurs. “Total mean number of species” refers to the mean number of species associated with all kind of habitats.

Table 2

Habitat	Number of species	Number of sites	Mean site surface area (ha)	Mean number of sites per species	Mean number of species per habitat	Total mean number of species	Mean number of habitats per site
Open	284	565	686 ±41	7.8 ±0.6	3.9 ±0.2	10.0 ±0.4	2.8 ±0.0
Coastal	103	142	613 ±90	10.7 ±1.0	5.5 ±0.4	12.6 ±0.7	2.7 ±0.1
Wetland	124	439	622 ±46	9.6 ±1.0	2.7 ±0.1	10.2 ±0.5	2.8 ±0.1
Forest	51	235	970 ±71	9.9 ±2.2	2.1 ±0.1	13.2 ±0.9	3.3 ±0.1
Rocky	142	335	804 ±51	9.6 ±1.1	4.1 ±0.3	11.7 ±0.7	3.1 ±0.1
Agricultural	12	73	973 ±170	6.4 ±1.9	1.1 ±0.0	11.3 ±1.3	3.3 ±0.1
Undetermined	/	13	155 ±49	/	/	/	/
Overall	741	793	591 ±33	9.0 ±0.4	/	8.3 ±0.3	2.4 ±0.0