ITALIAN ECOLOGICAL NETWORK
THE ROLE OF THE PROTECTED AREAS IN THE CONSERVATION OF VERTEBRATES

Ministry of Environment
Nature Conservation Directorate

University of Rome "La Sapienza"
Animal and Human Biology Department

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All the data utilized in the study relating to the National Ecological Network for Vertebrates are currently available on-line at the following URL: http://www.gisbau.uniroma1.it/REN/index.htm.

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Italian Regions and main mountain chains.

1 Introduction

In 1999, the Ministry of Environment (Nature Conservation Directorate) approved a document outlining the design parameters for the National Ecological Network (REN – Rete Ecologica Nazionale) and defining the structure and principal objectives of the system nationwide. Basically, REN is an integrated programme that aims to rebalance socio-economic development trends within a framework of sustainable growth and optimal biodiversity conservation and, as such, it takes the form of a complex network of programmes relating to widely varying sectors of the economy, culture, territorial management and, of course, ecology and biodiversity management, particularly with regard to species and types of habitat.

The new course of conservation policy follows the main European Directives on nature conservation, developing them into a more holistic concept of the land and its natural and human components. It is also integrated with the renewed efforts of the Council of Europe to promote a more comprehensive, less fragmented approach to territorial administration, recently leading to the adoption of the European Landscape Convention. In short, this tendency aims to do more than just emphasize the conservation of individual species or protected areas: the focus has shifted onto a systematic policy involving all environmental components, in close connection with European strategies.

The said document and related ministerial directives must now find support among the various disciplines for the definition of methods, guidelines and planning characteristics, so as to create the basic structure of a national network. In particular, it seems a good time to set up a mechanism for calibrating the national ecological network, with the specific aim, among other things, of conserving Italian biodiversity.

Altogether, the protected areas in Italy (with the exception of the Sites of European Community Importance- SCI - and Special Protection Areas- SPA -, which are still at the approval stage) cover almost 11% of the country; in view of their natural features, they can be considered one of the most important components of a potential ecological network dedicated to biodiversity conservation (Figs. 1-3). Nevertheless, because of their size and the criteria by which they were chosen, Italy's protected areas are not sufficient to satisfy the requirements of biodiversity conservation. They can be important nodes in an ecological network, as long as they are considered within the context of the territory as a whole and their role is verified within an environmental infrastructure (protected areas and corridors) that is also calibrated to take account of the biological and ecological requirements of the various species and habitats.

The present document sets out, in a concise and readable form, the results of an analysis of the content of protected areas in Italy, particularly in terms of vertebrate species. The aim of the study is to verify whether the system of protected areas corresponds to the pattern of biodiversity for vertebrates and to determine what sort of action should be taken in order to render the system more efficient in conserving this important component of biodiversity. The study was carried out, in response to a request from the Ministry of Environment, Nature Conservation Directorate, by the Animal and Human Biology Department University of Rome "La Sapienza", and is based on data resulting from the study completed in February 2002 on the definition of the National Ecological Network for the conservation of vertebrates.

Pollino National Park (Calabria – Southern Italy)

1.1 Ecological networks and biodiversity

Ecological networks are a conceptual tool of the utmost importance for nature conservation and sustainable land use. Their theoretical foundation lies deep in conservation biology and is based on the obvious premises that all species, both animal and vegetable, are distributed over the land with an irregular pattern and that this discontinuity is due chiefly to intrinsic natural factors, which may also be

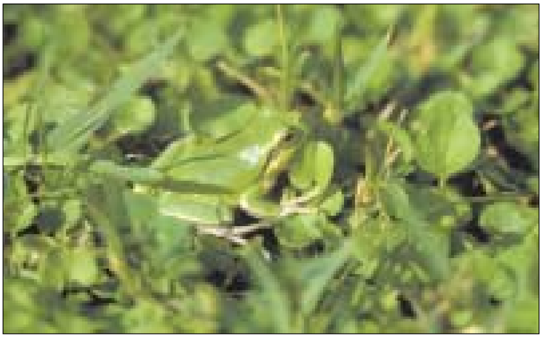
Little Bittern *(Ixobrychus minutus)*

aggravated by historical and human factors. The distribution range of each species consists of a number of different areas, in which the density of the species is not always the same. Under optimum conditions, these areas are joined to one another by corridors, forming a network. The links can be of widely varying kinds, depending on the species in question. They may consist of individuals that disperse and move across the land following routes determined to some extent by the suitability of the terrain traversed, or they may be almost entirely independent of the terrain because mobility is achieved by aerial means (seeds, spores, birds, insects etc.).

It is therefore clear that the concept of ecological network can find practical expression in completely different ways, depending on the species taken into consideration. The global ecological network, represented by overlaying the innumerable networks of all animal and vegetable species, produces minute fragmentation of the territory into tiny homogeneous areas, representing the true - and theoretical - ecological network existing in the country.

In practice, this “web of networks” can only be transformed into an effective tool for managing the territory by aggregating several similar areas so as to achieve a level of detail that can be handled by the tools normally used for land use projects. To this end, it is helpful to reach the level of landscape characteristics, identifying the most homogeneous landscape units. While this operation undoubtedly offers practical advantages, however, it must not be seen as satisfying the requirements of all species: there is no guarantee that a network identified at a macroscopic level in this way will help to conserve a significant proportion of animal and vegetable species, nor is there any guarantee that it will help to conserve endangered types of habitat. An ecological network drawn up only on the basis of landscape characteristics may therefore be entirely irrelevant with regard to the functional objectives set.

An alternative method, aimed at ensuring that an ecological network represents a useful compromise between the requirements of the species and those of land use, might be a network calibrated according to the requirements of the species considered to be most important for the conservation of numbers and for the effectiveness of the systems; both these options must be assessed according to the intended interpretation of the global network. Once the network has been defined, the homogeneous landscape units to be used for land planning and management can also be defined. Since it is not possible to consider the requirements of all the species that inhabit a given area, the scope



Italian Tree Frog *(Hyla intermedia)*

must necessarily be restricted to the species viewed as critical, either because they are endangered or because they play a functional role within the ecological systems. From a practical point of view, and in the light of the various problems to be tackled by means of the resulting network, the species can be divided into various categories: a) keystone species, so called on account of their important roles in the ecological communities, b) umbrella species, so called because they are generally to be found at the upper hierarchic levels of the trophic chains and their conservation necessarily brings with it that of the species found at lower levels, c) flag species, so called on account of their ability to draw public attention and to facilitate conservation activity.

In terms of species, biodiversity in Italy consists of over 57,000 animal species, while there are far fewer vegetable species. It would therefore seem right to give priority to animal species, since their conservation

Red Deers *(Cervus elaphus)*

necessarily implies the conservation of the related vegetable systems on account of their position in the trophic chains. And from a zoological point of view, vertebrates undoubtedly occupy a “flag” role, to the point of being only too often the sole reference for conservation policy.

2 The Protected Areas in Italy

The system of existing Protected Areas (PA) in Italy, 1,004 of them altogether (Gambino & Negrini, 2001), include all those set up by formal directives issued by the State or the Regions. Not all the PA that exist in practice are included in the Official List of Protected Natural Areas (EUAP) which, according to the 4th version issued by the Ministry of the Environment and Territorial Protection, comprises 751 areas altogether.

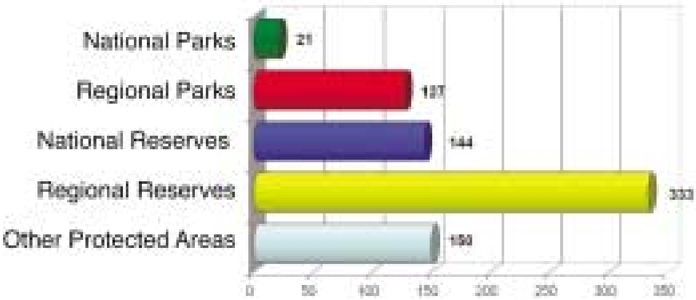


Fig. 1. Number of Protected Areas per type in Italy.

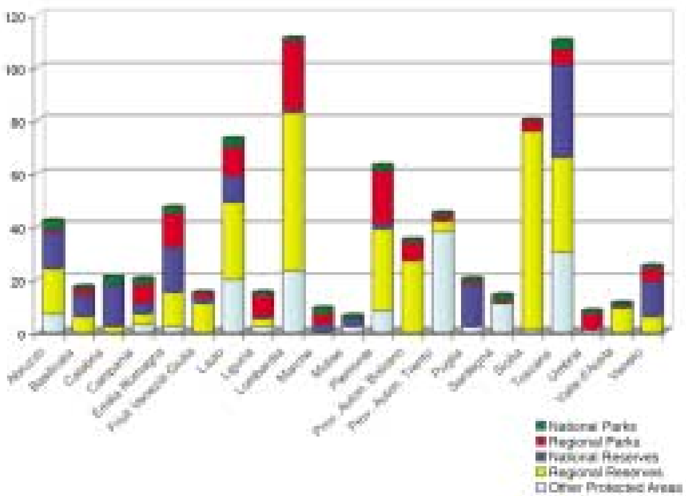


Fig. 2. Number of Protected Areas of the various types per region.

Seventeen areas listed in EUAP (16 Protected Marine Natural Areas and Marine Reserves and 1 Other National Protected Natural Area), together with the marine part of three National Parks (those of the Maddalena Archipelago, the island of Asinara and the Tuscan Archipelago) were omitted from the analyses carried out, because the data used to construct the habitat suitability models for Italian vertebrates do not cover the Protected Areas in question (for further details, see par. 4.3.).

Altogether, 775 PA were taken into consideration during the analysis (Figs. 1-8): as compared with the official list issued by the Ministry of Environment, only one National Reserve was omitted, besides the 17 areas mentioned above, because no relevant maps could be found, but the study included 13 Other Protected Natural Areas, 1 Regional Natural Reserve and 28 Regional Natural Parks that do not figure in the EUAP, either because the respective regions did not apply to the Ministry for registration or because these areas were considered incongruent with the conditions laid down by Italian legislation.

All references to PA made in the remainder of this document should be taken as referring to the above-mentioned 775 areas, for which a geo-referenced information system has been set up comprising the most recent data available as of September 2002, specifying identification details, institutional references and territorial boundaries. The SCI and SPA have been considered separately (see par. 2.3), but portions of them that fall within the protected areas are included in this study.

Fig. 3. Protected Areas in Italy (775 areas).

Fig. 4. National Parks in Italy.

Fig. 5. Regional Parks in Italy.

Fig. 6. National Reserves in Italy.

Fig. 7. Regional Reserves in Italy.

Fig. 8. Other Protected Natural Areas in Italy.

Fig. 9. SCI (Sites of European Community Importance) in Italy.

Fig. 10. SPA (Special Protection Areas) in Italy.

2.1 Type and size of the Protected Areas in Italy

Altogether, the PA in Italy cover over 3 million hectares[1], corresponding to 11% of the national territory (Fig. 11). They are distributed extremely irregularly among the regions (Fig. 12): in some regions, 25% or more of the territory is protected (e.g. Abruzzi, Lombardy, Autonomous Province of Bolzano, Campania), whereas in others less than 5% of the territory is protected, as in the extreme cases of Molise, 1.5%, and Sardinia, less than 1%.

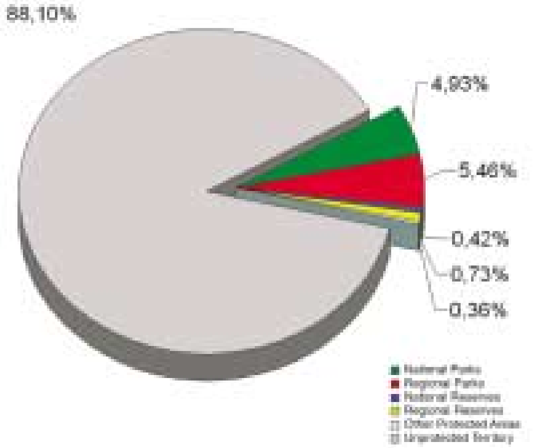


Fig. 11. Percentage of national territory covered by the various types of Protected Areas. The percentages are only indicative, because of overlapping between the various types of Protected Areas.

If we analyse the overall distribution graph showing the size of the Italian PA (Fig. 13), various interesting aspects can be noted. For example, the PA have a mean size of 4,352.5 ha, but the median size is only 265.4 ha, showing that 50% of the PA are smaller than the median. The discrepancy between mean and median area is due essentially to the considerable size of five National Parks, which cover a mean area of over 100,000 ha and have a maximum size (Pollino National Park) of over 183,000 ha[2].

The arithmetical average of the size of the PA is therefore heavily influenced by these five areas and consequently does not give a correct picture of mean conditions.

In fact, most of the PA cover a small area, at least from the biological/ecological point of view: 70% of them cover less than 1,000 ha, 60% less than 500 ha and 33% less than 100 ha.

The smallest PA is the Sasso di Preguda Regional Natural Monument (Lombardy Region), which covers 0.05 ha (according to the EUAP drawn up by the Ministry of Environment, it has an area of 0 ha.) It is also important to note that 9% of the PA in Italy are smaller than 10 ha.

There is a notable degree of overlapping between the various kinds of PA (Table I). For

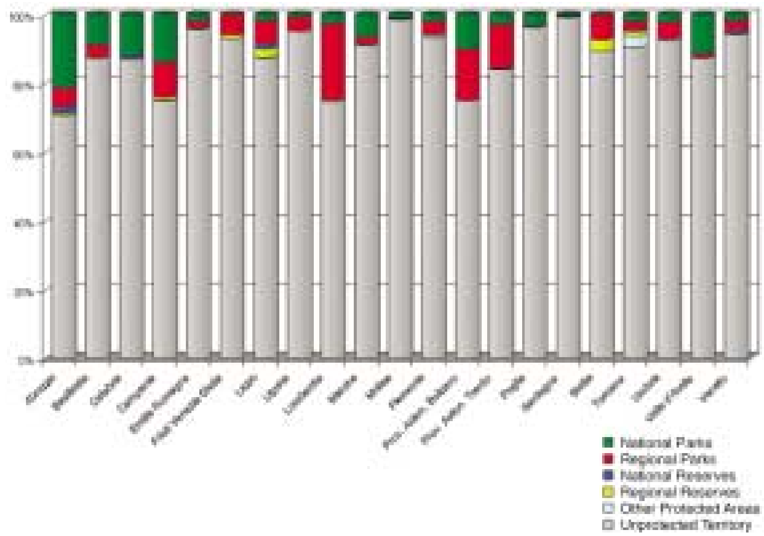


Fig. 12. Percentage of regional territory covered by the various types of Protected Areas. The percentages are only indicative, because of overlapping between the various types of Protected Areas.

example, 47% of the area of National Reserves (over 59,000 ha) falls within National Parks, while 4% (about 5,650 ha) falls within Regional Parks. As far as the remaining types are concerned, the degree of overlap is generally very low (on average about 2%), but it should be emphasised that there are a considerable number of cases in which a protected area falls entirely within another PA of a different kind.

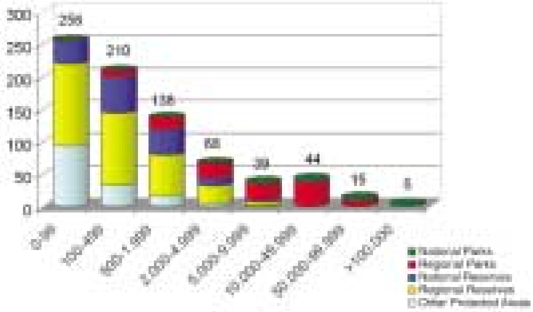
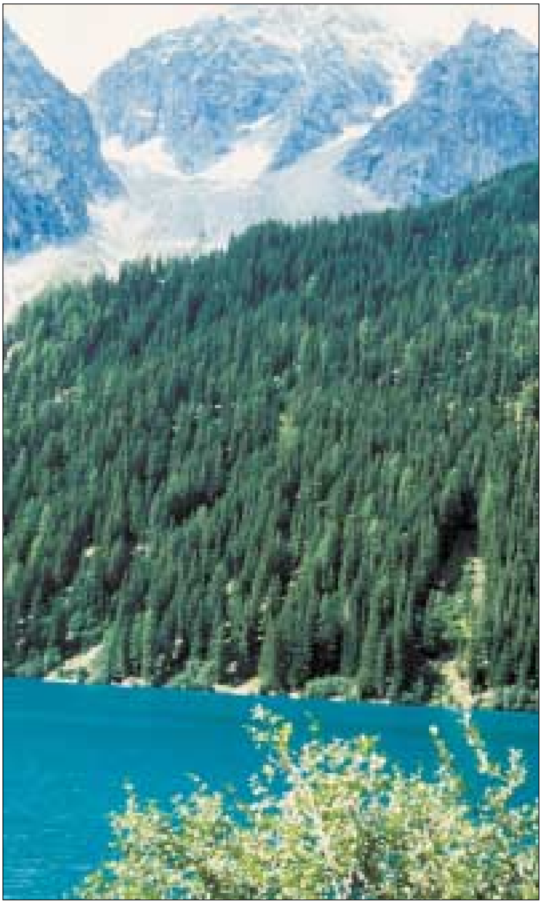


Fig. 13. Number of Protected Areas present in Italy subdivided by classes of area (ha).

	National Parks	Regional Parks	National Reserves	Regional Reserves	Other Protected Areas	SCI	SPA
National Parks	0	0	59.980	188	0	640.756	638.230
Regional Parks	0	0	5.647	3.795	597	866.812	535.802
National Reserves	59.980	5.647	0	555	1.155	79.901	86.616
Regional Reserves	188	3.795	555	0	1.009	152.071	49.206
Other Protected Areas	0	597	1.155	1.009	0	41.995	14.146
SCI	640.756	866.812	79.901	152.071	41.995	0	1.391.213
SPA	638.230	535.802	86.616	49.206	14.146	1.391.213	0

Tab. I. Overlapping between the various types of Protected Areas, SCI and SPA. The table shows hectares covered by two types at the same time.



Dolomiti Bellunesi National Park (Veneto – Northern Italy)

[1] *The areas mentioned in the present publication were calculated on the basis of the digital maps used in the ArcGis environment: this means that the areas given by the authors often do not coincide precisely with the official areas declared in the EUAP drawn up by the Ministry of Environment. In certain cases, there is a considerable discrepancy between the official area of a PA and the area calculated using ArcGis: in these cases, too, we have chosen to adopt the value calculated by using the maps, since this meant that it corresponded more closely to the map situation.*

[2] *It should be noted that, according to the EUAP drawn up the Ministry of Environment, the largest park is the Cilento and Vallo di Diano National Park, which covers over 178,000 ha.*

2.2 Physical and geographic characterization

The environmental and human presence characterizations within the PA were analysed by examining the three cartographic strata available: land cover (CORINE Land Cover), Digital Terrain Model (DTM, showing elevation) and road network.

The third level of the CORINE Land Cover classification has a total of 44 classes, but in order to give a simpler, clearer overall picture the 11 categories of the second level were used, plus one category at the first level including all the artificial areas mapped[3].

An analysis of the internal composition of the PA shows a preference for the categories "Wetlands", "Forest", "Shrub and/or herbaceous vegetation" and "Open Spaces" (i.e. these classes are present in percentages exceeding the national average), whereas the remaining categories are rarely to be found, particularly "Artificial Areas", "Arable Land" and "Permanent Crops" (Fig. 14, Table II)[4].

The same trend, with regard to the distribution of the CORINE classes, is found in the individual types of PA, although in some of them, such as the National Parks, "Forest", "Shrub and/or herbaceous vegetation" and "Open Spaces" are more frequent, while "Inland Waters" and "Wetlands" are more rarely found.

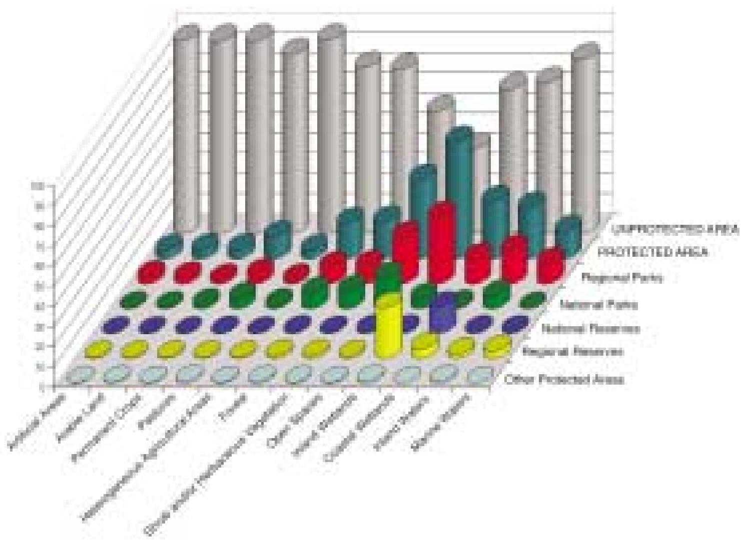


Fig. 14. Percentage of the various CORINE Land Cover categories in each type of Protected Areas, in all the Protected Areas and in unprotected territory.

[3] *The CORINE Land Cover classes Continuous urban fabric, Discontinuous urban fabric, Industrial or commercial units, Road and rail networks and associated land, Port areas, Airports, Mineral extraction sites, Dump sites, Construction sites, Green urban areas, Sport and leisure facilities have been grouped together in the class "Artificial Areas"; the classes Non-irrigated arable land, Permanently irrigated land, Rice fields have been grouped together in the class "Arable Land"; the classes Vineyards, Fruit trees and berry plantations, Olive groves make up the class "Permanent Crops"; the class "Pastures" stays the same; the classes Annual crops associated with permanent crops, Complex cultivation patterns, Land principally occupied by agriculture with significant areas of natural vegetation, Agro-forestry areas have been grouped together in the class "Heterogeneous agricultural areas"; the classes Broad-leaved forest, Coniferous forest, Mixed forest have been grouped together in the class "Forest"; the classes Natural grassland, Moors and heathland, Sclerophyllous vegetation, Transitional woodland scrub have been grouped together in the class "Shrub and/or Herbaceous Vegetation"; the classes Beaches, dunes and sand plains, Bare rock, Sparsely vegetated areas, Burnt areas, Glaciers and perpetual snow have been grouped together in the class "Open spaces"; the categories Inland marshes, Peat bogs have been grouped together in the class "Inland Wetlands"; the categories Salt marshes, Salines, Intertidal flats have been grouped together in the class "Coastal Wetlands"; the categories Water courses, Water bodies have been grouped together in the class "Inland waters"; the classes Coastal lagoons, Estuaries, Sea and ocean have been grouped together in the class "Marine Waters".*

[4] *The internal composition of the protected areas, as regards both individual types and the system of PA, has been compared with the average situation in the Italian peninsula; this means that, at a regional level, there may be discrepancies, and even important ones, with respect to the situation documented at a national level, and it is therefore important to emphasize that the analyses carried out at a regional level must be evaluated in the light of the average situation pertaining in the region in question.*

	Unprotected Territory	Protected Areas	National Parks	Regional Parks	National Reserves	Regional Reserves	Other Protected Areas	SCI	SPA
Artificial Areas	95,89	4,11	0,45	3,18	0,11	0,30	0,10	2,25	0,89
Arable Land	95,82	4,18	0,46	2,74	0,20	0,43	0,38	3,85	1,77
Permanent Crops	95,79	4,21	1,76	1,69	0,07	0,49	0,20	3,92	1,47
Pastures	89,13	10,87	4,88	4,37	0,32	0,47	0,90	9,41	2,32
Heterogeneous Agricultural Areas	96,19	3,81	1,59	1,58	0,07	0,41	0,20	5,94	1,66
Forest	82,60	17,40	7,57	7,90	0,83	1,08	0,53	21,62	9,03
Shrub and/or Herbaceous Vegetation	81,62	18,38	8,45	8,42	0,49	1,07	0,35	26,57	12,24
Open Spaces	60,90	39,10	14,98	22,91	1,04	0,86	0,24	45,32	23,07
Inland Wetlands	42,20	57,80	4,69	32,78	0,96	24,87	0,86	80,64	48,50
Coastal Wetlands	71,78	28,22	0,98	12,11	12,79	4,58	0,00	84,91	32,65
Inland Waters	74,91	25,09	6,06	16,37	0,88	1,89	0,77	30,11	19,85
Marine Waters	86,67	13,33	0,00	9,93	0,85	3,48	0,00	88,04	41,33

Tab. II. Percentage of the area occupied by the CORINE Land Cover categories that falls in each type of Protected Areas, in all the Protected Areas and in unprotected territory. N.B.: the various types of PA, like the SCI and SPA, overlap with one another; as a result, the percentages indicated in this table do not necessarily add up to 100%.

Analyses at a regional level naturally produce a very varied situation, with characteristics that in some cases differ markedly from the global picture. Abruzzi, Basilicata, Calabria and Friuli follow the national trend fairly closely, and so do the Marche and Apulia, although here the category "Pastures" is also common. The case of Latium is interesting, too: the region follows the general trend fairly well and seems to offer particular protection (in the form of National Reserves) to the CORINE category "Coastal Wetlands", which is totally protected. It is worth noting the anomalous case of Sardinia, for which the most important class found in the PA is undoubtedly "Open Spaces", while all other classes are almost entirely unprotected, and that of Molise, where the only type of PA to play a significant role seems to be National Parks, concentrating chiefly on "Forest" and "Open Spaces".

Although this tendency towards classes involving a more "natural" use of the soil indicates a preference determined by strongly naturalistic criteria, it remains to be seen whether the system is congruous in covering significant portions of landscapes with "widespread natural characteristics", where the mosaic of areas with different types of land use produces the well-defined, highly-prized features of the Italian landscape.

If we compare the elevation of the PA with the overall situation in Italy, it can be seen that, in general, the elevation of most of the PA (median = 902 meters; mean = 1,017 meters) is greater than the mean value for Italy as a whole (median = 337 meters; mean = 535 meters) (Fig. 15); this is particularly obvious in the case of the National Parks (median = 1,043 meters; mean = 1,157 meters) and Regional Parks (median = 971 meters; mean = 1,054 meters). The National Reserves (median = 763 meters; mean = 783 meters), despite having a mean elevation greater than that of Italy as a whole, cover a wide range of altitudes, which therefore also include the mean values for Italy. The Regional Reserves and Other Protected Natural Areas, on the other hand, reflect the overall situation in the country.

On a regional scale, elevation can of course be very different from the situation described above. For example, in Latium, the National Reserves and Other Protected Natural Areas have an elevation pattern lower than the regional average; in Tuscany, all types of PA have an elevation pattern that perfectly coincides with the regional average; lastly, in Sardinia, all types, except for Other Protected Natural Areas, have an elevation pattern lower than the regional average.

In order to quantify human presence and to determine its influence in the natural processes that take place in the protected areas, a comparison was made between the presence of roads in the PA and the average for Italy as a whole. The existence of roads was taken as a good indication of the presence of human activity in a given area, since they represent permanent infrastructures which, subdivid-

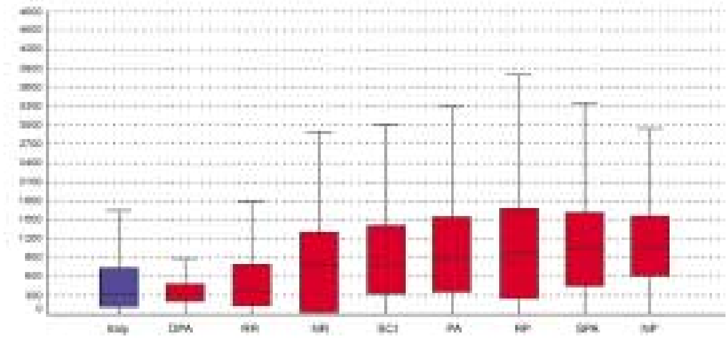


Fig. 15. Elevation distribution of Protected Areas, SCI and SPA. The black horizontal line in each box indicates median altitude. The lower and upper edges of the box respectively indicate 25% and 75% distribution percentiles. The lines outside the box indicate 95% of elevation distribution. NP = National Parks; RP = Regional Parks; NR = National Reserves; RR = Regional Reserves; OPA = Other Protected Natural Areas; SCI = Sites of European Community Importance; SPA = Special Protection Areas.

ed into the various kinds (Motorways, Main Roads, Secondary Roads) give a good idea of the type and extent of human interference.

In Italy as a whole, roads cover a total of 2,199,514 ha, i.e. more than 7% of the area of the country. In the PA, taken together, the area occupied by roads amounts to less than 4%, indicating a preference for less disturbed areas. Most of this percentage consists of Secondary Roads, while only a very small area is affected by the presence of Motorways (Fig. 16, Tab. III).

As far as the individual types are concerned, the case of the National Parks is particularly interesting: here roads account for just over 3% of the total area and practically none of them belong to the classes Motorways and Main Roads. Only 687 ha (0.05% of the area covered by the National Parks) are affected by the presence of Motorways, while only 980 ha (0.09% of the area) are covered by Main Roads.

In the case of roads, too, as described above for CORINE Land Cover and elevation, analysis at a regional level shows widely varying trends, with certain types of PA distinguished by the almost total absence of roads and others by a road density higher than the regional average. The latter situation is to be found in Basilicata (with the Regional Reserves), in Campania (with the National Reserves), in Emilia Romagna (with Other Protected Areas) and in the Autonomous Province of Trento (with Other Protected Areas). The situation found in Aosta Valley and Friuli Venezia Giulia is exactly the opposite: here practically all types have a road density approaching zero. There are a few special cases: Apulia, where 17% of the Other Protected Areas are covered by roads; Liguria, where 20% of Other Protected Areas are covered by roads; and Emilia Romagna, where, again, 10%

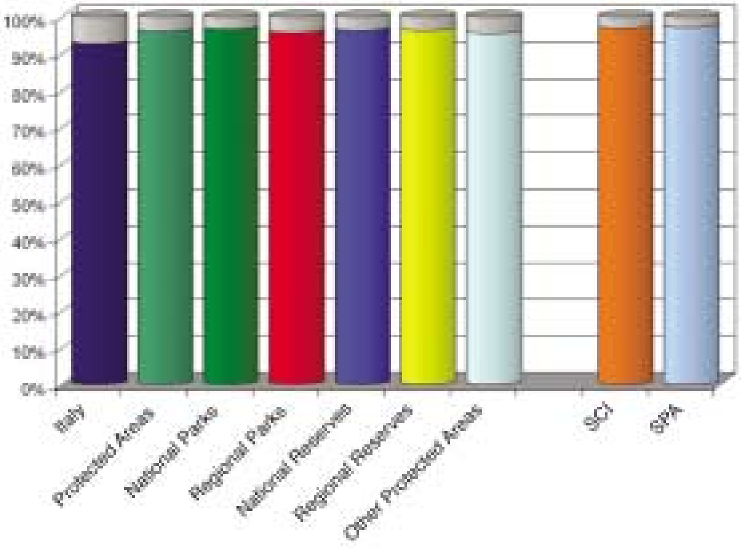


Fig. 16. Percentage distribution of roads in the country, in all the Protected Areas, in each type of PA, in the SCI and in the SPA. The percentage of territory occupied by the road network is indicated in grey.

of Other Protected Areas are covered by roads. In these cases it must be underlined that, in view of the very small size of the areas considered, the presence of even a few roads can have a marked effect on density values.

	Italy	Protected Areas	National Parks	Regional Parks	National Reserves	Regional Reserves	Other Protected Areas	SCI	SPA
No Roads	92,72	96,12	96,65	95,78	96,40	96,43	95,57	97,00	97,13
Motorways	0,27	0,10	0,05	0,12	0,21	0,17	0,08	0,06	0,07
Main Roads	0,64	0,29	0,09	0,40	0,43	0,44	0,55	0,21	0,21
Secondary Roads	6,36	3,49	3,20	3,70	2,96	2,96	3,80	2,73	2,59

Tab. III. Percentages of roads in the country, in the Protected Areas, in each type of Protected Areas, in the SCI and in the SPA.

Little Egret *(Egretta garzetta)*

3 Nature 2000 Network in Italy

Nature 2000 Network, as described in Directive 92/43/CEE issued in 1992, is intended to be a series of areas with the function of protecting biodiversity in the territory of the European Community. When the network has been completed, through agreements to be reached between the European Union and the member countries, it will consist of two kinds of areas: SCI (Sites of European Community Importance) and SPA (Special Protection Areas). Both types are currently undergoing final verification by the European Commission, and if they are approved they will represent the potential future for the growth of the PA system in Italy. For the moment, the status of these areas is that of proposed sites (SCI) subject to transitory provisions.

In Italy, Nature 2000 Network currently consists of 343 SPA and 2,417 SCI (see Figs. 9-10, 17-18).

Taken together, the SCI cover 4,172,447 ha, corresponding to over 13.8% of the area of the country. The SPA cover 1,845,619 ha, amounting to 6% of the area of the country.

The SCI have a mean size of 1,789 ha and a median size of 500 ha. Only one area, out of the total of 2,417, has an area of over 100,000 ha, while most of them (65%) cover an area of less than 1,000 ha and 27% less than 100 ha (Fig. 19). In the light of these figures, their role within the protected areas system in Italy must be given serious consideration.

As far as the SPA are concerned, the mean area is 5,381 ha, while the median area is 1,138 ha. The largest SPA covers an area of over 100,000 ha, while the smallest covers just over 4 ha. For both SCI and SPA, the largest area covered is that of the Murgia Alta district in Apulia (Fig. 19).

At a regional level, Sicily is the region where the largest number of SCI have been proposed (214), while Latium has the greatest number of SPA (48) (Tab. IV). Looking at the percentage of territory proposed for Nature 2000 Network, Liguria has identified over 25% of the region as SCI, while Abruzzo has indicated over 29% of its area as SPA.

The environmental and physiognomic characterization of the SCI and SPA shows that for both of them the preferred CORINE Land Cover classes (Fig. 20, Tab. II) are the same as for the PA, but with the addition of "Wetlands", "Inland Wetlands" and "Marine Waters". Here, too, regional characterization reveals situations that differ considerably. In Campania, Emilia Romagna, Friuli

Fig. 17. Percentage of the country covered by SCI and SPA; the number of SCI and SPA in Italy is indicated.

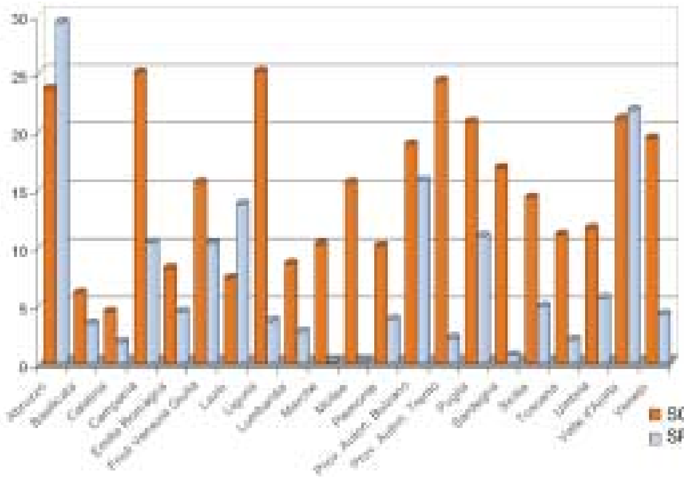


Fig. 18. Percentage of regional territory covered by SCI and SPA.

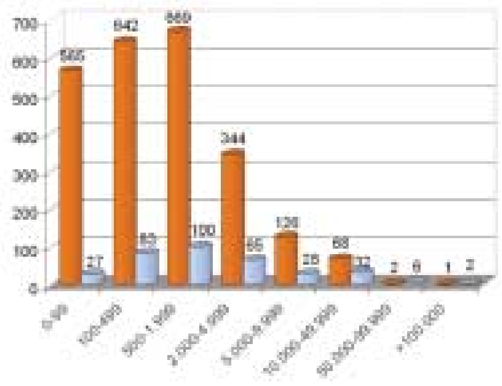


Fig. 19. Number of SCI (in orange) and SPA (in blue) in Italy by classes of area (ha).

Venezia Giulia and Latium, the preferred classes for both SCI and SPA include "Pastures" in addition to the above-mentioned categories, while Abruzzi and Campania closely follow the regional trend. A very interesting situation is to be found in certain regions, such as the Aosta Valley, the Autonomous Province of Trento and Molise, where both SCI and SPA seem to focus on certain CORINE categories (essentially "Wetlands" and "Inland Waters") that are hardly covered at all by the PA.

On average, the SCI and SPA are to be found at elevations higher than the mean values for Italy, and with a few exceptions the same is true for the analyses carried out at a regional level (Fig. 15). For SPA, Sardinia, Emilia Romagna and Tuscany have an unusual elevation distribution, below the mean values for the region.

With regard to the presence of roads, too, both SCI and SPA roughly follow the trend of the PA and usually avoid zones with a high road density, although the situations to be found in the individual regions undoubtedly vary widely, ranging from the case of the Aosta Valley, where there are very few roads in either SCI or SPA, to that of Molise, where the road density is very close to that of the region as a whole.

If we compare the location of the SCI and SPA with that of the existing PA, we find that no less than 68% of the area of the SPA and 41% of the area of the SCI fall within existing PA (Tab. I, Figs. 21-22). The biggest overlap for the SCI is with respect to Regional Parks (21% of the area of the SCI) and National Parks (15% of the area of the SCI), whereas the SPA overlap with National Parks (35% of the area of the SPA) and Regional Parks (29% of the area of the SPA). Overlapping with other types of PA occurs very rarely (around 2% for SCI and 5% for SPA), although it often involves existing PA in their entirety. There is also considerable overlapping between SCI and SPA, involving a substantial portion of the area covered by the SCI (33%) and most of the area covered by the SPA (75%).

	SCI (ha)	SPA (ha)	SCI (N°)	SPA (N°)
Abruzzo	256.022	318.749	130	4
Basilicata	60.998	34.237	69	17
Calabria	66.983	27.339	171	4
Campania	342.446	141.726	154	13
Emilia Romagna	181.782	97.960	105	41
Friuli Venezia Giulia	122.338	81.098	61	7
Lazio	126.033	235.619	177	48
Liguria	136.024	19.599	94	7
Lombardia	204.752	64.173	177	7
Marche	99.680	1.017	93	3
Molise	69.457	817	46	3
Piemonte	256.565	95.811	130	41
Prov. Auton. Bolzano	139.536	116.292	34	16
Prov. Auton. Trento	150.964	13.274	146	14
Puglia	406.036	213.592	75	16
Sardegna	405.623	16.118	114	9
Sicilia	368.993	126.143	214	47
Toscana	254.444	46.267	123	30
Umbria	98.156	47.151	102	7
Valle d'Aosta	68.699	71.130	26	1
Veneto	356.916	77.507	150	18

Tab. IV. Number of SCI and SPA in each region and area (ha) of regional territory occupied by them.

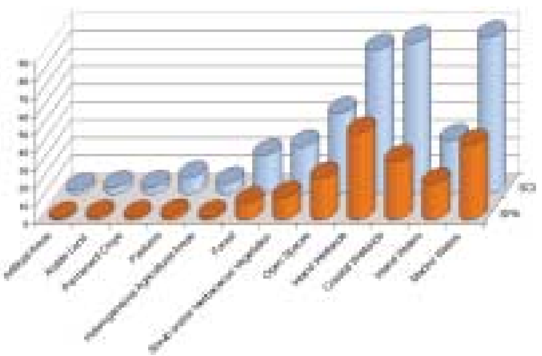


Fig. 20. Percentage of the various CORINE Land Cover categories in the SCI and SPA.

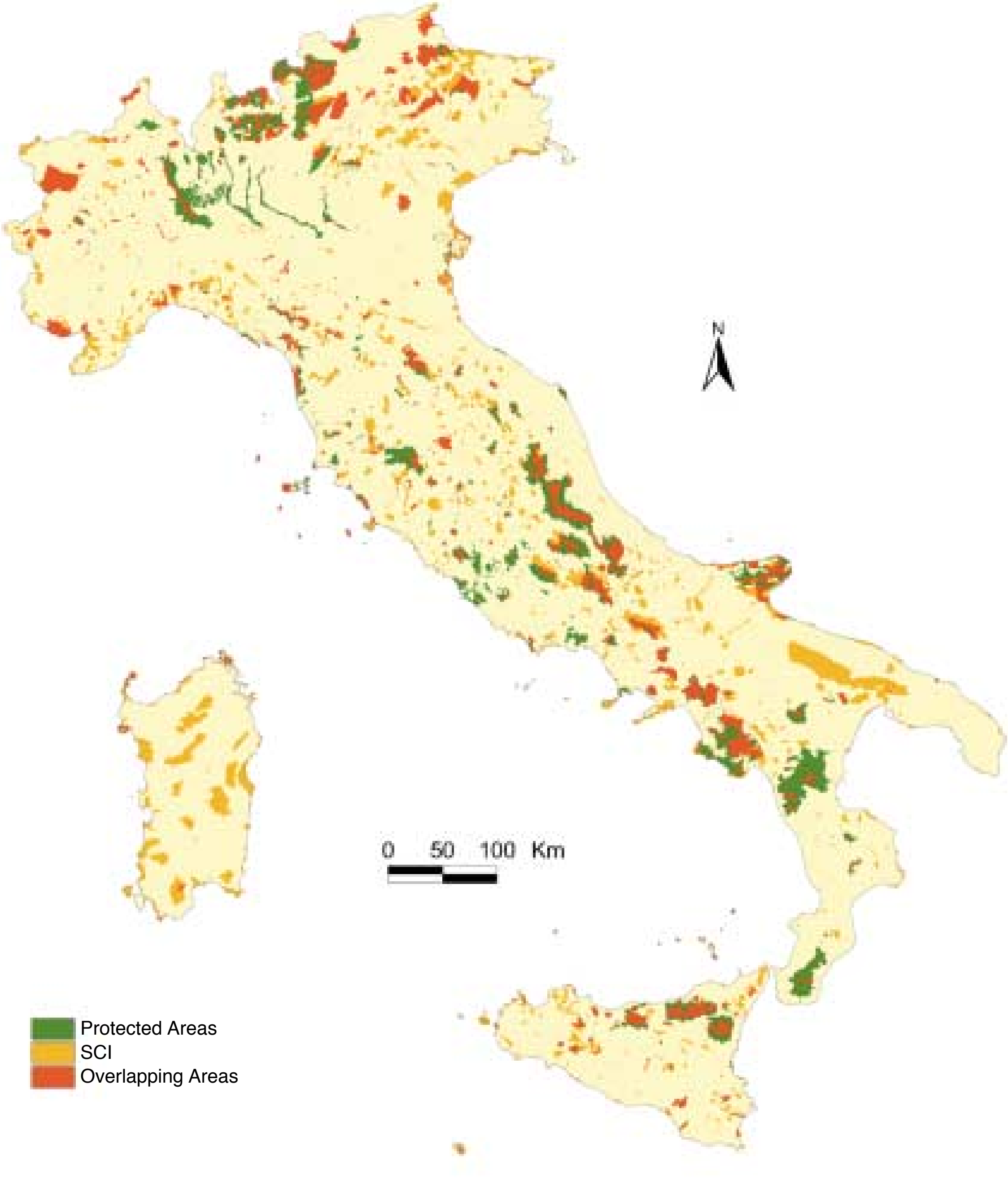


Fig. 21. Areas of overlapping between SCI and Protected Areas.

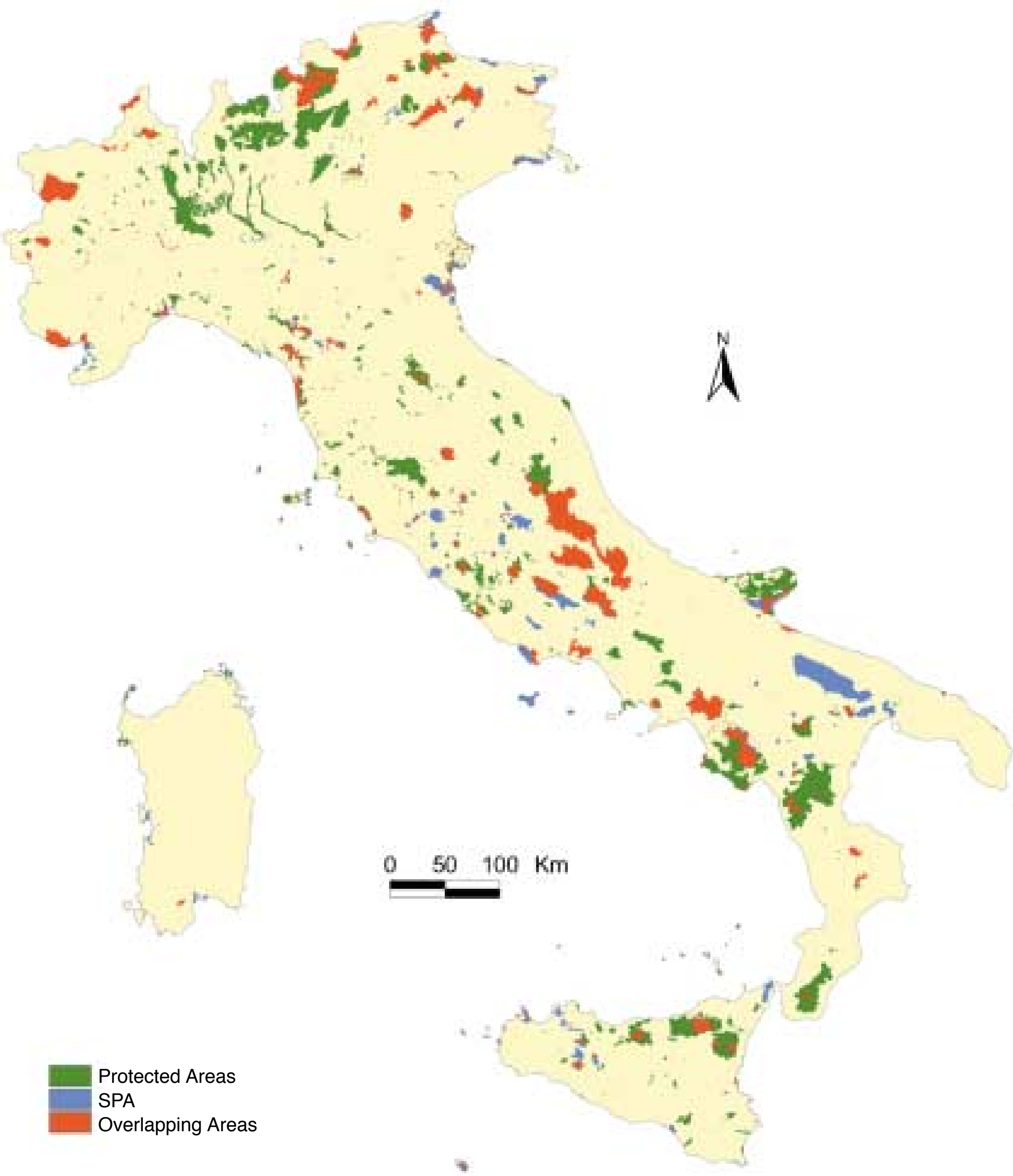


Fig. 22. Areas of overlapping between SPA and Protected Areas.

4 The Ecological Network: a paradigm of conceptual reference[5]

In recent years, the concept of ecological network has come into use in many disciplines, as a reference for both theoretical and practical applications. This widespread diffusion is due to the fact that it is an extremely versatile conceptual tool, which is applicable in a large number of contexts and which allows effective classification of different natural and human phenomena, examining them as a series of factors with different functions that intersect and cross like the mesh of a net.

We can identify four main spheres in which the concept of ecological network has been applied: in land use projects, where the network is the tool that makes it possible to represent the dynamism and interdependence of the natural and human components; in programmes for "sustainable" socio-economic development, where the network is used to illustrate, in a versatile fashion, resources, information flows, responsibilities and services compatible with the conservation of natural resources in the area under consideration; in designing an integrated system of protected areas and in assessing their effectiveness; in the scientific disciplines of ecology and conservation biology, where the concept of network effectively brings together the mechanisms that determine the pattern of the various life forms within the territory (Reggiani et al., 2000).

Crested Porcupines *(Hystrix cristata)*

In the concept of network linked more closely to the disciplines of ecology and conservation biology, and in applications relating to planning and managing land

Circeo National Park (Latium – Central Italy)

use in particular, reference has been made to the need to identify (and preserve) core areas in which a given species has a stable presence, to surround these areas with buffer zones in order to protect them from outside influences that might be harmful, and to identify (and preserve) landscape features – whether continuous (corridors) or discontinuous (stepping stones) - that enable individuals of a certain species to move between core areas. In addition, consideration has been given not only to the relationships between the various components of the network, but also to those between the said components and the environmental matrix (Dunning et al., 1992).

[5] *The points made in Chapter 4 make reference to: Boitani et al., 2002.*

4.1 Methodological approaches

The methodological approaches utilized to identify an ecological network are closely connected with the attitudes of the disciplines in which this concept has been applied.

In the field of landscape ecology in particular, “network” often has a strictly territorial connotation. In this approach, the territory is interpreted and analysed on the scale of a landscape, the degree of fragmentation and the connectivity of its various components being assessed as a whole.

In the case of conservation biology, the starting point may still be a structural approach, aimed firstly at assessing the territory and identifying its components (Battisti, 2002), but this phase must necessarily be followed by a phase in which the network is qualified as to its contents by adopting the ecological perspective of a species or group of species with respect to the territorial system analysed. This concept of network, therefore, always incorporates the ecological and ethological perspective of the species in question (Gustafson & Gardener, 1996): the importance of a certain type of habitat, the possible presence of a barrier or ecotone (Manson et al., 1999) or the permeability of an environmental matrix always refers to the particular species under consideration.

The choice of the species is clearly a crucial point, for which various criteria have been suggested: the conservationist criterion, in which the network centres on a species or group of species that is endangered as the result of a complex web of human and natural factors; the bio-geographic criterion, in which the network focuses on a species or group of species with a particularly significant distribution pattern, and lastly the ecological criterion, in which the species included in the network can have a key role in signalling the ecological needs of other species (umbrella species), or in highlighting the functionality of an ecosystem (key species), or in underlining, from an ecological viewpoint, the problem of territorial fragmentation (species sensitive to fragmentation), or in providing a framework for possible expansion (introduced species) etc. (Boitani, 2000).

It is therefore clear that the choice of a species or group of species is effective only in responding to one particular study objective, and it is unlikely that the results obtained can be extended to all biodiversity.

In the scientific world, this problem is at the centre of a heated debate. On the one hand, some people are studying the possibility, in various ecosystems, of utilizing a limited number of species to indicate the status of total biodiversity (Oliver et al., 1998; Dobson et al., 1997), while on the other hand this is frequently found to be impossible (Kerr, 1997; Williams et al., 1996).

It is clear that the scientific world is actively engaged in attempting to map the complexity of biodiversity by means of a part of it; if it were to succeed, the repercussions from the management point of view would be far-reaching, and such attempts are therefore worthy of great attention and participation by all the scientific community.

In view of the fact that the scientific world has not reached a consensus on the ethical and scientific legitimacy of choosing a group of species in order to evaluate overall biodiversity, the innovative contribution of REN has been to broaden the foundation of the analysis procedure by adopting and refining the ecological perspective of all Italian terrestrial vertebrates and freshwater fish.

In this context, then, the REN project consists of five main phases of research and analysis:

1) synthesis of information on the distribution and ecology of Italian vertebrates, leading to the creation of the Banca Dati Faunistica (Animal Database) in 2002;

2) elaboration and analysis of the potential distribution of each species over the national territory, through the creation of habitat suitability models;

3) analysis and critical interpretation of each habitat suitability model, paying particular attention to the fragmentation of suitable areas, and proposals for the conservation and management of suitable habitats for each species considered;

4) validation of habitat suitability models by means of an independent data set;

5) definition and construction of the National Ecological Network for vertebrates.

4.2 Animal Database

The Animal Database 2002 (Banca Dati Faunistica 2002) was created as a tool necessary for the National Ecological Network and useful for the conservation of all Italian vertebrates. The collection and organization of scientific data, and the provision of access to them, represent essential steps in any conservation policy.

The Animal Database 2002 consists of a complete revision of the previous Animal Database created for the Ministry of Environment in 1992. The revised database includes all species of Italian vertebrates codified in the most recent check-lists published for the various groups (Kottelat, 1997; Bianco, 1998; Societas Herpetologica Italica, 1996; Brichetti & Massa, 1998; Amori et al., 1999), giving a total of 504 species. Of these, 82 species are freshwater fish, 34 amphibians, 43 reptiles, 244 birds regularly breeding in Italy and 102 mammals.

The information contained in the Animal Database was approved by experts on the various taxa who were called in to act as guarantors, ensuring that the information was concise and up to date.

Fig. 23. Opening page of the Animal Database 2002 which includes, for each species of Italian vertebrate, a taxonomic and systematic description (Level 1: SPECIES DETAILS), and synthesis of the principal biological and ecological characteristics (Level 2: HABITAT REQUIREMENTS), an assessment of habitat preferences (Level 3: HABITATS INFLUENCE) and an illustration of the distribution range in Italy (RANGE).

The database is an interactive system allowing consultation of and access to the information by means of the software Microsoft Access 97© (Fig. 23). In order to make it simple and easy to consult, the information has been organized as a system of data sheets, one for each species. Each data sheet consists of four sections: a systematic taxonomic description, a summary of the main biological and ecological characteristics of the species, an assessment of the environmental features it prefers, an updated map of its distribution range in Italy.

4.3 Environmental suitability models for the various species

Habitat suitability models make it possible to develop and summarize species-environment relationships and represent a valid tool for use in surveys and projects relating to conservation and land use (Dupré, 1996). They provide a map showing how the various areas can offer different types of habitat for each species.

Through a series of procedures (Boitani et al., 2002), the information contained in the database for each species of Italian vertebrates was developed and translated into an habitat suitability map covering the whole of Italy. The models were created taking advantage of the potential of the Geographic Information System (GIS) and utilizing geographic data of various kinds: CORINE Land Cover, Digital Terrain Model, water and road networks. For each model, four suitability classes were identified (Box 1).

Habitat suitability models were drawn up for 477 of the 504 species included in the database. The species for which there was too little information available were omitted. In order to ensure that the model suited the natural history characteristics of the species, nine different types of model were developed.

According to the quality and quantity of data available, the results given by the models ranged from offering no improvement with respect to simple information about the distribution range (i.e. the model was unable to make any useful distinction within the territory inhabited by the species) to identifying possible mosaics of suitable habitat for the species (Fig. 24).

To give a better interpretation of the environmental mosaics, an analysis was then carried out on the fragmentation of areas with varying suitability, for the portion of the model included in the distribution range only. This analysis made it possible to study in greater detail how the network of areas of differing importance to the species is structured (McGarigal & Marks, 1999).

Each model is introduced by notes on the distribution of areas with different levels of suitability, the degree of fragmentation and the overall performance of the model (Box 2).

BOX 1

Suitability classes

UNSUITABLE

Environments that do not satisfy the ecological requirements of the species.

NOT VERY SUITABLE (LOW SUITABILITY)

Habitats that can sustain the presence of the species only in a way that does not guarantee long-term stability.

FAIRLY SUITABLE (MEDIUM SUITABILITY)

Habitats able to sustain a stable presence of the species but which do not generally appear to be optimal habitats.

VERY SUITABLE (HIGH SUITABILITY)

Ideal habitats for the presence of the species.

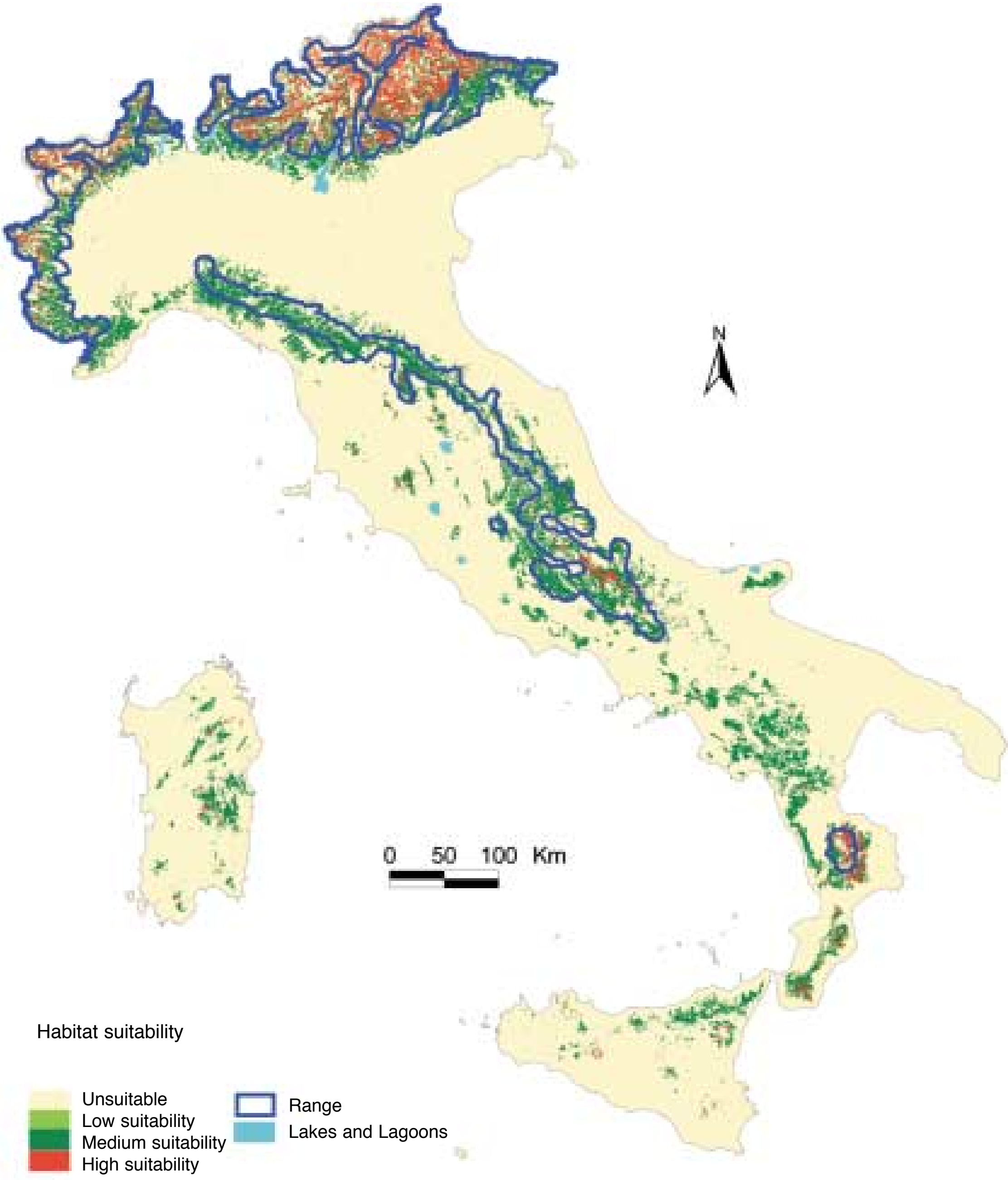
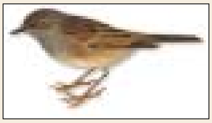


Fig. 24. Habitat suitability model for the Dunnock *(Prunella modularis)*; the distribution range of the species includes mountainous areas in the Alps and Apennines, while the model is able to show more clearly the areas within the range that have different degrees of importance for the species.

BOX 2

Example of description accompanying each environmental suitability model: includes notes on distribution range, fragmentation, priority conservation activity, model performance.



DUNNOCK *(Prunella modularis)*

In Italy this species has a continuous breeding range occupying the Alpine and pre-Alpine sectors, from the western Maritime Alps to the Carnic Alps, and also the Apennine ridge from the area near Pavia to Molise. An isolated reproductive nucleus is present in Calabria, on Mount Sila.

The Dunnock prefers mountainous environments, particularly forests interspersed with open spaces. In the model (MOD1)[1] coniferous forest and moors and heathland have been considered the environmental categories most suitable for breeding, but broad-leaved forest, mixed forest, sparsely vegetated areas (steppa, tundra) and transitional woodland shrub have also been judged fairly suitable.

Over half the distribution range (almost 60%) consists of suitable areas: 40% fairly suitable areas and 20% very suitable areas.

The fairly suitable areas lie chiefly at the foot of the Alpine arc and along the Apennine ridge; the very suitable areas are most frequent in the eastern Alps, while the only significant nuclei in central-southern Italy are in the Abruzzi Apennines and on Mount Sila.

Suitability Classes	Surface (km^2)	%
Unsuitable	20.292,74	40,29
Low suitability	0,00	0,00
Medium suitability	20.022,17	39,75
High suitability	10.051,33	19,96
Total	50.366,24	100,00

There is clearly a close link between the pattern of suitable areas and that of the distribution range throughout the length of the peninsula, while the fairly suitable areas, located between Campania and Basilicata and in southern Calabria, are the only ones of any size that seem not to be utilized by the species.

Suitable patches have been aggregated (PLADJ[2] has a high value, equal to 84.43) and on average cover a good area (AREA_MN[2], corresponding to 50,10 Km^2), even if the largest patch covers no more than 15% of the whole range (see LPI[2]). The fairly suitable areas have a significant weight for the purposes of the continuity of suitable habitats within the range, because if we exclude them from the analysis we see a considerable increase in the number of patches (see NP[2]) at the expense of their area (see AREA_MN[2], LPI[2]).

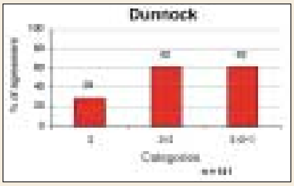
The model indicates the need to take appropriate measures to ensure the maintenance of the complex mosaic of areas of an ecotonal kind frequented by the species in the mountainous sectors of the peninsula.

Suitability Classes	Number of patches[2] (NP)	Mean patch Size[2] (AREA_MN) Km^2	Patch size[2] SD (AREA_SD)	Largest Patch Index[2] (LPI)	Mean Shape Index[2] (SHAPE_MN)	Area-Weighted Mean Shape Index[2] (SHAPE_AMN)	Percentage of Like Adjacencies[2] (PLADJ)
Unsuitable (0)	2.810	7,07	38,95	1,59	1,42	4,94	75,81
Suitable (1,2,3)	610	50,10	436,18	14,81	1,55	17,51	84,43
Highly suitable (3)	1.715	5,79	81,38	6,33	1,40	11,47	69,49

VALIDATION

The model for the species has been validated, with an agreement index of 62%.

The model that includes wintering phenology[3] has also been validated with an agreement index of 62%.



[1] MOD1: this is one of the nine types of model created (for further details see Boitani et al., 2002).

[2] Fragmentation indices utilized (for further details see Boitani et al., 2002).

[3] For certain species of bird a further suitability model has been constructed, which also takes into consideration information relating to phenologies other than breeding phenology (for further details see Boitani et al., 2002).

4.4 Validation of suitability models

The validation exercise represents a crucial moment in the construction of a model. Since this is a conceptual projection, and as such cannot be right or wrong, validation consists in evaluating how well or otherwise the model corresponds to the modelled phenomenon.

Arcipelago Toscano National Park (Tuscany – Central Italy)

Consequently, this phase involves assessing the model on the basis of how closely the picture given corresponds to reality. Many different criteria can be adopted for the assessment, some more stringent than others but all equally applicable. It is necessary, however, to establish a basic assessment criterion, in order to discriminate between models with different degrees of correspondence to reality.

In the project, the validation exercise was carried out by comparing the potential distribution pattern of a given species, defined as the set of suitable areas resulting from the model, with independent data relating to the actual presence of the species in question. The basic criterion for assessment and the analysis procedure were chosen according to the quality of the data available for each taxonomic group.

The validation exercise was carried out on the models for species for which at least 10 presence location data were available. It therefore covered 54% of the models for mammals, 60% of those for birds, 67% of those for reptiles, 82% of those for amphibians and 47% of those for fish. The models for fish, amphibians and reptiles were all found to be validated, those for birds in 68% of the cases and those for mammals in 96% of the cases.

In interpreting the results it is important to remember that the presence location data were collected for reasons unrelated to this validation exercise; as a result, they do not always have all the requisites for a fully reliable assessment of the models. Nevertheless, the excellent results obtained (83% of the models analysed were found to be validated) demonstrate the predictive capacity of the proposed models and confirm their value as effective tools for land use management at a national level.

Red Heron *(Ardea purpurea)*

4.5 Ecological networks

Within the framework of the project, various ecological networks were drawn up: a "global network", taking into consideration all vertebrates (Fig. 25c), a network for each taxonomic group (mammals, birds, reptiles, amphibians and fish) (Figs. 26c, 27c, 28c, 29c, 30c) and one for the 149 endangered species listed in the Italian Red List Book (Bulgarini et al., 1998) (Fig. 31c). Each ecological network represents species richness distribution throughout the country and is created by overlaying the habitat suitability models for the species considered. From each model, all the suitable zones within the distribution range of the species have been extracted, regardless of the level of suitability. No distinction has been made between the various levels of habitat suitability, so as to include all the areas with differing potential for hosting the individual species and to temper the different ecological significance of the various suitability classes with regard to the five taxonomic groups.

In drawing up the ecological networks, suitability models relating to both native and naturalized species were taken into consideration[6]. As far as fish are concerned, the study included non-native species which have become acclimatized in a stable fashion and which do not interfere, or have interfered only slightly, with the native communities (Bianco, pers. com.). Only validated models and those for which there were insufficient data for the validation exercise were included in the network.

For obvious reasons, the species richness values have a different distribution pattern, as to both latitude and elevation, for each ecological network (Boitani et al., 2002).

For each network, a Biodiversity Index was calculated, consisting simply in the ratio: (Max no. of species observed in the network)/(No. of species present in the cell considered)*1000. The Biodiversity Index was used both to graphically project the ecological networks and to analyse the biodiversity pattern of vertebrates in Italy.

Griffon Vulture *(Gyps fulvus)*

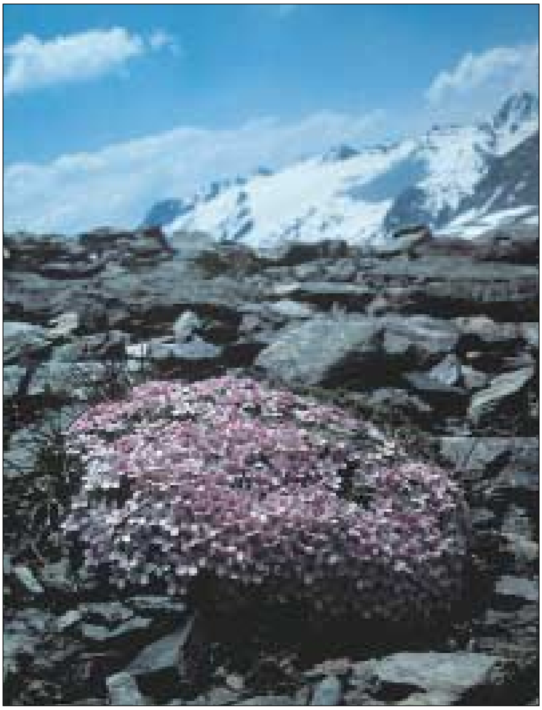
[6] Native species: species living in a given area which originated there or arrived there without the direct intervention of man. Naturalized species: species which have been part of the Italian fauna from historic times, consisting of self-sustaining breeding groups (Andreotti et al., 2001).

4.6 Comparison between networks

One of the most interesting analyses carried out was a comparison between the qualitative, quantitative and geo-referenced characteristics of the various ecological networks projected. The comparison of the overall network of all species with the networks of the various taxa and with that of endangered species demonstrated how the latter are representative for identifying the areas of Italy that have the greatest species richness.

The degree of overlapping between the overall network and the networks for the individual taxa is affected by the number of species and above all by the ecological importance of the considered taxon. While birds and mammals are amply diversified, in these terms, this is far less true of amphibians and reptiles. It was therefore expected that the bird network would be the most representative and that the networks for amphibians and reptiles would be at the opposite end of the scale.

A comparison between the overall network and the network of endangered species shows that the distribution of the areas with the greatest species richness has a very similar pattern in both networks; this means that the network of endangered species can be considered representative (an indicator) of the diversity of Italian vertebrates.



Stelvio National Park (Lombardy – Northern Italy)

5 Congruency analysis of Protected Areas based on number of vertebrate species

The pattern of the biodiversity index for vertebrates in Italy (with values ranging from 0 to 1,000) (Figs. 25a, 25b) was compared with the pattern of the same index within the system of Protected Areas as a whole and within that of the individual categories of PA (National Parks, Regional Parks, National Reserves, Regional Reserves, Other Protected Areas, SPA, and SCI), with the aim of analysing which types of Protected Area play a particularly important part in the conservation of vertebrates. A further comparison, with the parts of Italy not covered by PA, made it possible to pinpoint any high biodiversity values not yet included in the PA. A similar comparison was made, with the parts of Italy omitted from the PA (Fig. 25d) and those omitted from the total of PA plus SCI and SPA (Fig. 25e), in order to assess their contribution to biodiversity conservation. Lastly, a comparison between a map of biodiversity indices and a map of PA (plus SCI and SPA) made it possible to identify zones with maximum biodiversity values that are still outside the system of PA. Two important aspects of this study should be emphasized: a) the analyses were carried out on a scale of 1:100,000 and the notes that follow are valid for this scale: it is not technically correct to interpret the same data at a greater level of detail; b) the whole analysis is based on species diversity and does not take into account another important parameter that is fundamental for the PA policy: the protection of endemisms that are not necessarily associated with high overall biodiversity values.

The following paragraphs illustrate only the most significant results of the study.

Dolomiti Bellunesi National Park (Veneto – Northern Italy)

Abruzzo National Park (Abruzzi – Central Italy)

5.1 All species of vertebrates

In the system of existing and proposed PA (all the PA plus SCI and SPA), the pattern of the biodiversity index differs from that of Italy as a whole, indicating that the system of PA does not cover a random sample of land but makes specific choices (Figs. 25a, 25b). In particular, portions of territory with high biodiversity seem to be well represented, but portions with high diversity values that are nevertheless lower than maximum values are poorly represented. Furthermore, the system includes a considerable amount of land that has diversity values equal to those most widespread in Italy and, strangely, also includes portions of territory that have a higher percentage of extremely low diversity values than Italy as a whole. An aggregated result of this kind is of little significance for practical purposes and separation into areas of different types gives more information (Figs. 25a, 25b). The areas that protect land with high biodiversity in the most selective manner are the National Parks and SCI, followed by Regional Parks, although the latter also include many less important areas, some of them with extremely low values. The National Reserves show almost the same distribution pattern as the index for Italy as a whole, apparently indicating that they do not cover areas of particular significance for the conservation of the diversity of Italian vertebrates. The Regional Reserves have a similar trend but have a more marked peak at high diversity values, indicating a precise, targeted preference for protecting limited areas. The category Other Protected Areas does not seem to be very significant. The SPA are in an intermediate situation: they include a high percentage of areas with low biodiversity values alongside areas with intermediate or high biodiversity. This pattern can easily be explained by the nature of the SPA, which are dedicated to protecting species of birds in fulfilment of European Directive 79/409/CEE: these species often utilize open spaces, cultivated land and marginal areas where the overall diversity value of vertebrates is relatively low. It is therefore possible that the SPA fulfil the function for which they were created perfectly well although they are generally located in areas with low overall biodiversity.

An analysis of the diversity index distribution maps (Fig. 25c) immediately reveals the fundamental role of the Apennines, and to a lesser extent the Alps: they constitute authentic backbones and ecological corridors that are invaluable for Italian vertebrates. The diversity found in the mountains and foothills is striking in comparison with that of the coastal areas and plains, where diversity values are lower. Of the mountainous terrain, at least three large areas are notable for having the highest diversity values: the central Apennines, between Molise and Abruzzi; the Ligurian Apennines and the Maritime Alps; and the eastern Alps. It is important to note the great territorial block with high mean diversity values, running unbroken from the Casentine Forests to the frontier with France, including the whole stretch of the Apennines across Tuscany and Romagna, together with the Ligurian Apennines. The existing PA cover large portions of the central Apennines, but the rest of the Apennine chain would be very sparsely covered were it not for a close network of SCI which, in many cases, helps to provide solutions of quasi-continuity between existing PA and to cover important areas devoid of other protection. The SCI network plays an important role throughout much of the Apennine chain, but there are a few gaps, which will be defined more clearly and described more precisely in subsequent studies dedicated to the various classes of vertebrates (Figs. 25d, 25e): in the eastern Alps there are large areas with high diversity values that still have no coverage whatsoever; in Liguria the system of PA shows a marked bias towards certain types and is hugely dependent on SCI and SPA; the Apennines in Tuscany and Romagna are not yet adequately covered by a network of PA; the inland areas of Molise have very high diversity values but are still outside the system and this is all the more worrying in view of the fundamental role of the Molise Apennines as a link between central and southern Italy; lastly, it is urgently necessary to find a way of joining the Cilento and Vallo di Diano National Park to the Pollino National Park, since the areas between them are of great importance as far as the diversity of vertebrates is concerned. An overall view shows how few PA of any kind there are among the foothills of the Alps and the northern part of the Apennines. This is all the more serious in the light of the role played by these portions of territory in maintaining an ecological link between mountains and plains.

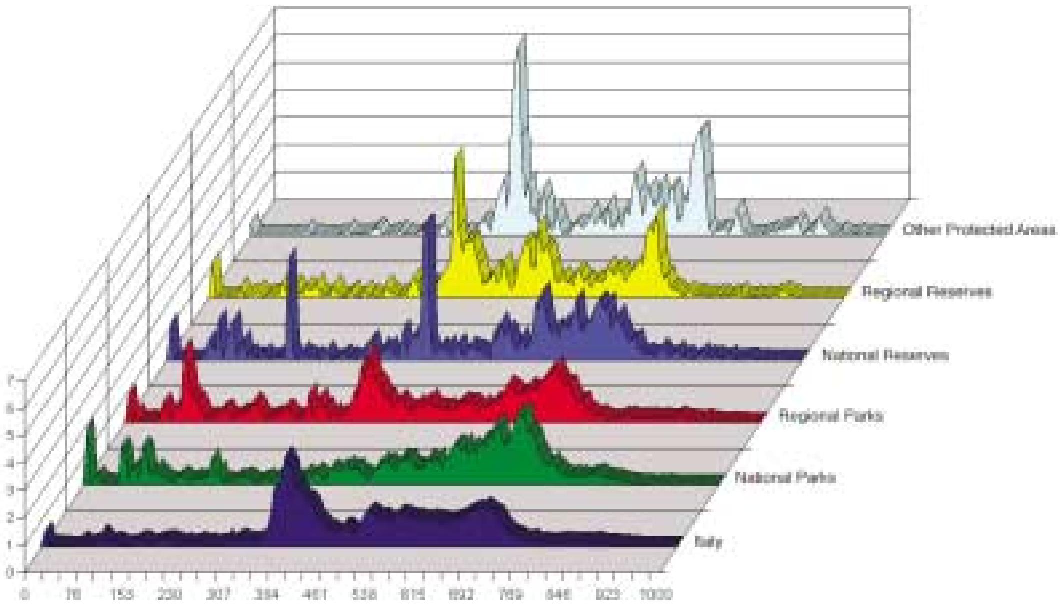


Fig. 25a. Biodiversity Index frequency pattern (see par. 4.5) for Vertebrates in the different types of Protected Areas and in the country.

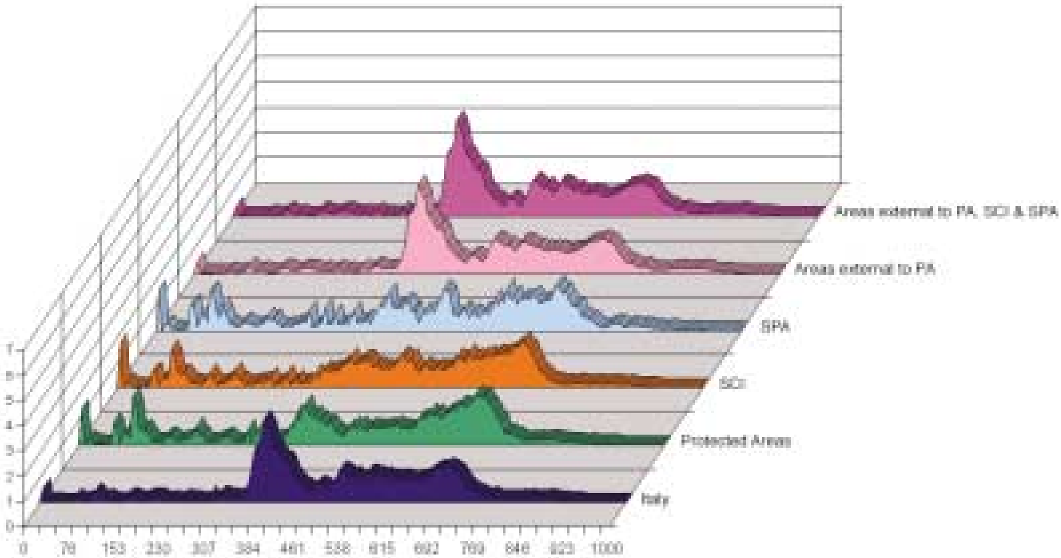


Fig. 25b. Biodiversity Index frequency pattern (see par. 4.5) for Vertebrates in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas, and in the areas outside the whole system of SCI, SPA and Protected Areas.

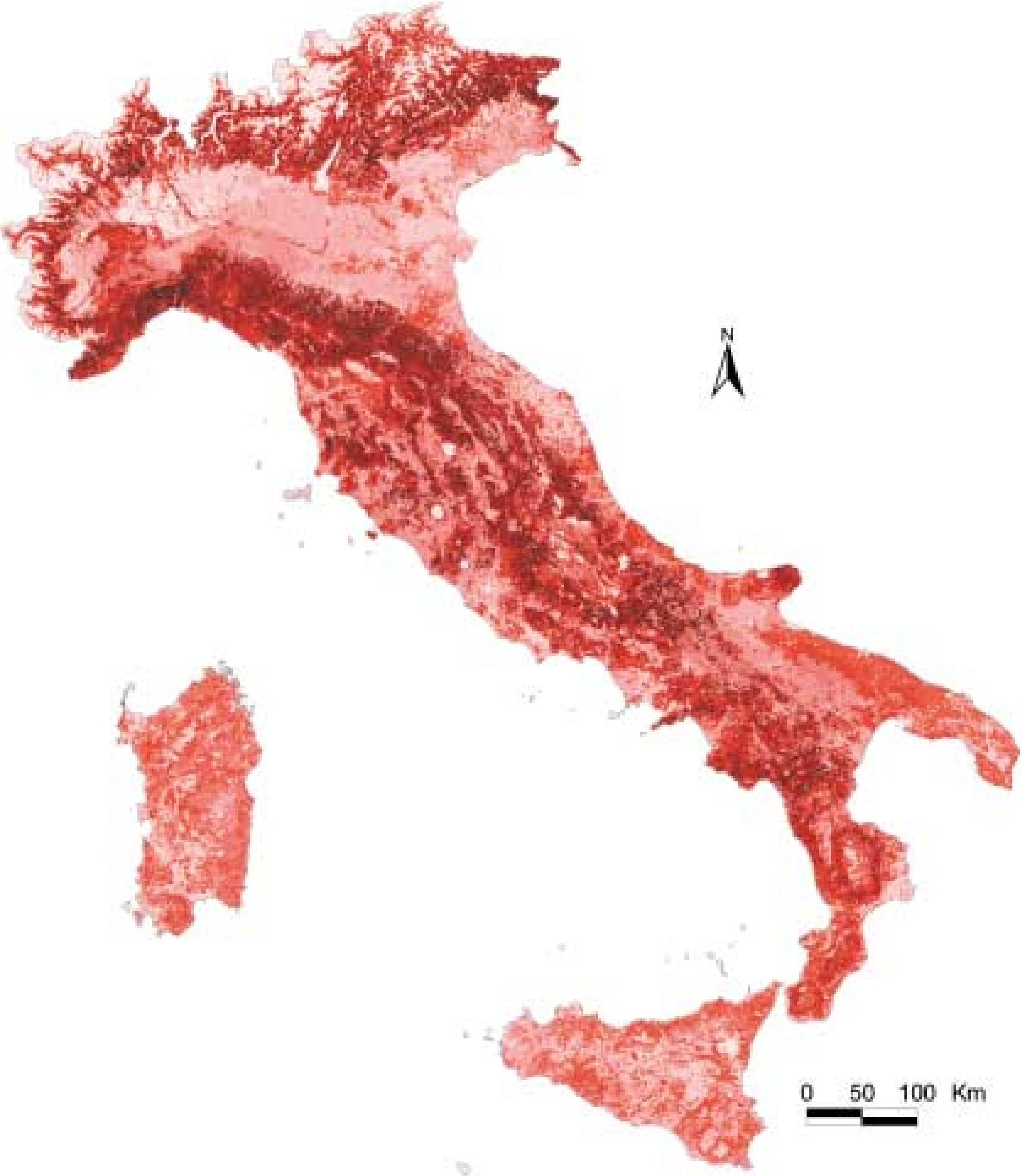


Fig. 25c. Ecological Network of Italian Vertebrates (darker shades of red indicate suitability for a greater number of species, up to a maximum of 182).

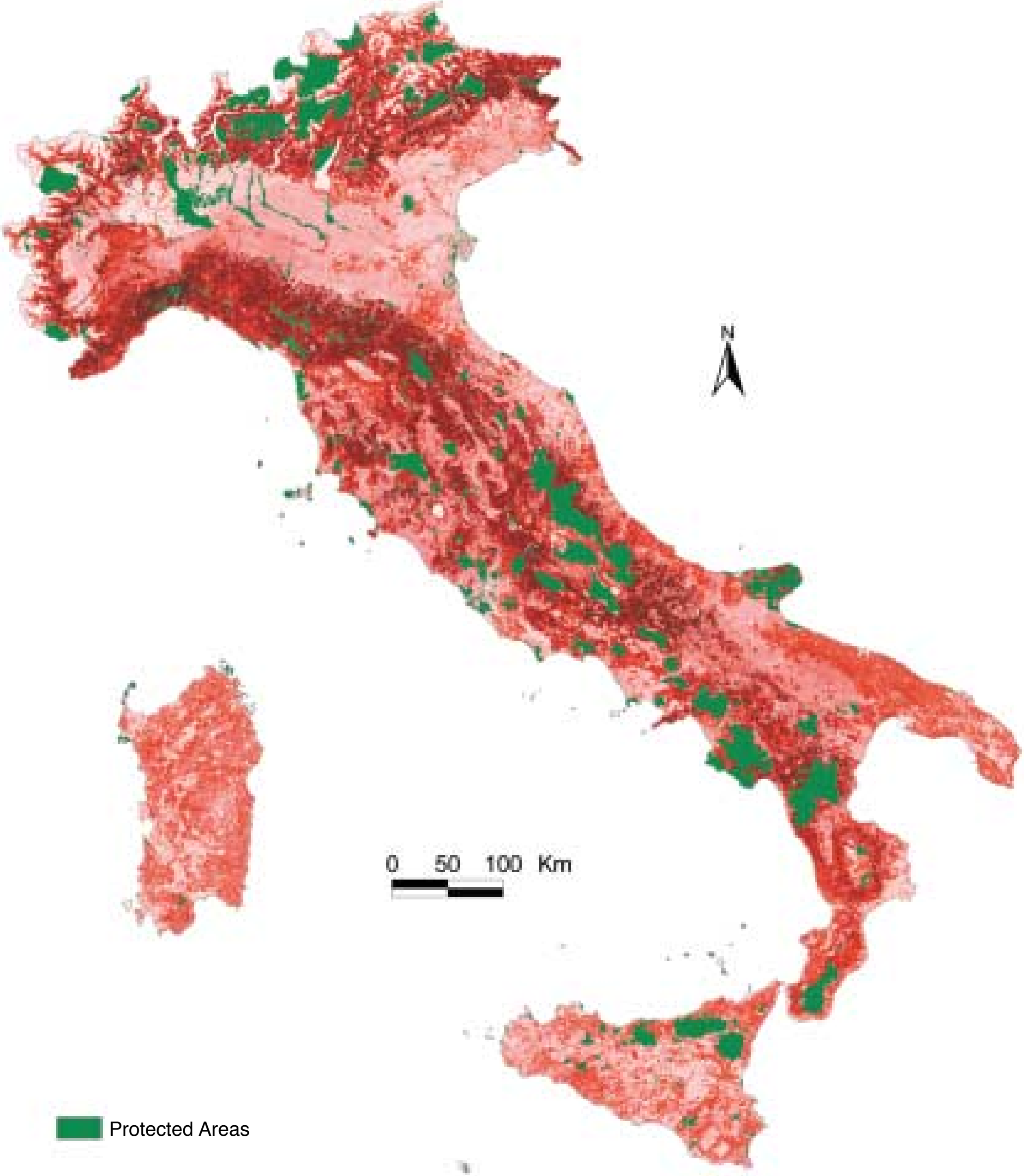


Fig. 25d. Potential number of vertebrate species present in Italy, outside the Protected Areas.

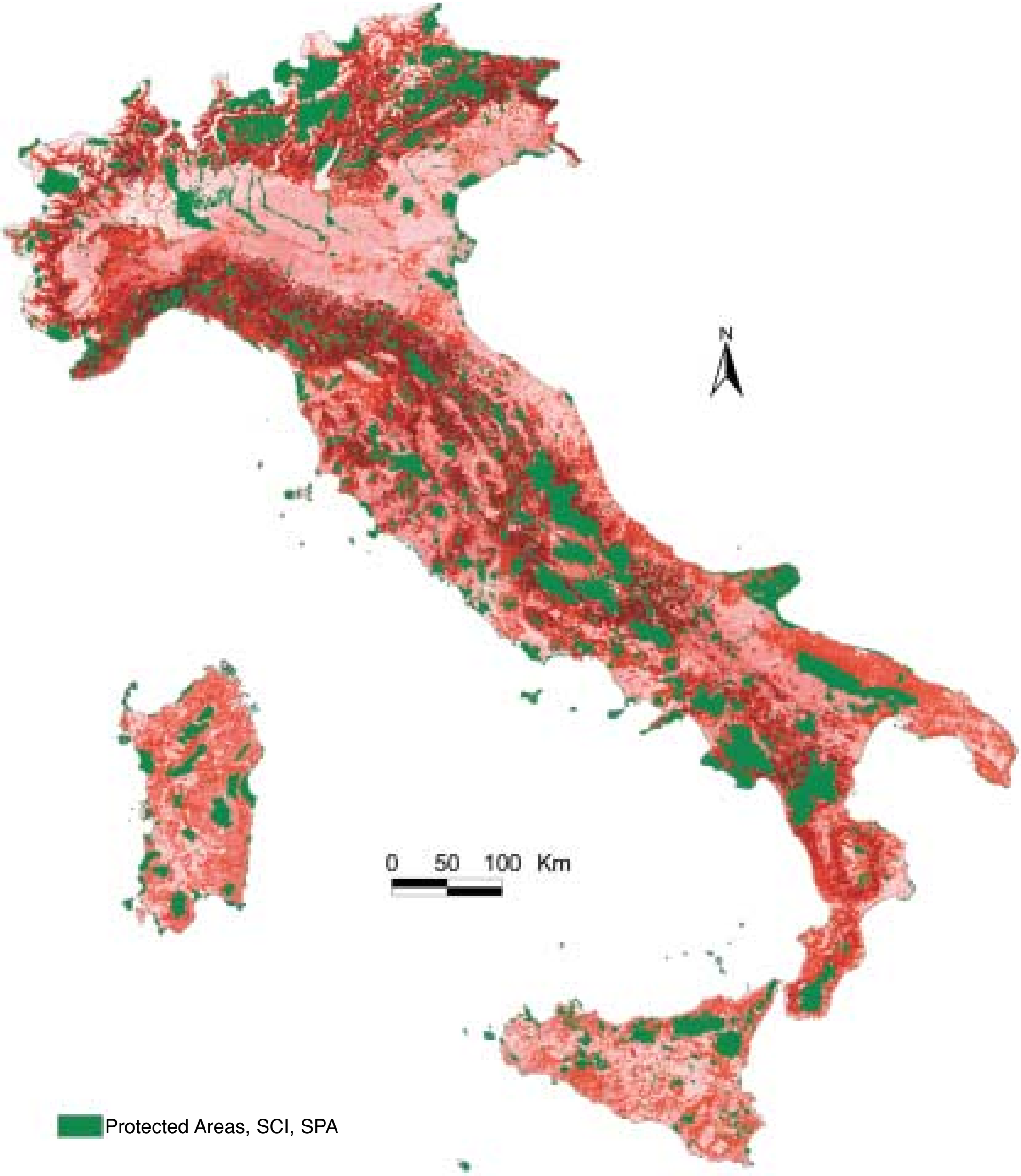


Fig. 25e. Potential number of vertebrate species present in Italy, outside the Protected Areas, SCI and SPA.

5.2 Mammals

The National Parks seem to play a particularly important role with regard to the entire class of mammals. In the National Parks, the values of the diversity index for this class fall entirely within the peak of maximum diversity, reflecting one of the criteria most frequently adopted in choosing a National Park, i.e. the presence of species of large vertebrates. The Regional Parks, on the other hand, despite having a peak of high diversity greater than that of Italy as a whole, also include a greater proportion of areas with very low diversity, indicating that the importance of the areas covered is often unconnected with the presence of a particularly important fauna (Figs. 26a, 26b, 26c).

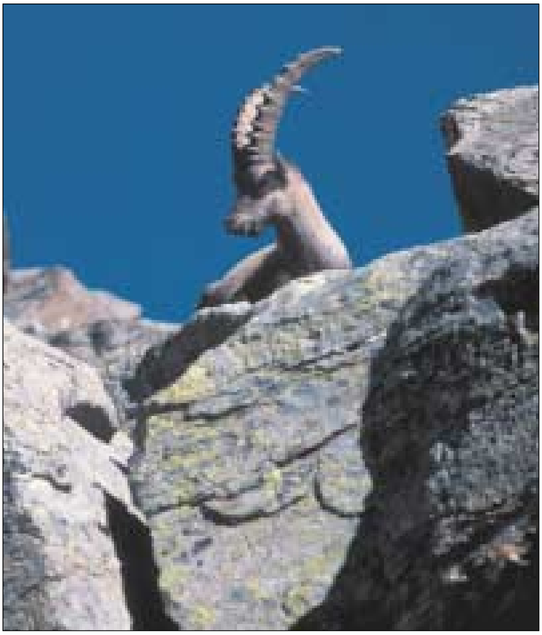
The Regional Parks, taken together, cover a very wide area, influencing the distribution trend of the whole system of existing and proposed PA, which shows a similar diversity pattern.

National Reserves and Regional Reserves, too, include sectors with a high diversity of mammals, but they also include many areas with medium and low diversity. The SCI show three frequency peaks corresponding to high, average and low diversity values for mammals, confirming that they have been proposed for specific reasons, often calibrated on only a few species, and not only mammals (Figs. 26a, 26b).

Mammals are found over a very wide range of different ecological scales, from the microhabitats of the smallest insectivores to the extensive areas occupied by the largest, most mobile species, and it is certainly difficult to make any kind of generalization, but they undoubtedly constitute one of the classes for which it is most necessary to adopt an authentic ecological network approach, in order to ensure mobility and links between fragmented metapopulations. An effort can probably be made to modify the boundaries and dimensions of the SCI in order to emphasize their supporting role for the system of Other Protected Areas (as links between parks and buffer zones around their boundaries), particularly in the case of National and Regional Parks (Fig. 26c).

The diversity distribution maps show at least three areas with very high mammal diversities that have not yet been included in any protected area, either existing or proposed (Figs. 26d, 26e). The eastern Alps (northern and eastern Friuli), despite the presence of a good number of SCI complementing a few Other Protected Areas, deserve particular attention with regard to setting up a network of PA that are effectively and efficiently connected to one another. Good network management might be an alternative to extending the area covered by the protected areas. In western Piedmont, the foothills between Pinerolo and Cuorgnè have been found to have extremely high mammal diversity, and yet the area is devoid of protection: since this is a transversal area running across several hydrographic basins, action to ensure continuity within the area should be given high priority.

Lastly, the area of the mountain pass between Tuscany and Emilia to the east of Abetone, though surrounded by a few PA and numerous SCI, is still outside the system, despite the fact that it is an important node in the mammal network of the northern Apennines.



Ibex *(Capra ibex)*

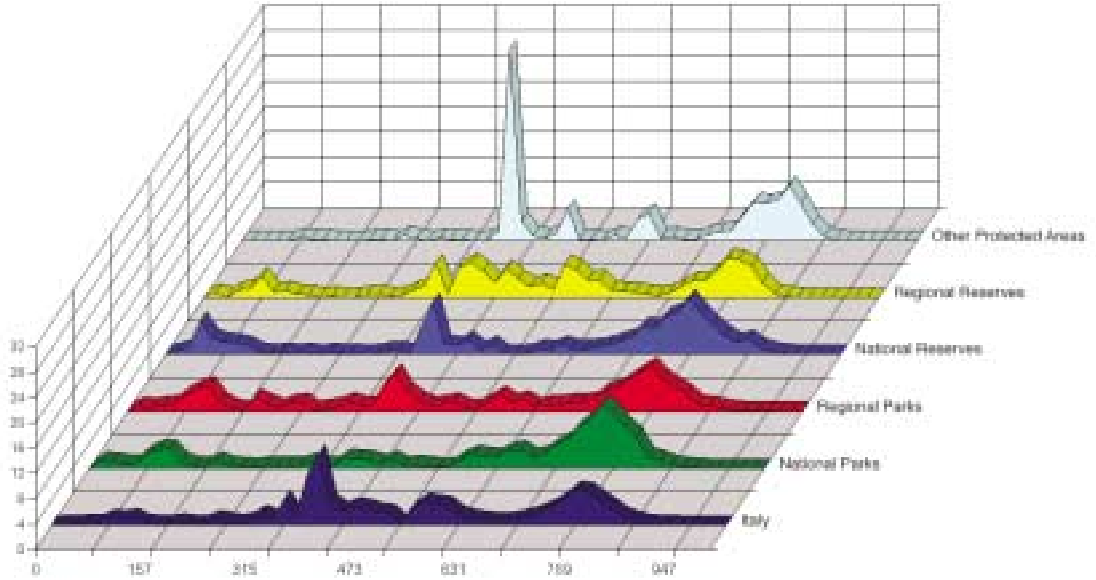


Fig. 26a. Biodiversity Index frequency pattern (see par. 4.5) for Mammals in the various types of Protected Areas and in the country.

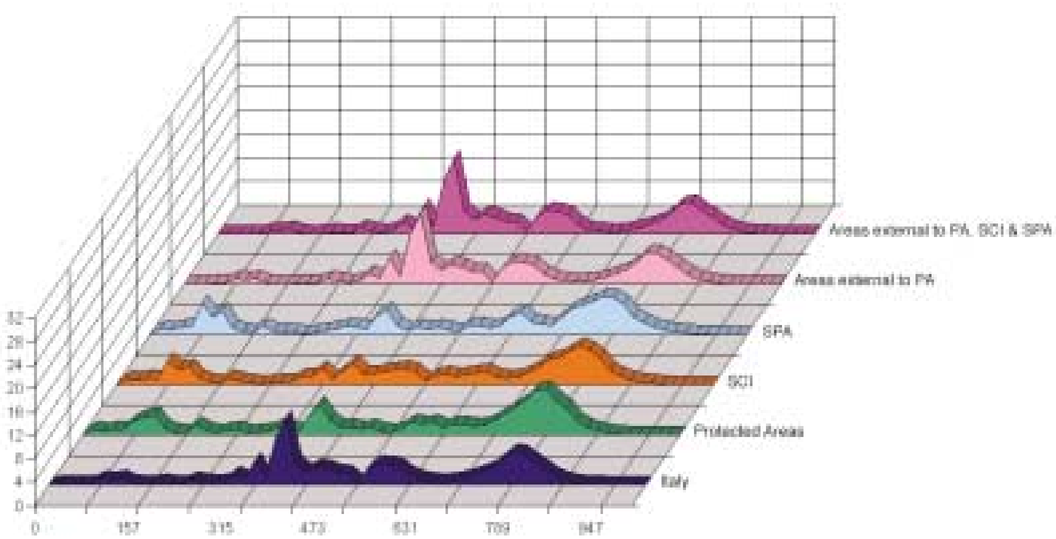


Fig. 26b. Biodiversity Index frequency pattern (see par. 4.5) for Mammals in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas and in the areas outside the whole system of SCI, SPA and Protected Areas.

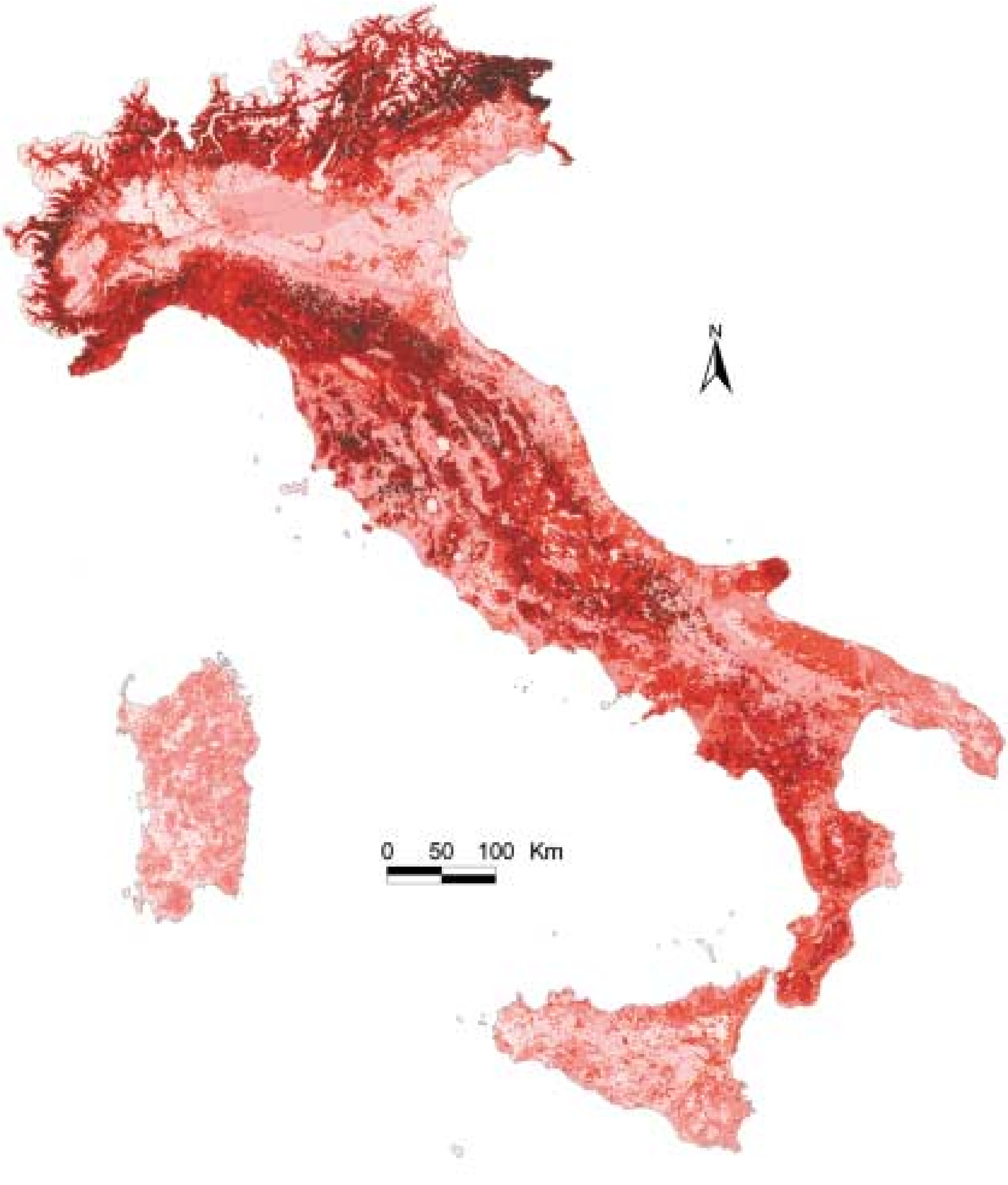


Fig. 26c. Ecological network of Italian Mammals (darker shades of red indicate suitability for a greater number of species, up to a maximum of 57).

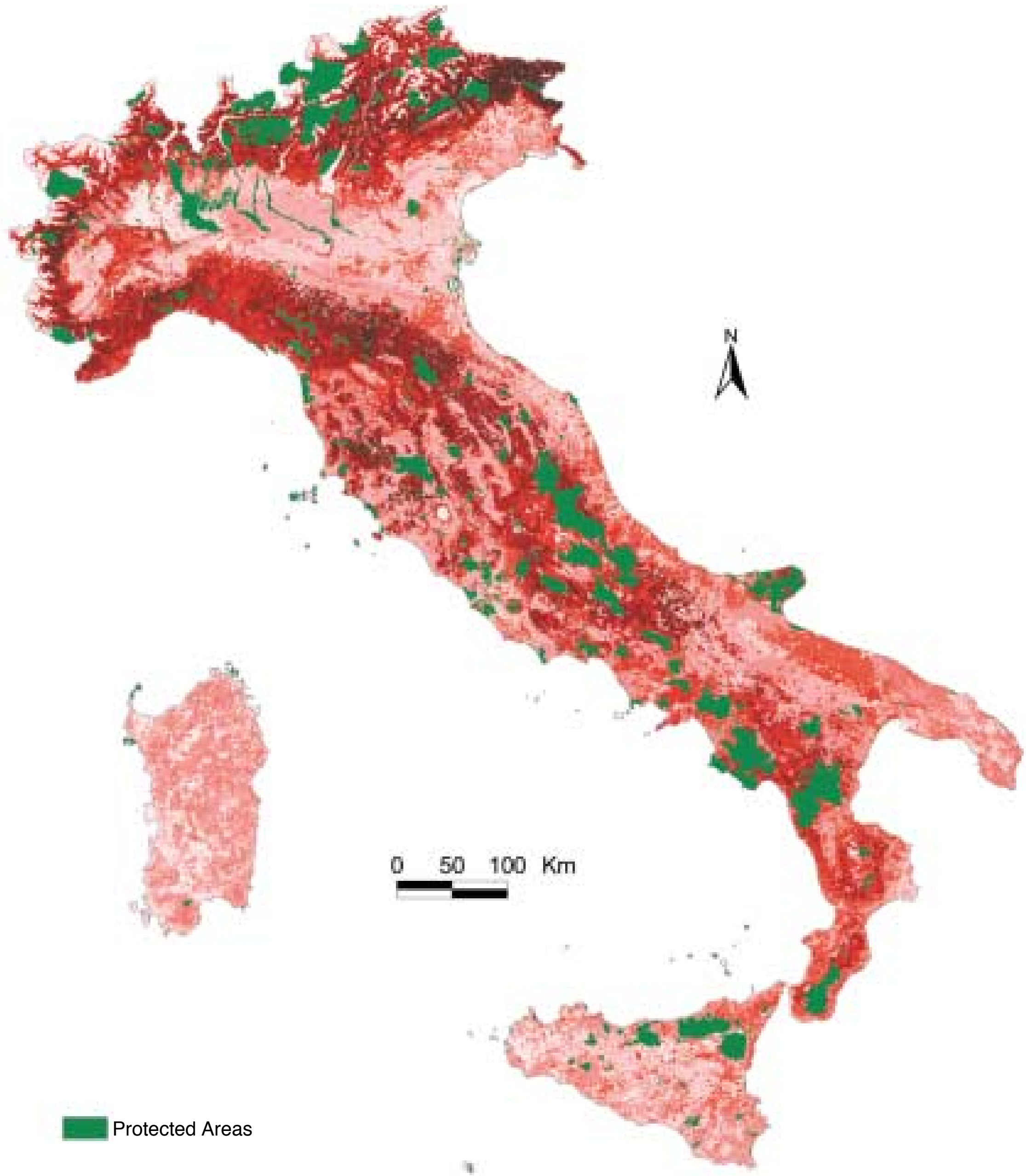


Fig. 26d. Potential number of mammal species present in Italy, outside the Protected Areas.

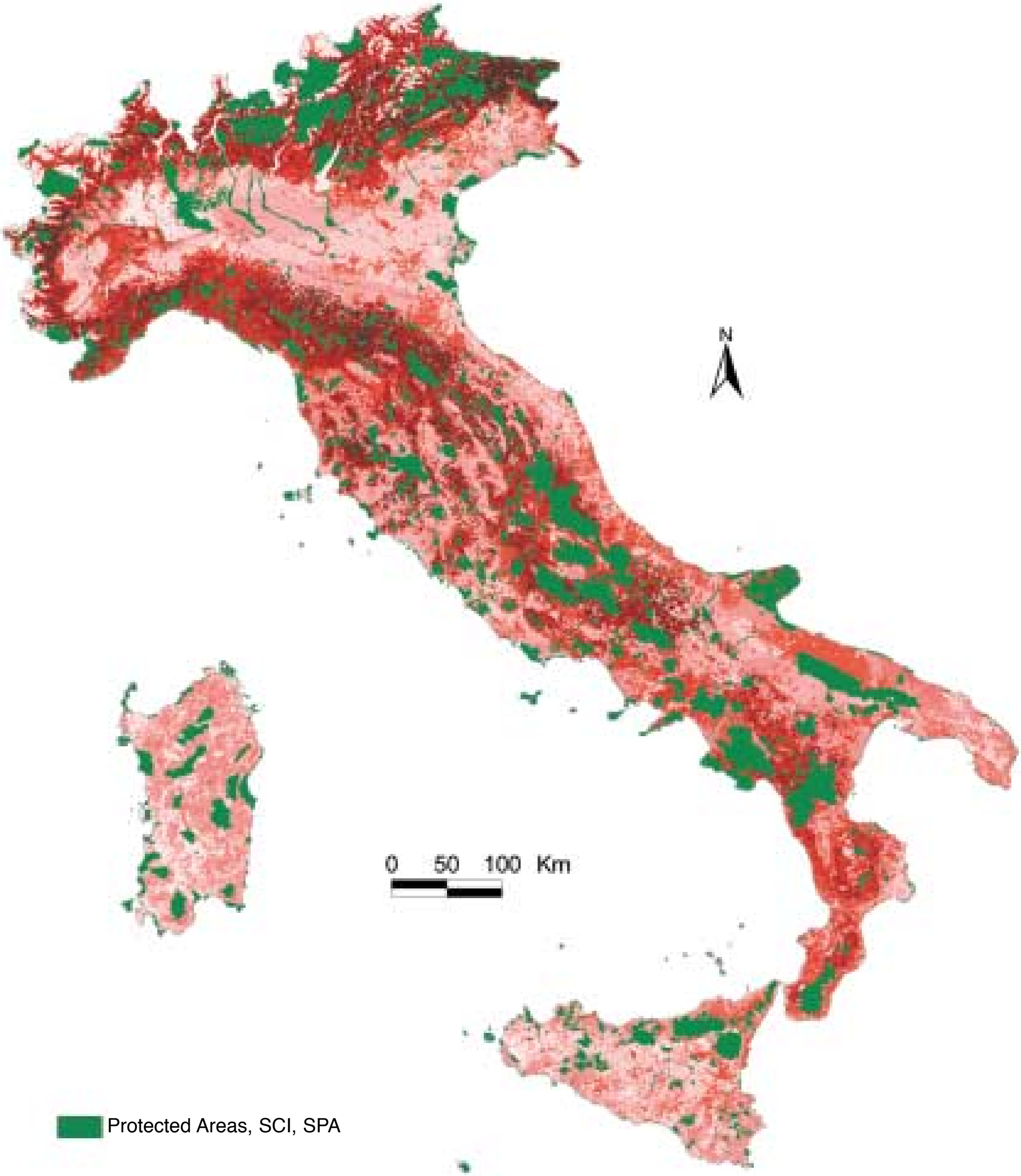


Fig. 26e. Potential number of mammal species present in Italy, outside the Protected Areas, SCI and SPA.

5.3 Birds

Our greater scientific knowledge of this class, together with the greater visibility of the species and the availability of a large number of research workers, both professionals and volunteers, has meant that birds have been one of the most frequent reasons given for setting up protected areas. Species diversity does not seem to have been the most important parameter, however, but rather the presence of a few particular species. The diversity pattern throughout Italy has a characteristic bimodal trend with two relatively central peaks. The system of PA, as a whole, effectively reflects this trend, indicating a general lack of preference for areas with higher diversity levels and indeed, on the contrary, including a disproportionate quantity of areas with a very low bird diversity level. The National Parks are confirmed as the type of protected area that most frequently includes territory with high diversity, while the Regional Parks, National Reserves and in general all other types of protected area do not seem to have any specific preference for this class. The SCI, on the other hand, are notable as being the areas with the highest bird diversity, whereas the SPA show a less clear-cut preference, very probably for the reasons already explained above (Figs. 27a, 27b, 27c).

Perhaps for no class as much as that of birds, the global network, consisting of PA plus SCI and SPA, appears to give adequate coverage to all the areas with the highest diversity. With the exception of Molise, where there are still large portions of territory with high diversity that do not form part of the system of PA (Figs. 27d, 27e), there do not seem to be other large areas of territory that have high diversity and yet are devoid of protection. On the northern slopes of the Apennines in Tuscany and Romagna there is a vast area with high diversity that appears to be very fragmented, but a close-set mosaic of SCI seems to form a homogeneous network, the ecological efficiency of which, however, should be verified.

In central-southern Piedmont there is a wide area with average diversity that does not seem to have an adequate number of protected areas: the extension of the area and its central position, overlooking the Po plain, make it potentially very interesting for conservation; the territorial layout of the protection system should be properly verified. The foothills in Piemonte, too, have average diversity and are poorly protected: as already mentioned, the role of this area as a link makes it more important, despite the fact that the diversity index is not very high.

Peregrine Falcon *(Falco peregrinus)*

Snow Finch *(Montifringilla nivalis)*

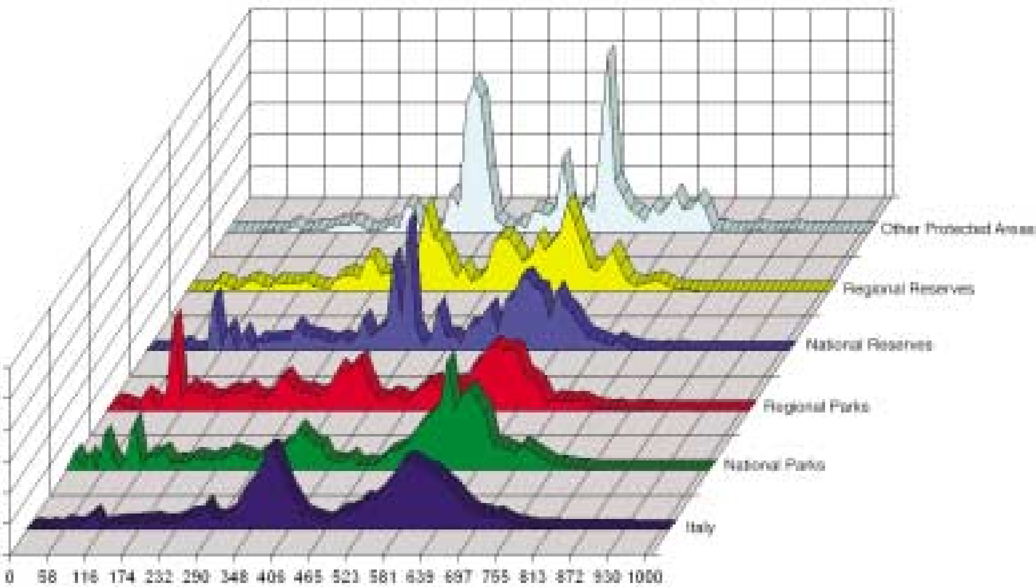


Fig. 27a. Biodiversity Index frequency pattern (see par. 4.5) for Birds in the various types of Protected Areas and in the country.

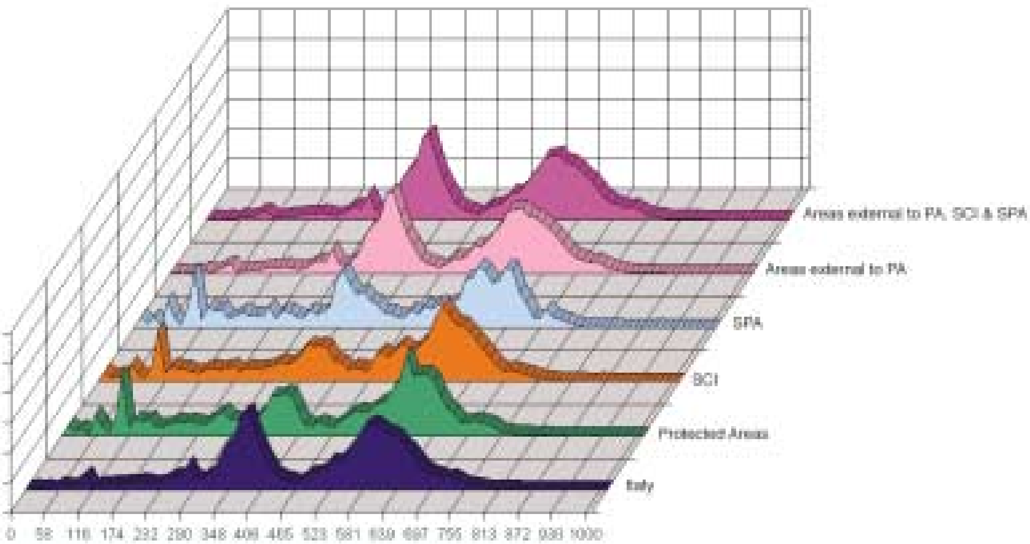


Fig. 27b. Biodiversity Index frequency pattern (see par. 4.5) for Birds in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas, and in the areas outside the whole system of SCI, SPA and Protected Areas.

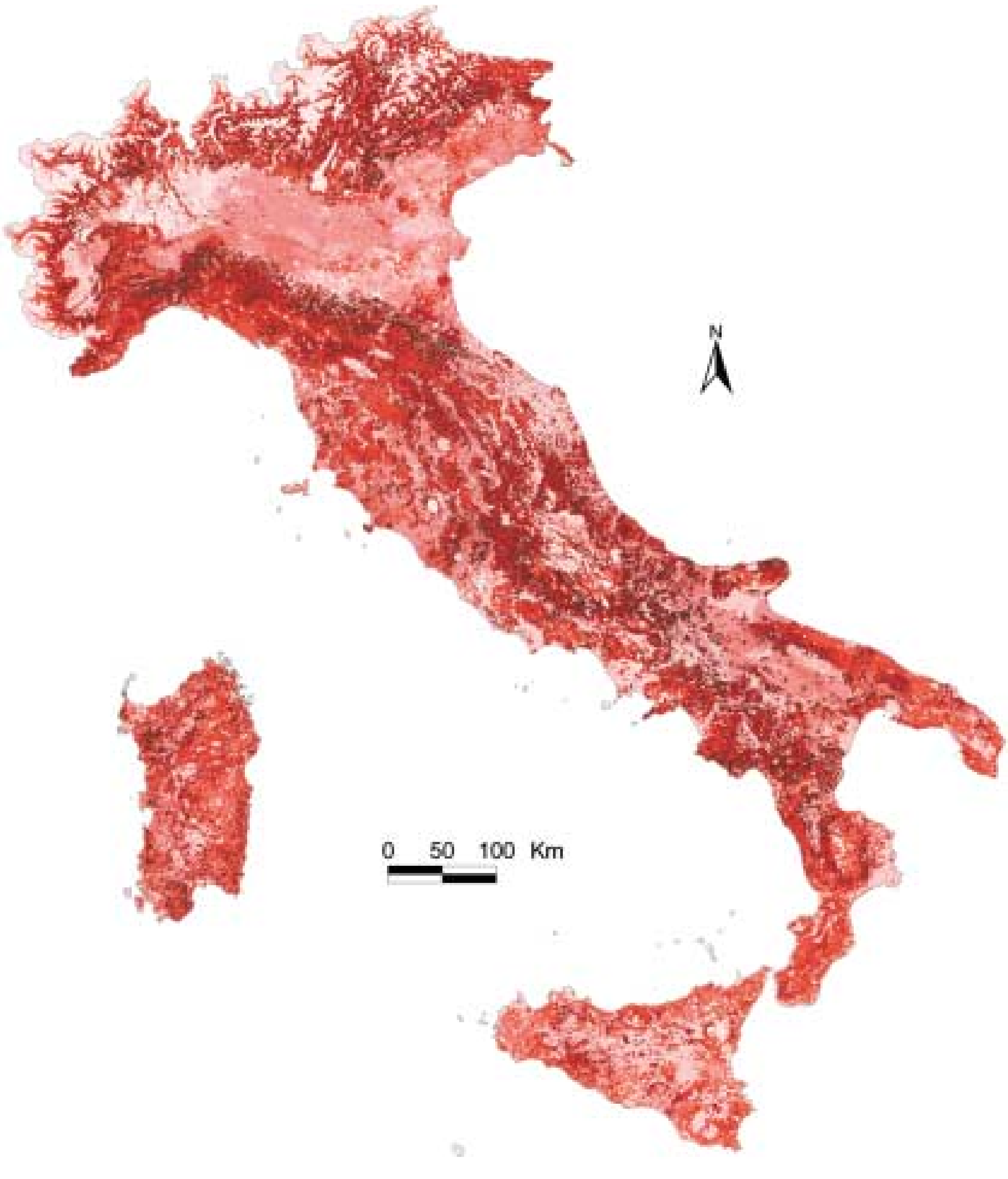


Fig. 27c. Ecological Network of Italian Birds (darker shades of red indicate suitability for a greater number of species, up to a maximum of 86).

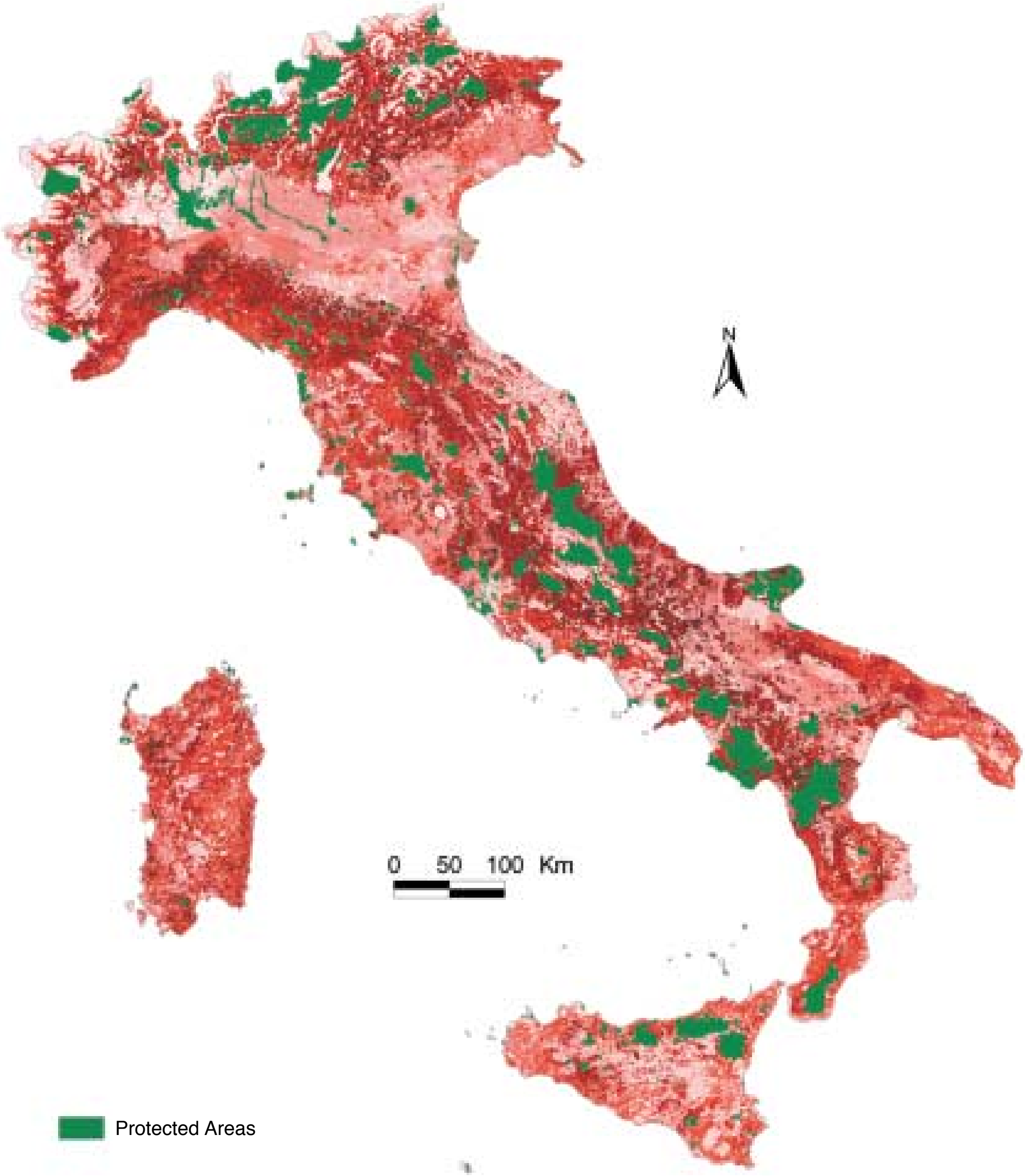


Fig. 27d. Potential number of bird species present in Italy, outside the Protected Areas.

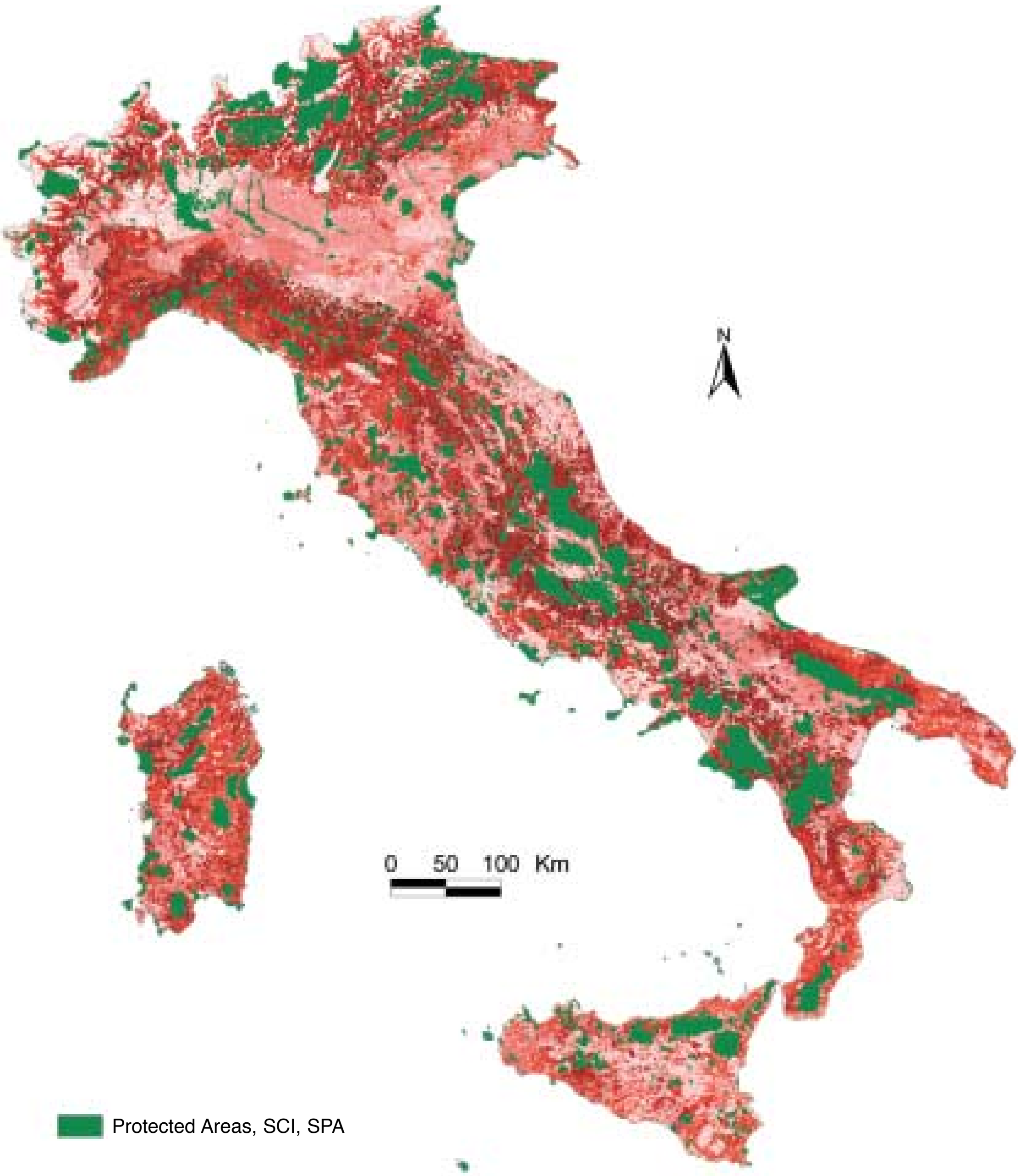


Fig. 27e. Potential number of bird species present in Italy, outside the Protected Areas, SCI and SPA.

5.4 Reptiles

The pattern of the biodiversity index for reptiles mirrors that of amphibians and shows a single peak, corresponding to the highest levels of biodiversity, indicating that, on the scale used to interpret the analyses, reptile species are more ubiquitous and have larger distribution ranges (Figs. 28a, 28b, 28c). In this connection, the various types of protected areas show trends for the diversity index that are essentially similar to one another and also to the trend of Italy as a whole. In other words, the PA do not seem to show any significant preference for areas with greater reptile diversity. Once again, the National Parks cover the peak of high diversity, while the category Other Protected Areas covers a single peak coinciding with extremely high diversity.

It is probably better to look at the distribution maps in order to identify any irregularity between biodiversity distribution and the PA system. Reptile distribution mostly concerns the Italian peninsula, and the areas of greatest diversity that appear to be least covered by the network of PA are central and western Liguria and central and southern Tuscany (Figs. 28d, 28e). In Liguria, the network of proposed SCI works well to cover mountainous and inland territory, but the coastal strip still seems very unprotected. In Tuscany, most of the hills between the hinterland of Livorno, the Metalliferous Hills and the Maremma, as far as the boundary with Latium, have no protection. In southern Italy, Calabria and eastern Sicily stand out as areas with high diversity levels, but they are only partially included in the system of protected areas: in Calabria it is chiefly the coastal strips that remain unprotected and in south-eastern Sicily the SCI cover only a small percentage of the most important areas. It should be emphasized that the completion of the ecological network for reptiles (as for certain other classes) does not necessarily have to be achieved by setting up new protected areas; often it is sufficient to ensure habitat suitability by means of rules and regulations regarding human activities, agricultural practices and the use of chemicals.

European Pond Turtle *(Emys orbicularis)*

Grass Snake *(Natrix natrix)*

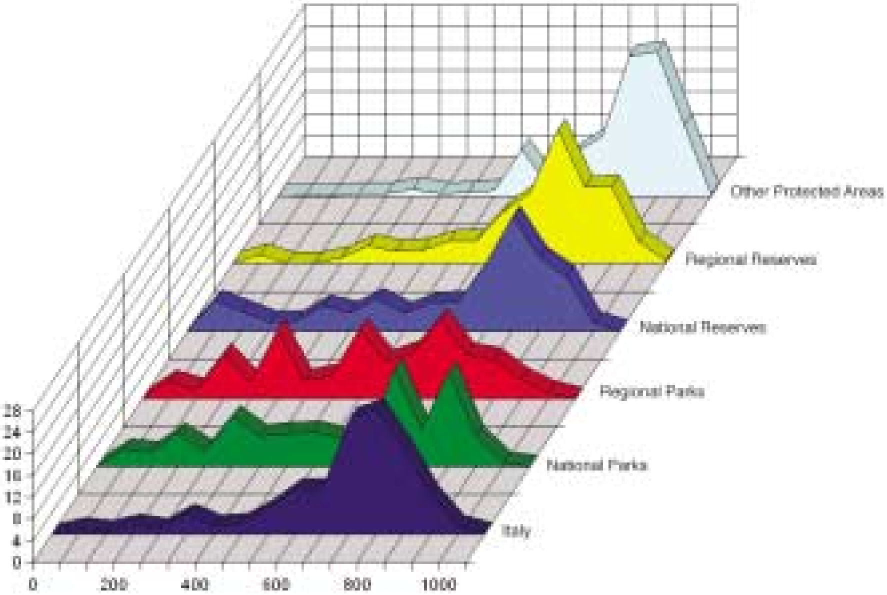


Fig. 28a. Biodiversity Index frequency pattern (see par. 4.5) for Reptiles in the various types of Protected Areas and in the country.

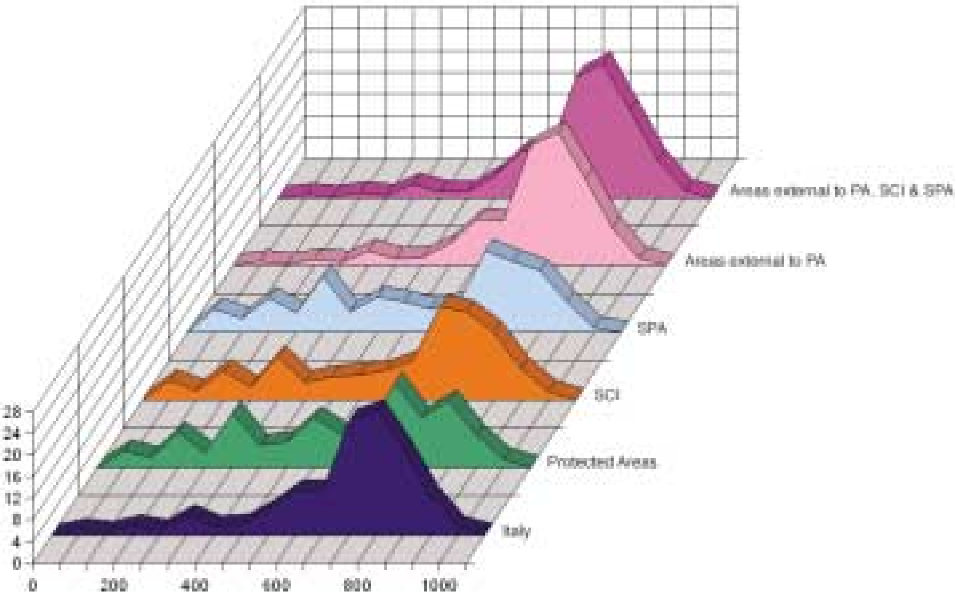


Fig. 28b. Biodiversity Index frequency pattern (see par. 4.5) for Reptiles in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas, and in the areas outside the whole system of SCI, SPA and Protected Areas.

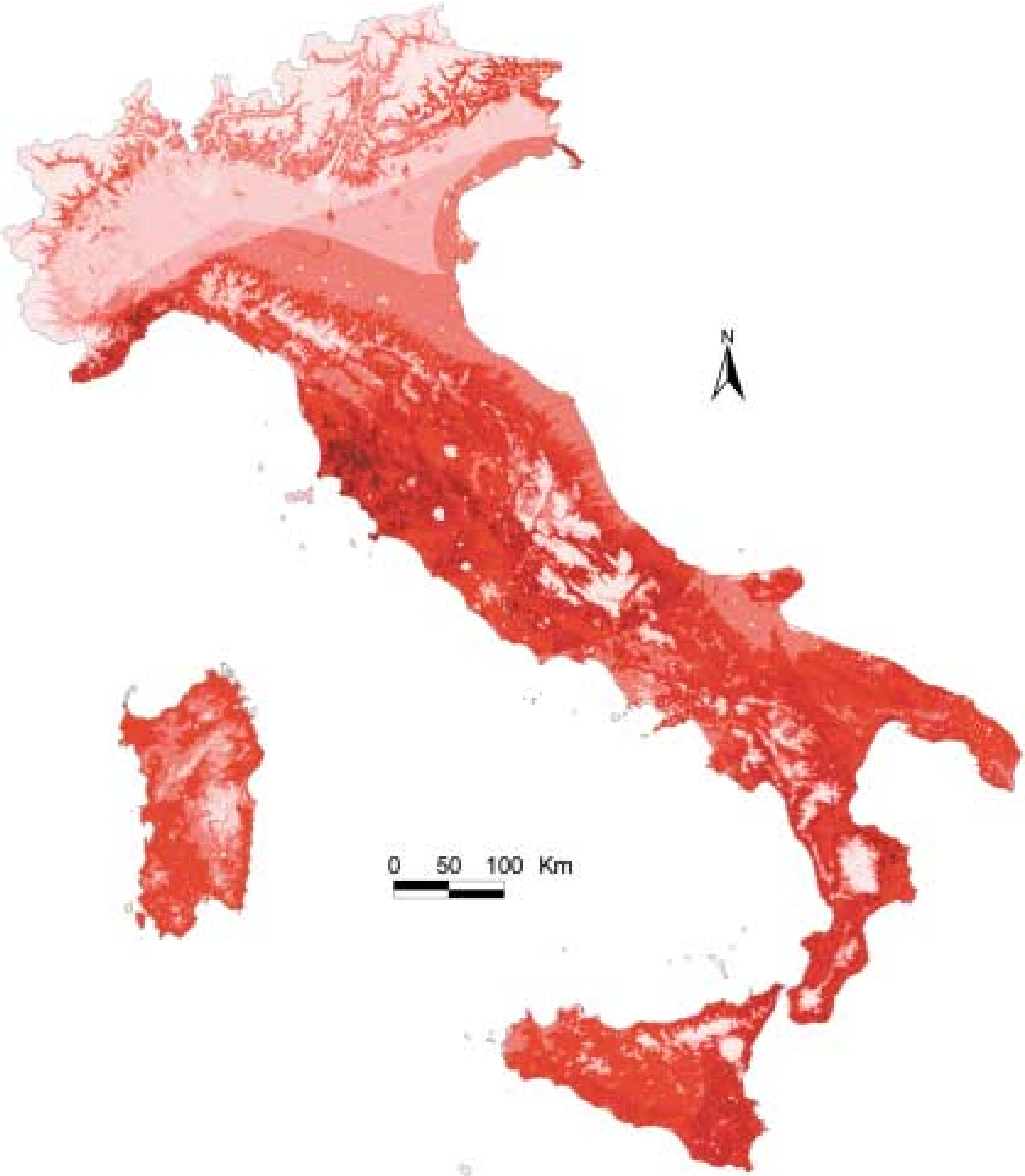


Fig. 28c. Ecological Network of Italian Reptiles (darker shades of red indicate suitability for a greater number of species, up to a maximum of 15).

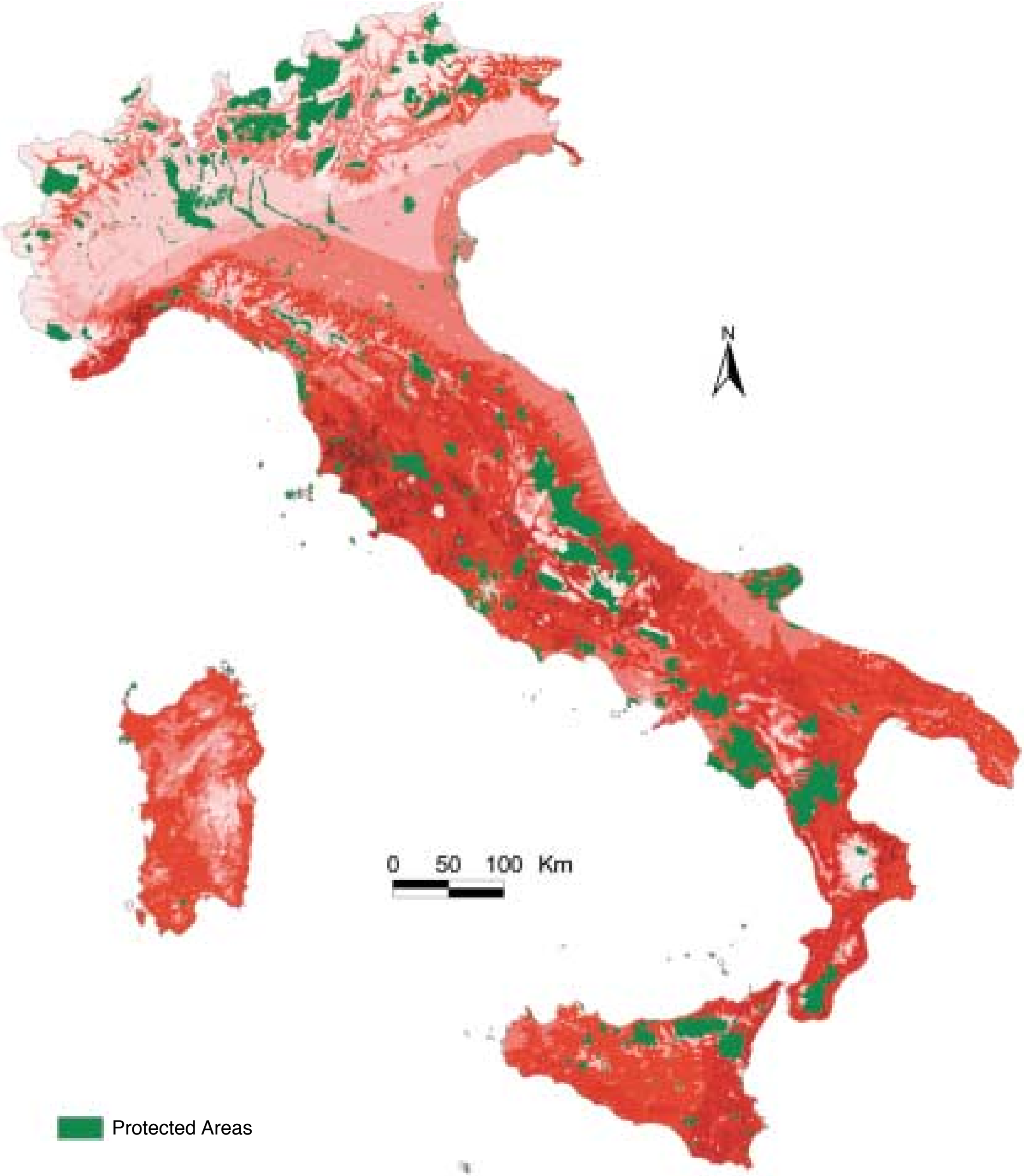


Fig. 28d. Potential number of reptile species present in Italy, outside the Protected Areas.

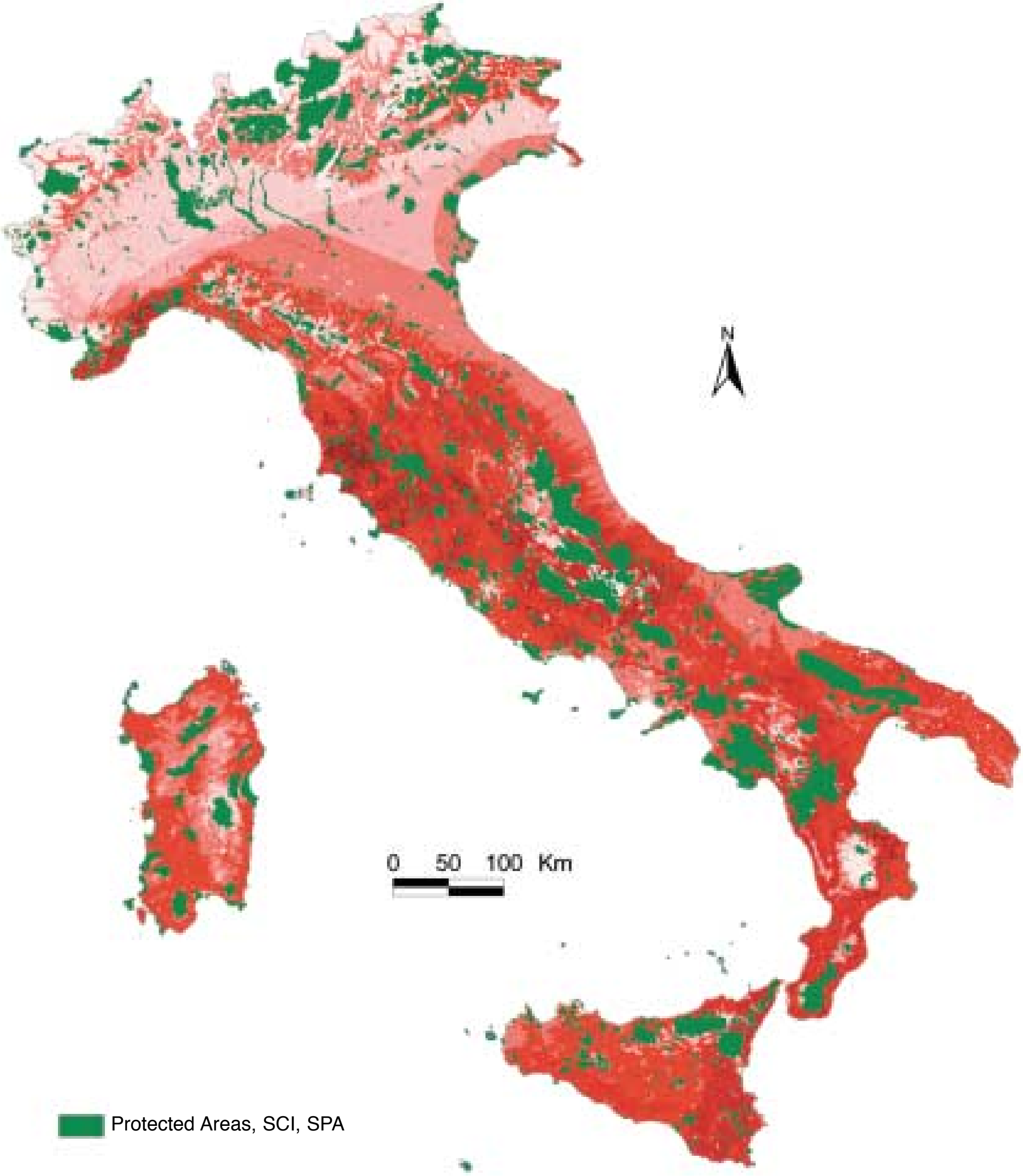


Fig. 28e. Potential number of reptile species present in Italy, outside the Protected Areas, SCI and SPA.

5.5 Amphibians

As might be expected in view of their unusual natural history and the number of species, amphibian diversity is essentially concentrated on average-low values throughout most of Italy (Figs. 29a, 29b, 29c). The system of PA, on the other hand, shows a clear-cut preference for areas of high diversity as well. The National Parks and, to a lesser extent, the Regional Parks and the National and Regional Reserves contribute to this preference. A key contribution towards enabling the system of PA to safeguard a good proportion of the areas with high amphibian diversity comes from the SCI, and still more the SPA. The latter components of the system are chiefly located in areas of interest for bird species that inhabit wetlands and so they naturally provide conditions that are equally suitable for amphibians.

Pool Frog *(Rana lessonae)*

It can be seen from looking at the distribution maps, on the large scale used for the whole study, that two important components of the ecological network for amphibians are worthy of particular attention. The first is the area of the Apennines in Tuscany and Emilia, and still more the Ligurian Apennines as far north as Genoa, where we find the highest levels of amphibian diversity that are not well covered by the network of PA. The poor mobility of the species and the fact that they are associated with ecological conditions that do not generally pertain over extensive areas mean that the ecological network project should be studied with particular care: the area in question has a good number of SCI but large portions of suitable territory still remain outside the system and activities must therefore be carefully regulated so as to keep possible links operating efficiently (Figs. 29d, 29e).

The second component of the ecological network for amphibians is the massive block of areas with average and high diversity that runs down from Molise to the Pollino National Park. This wide strip of land has a low density of protected areas and SCI, perhaps on account of the absence of other important biodiversity factors. The map shows that much of this strip of land is potentially suitable for amphibians and it is to be hoped that the SCI system will be modified to ensure that it gives adequate protection to this class of vertebrates (Figs. 29d, 29e).

Tyrrhenian Painted Frog *(Discoglossus sardus)*

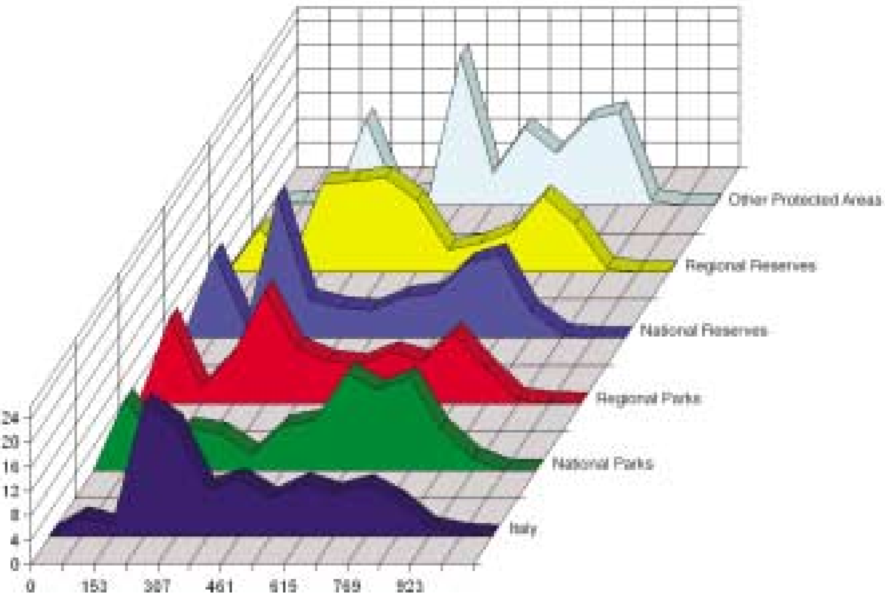


Fig. 29a. Biodiversity Index frequency pattern (see par. 4.5) for Amphibians in the various types of Protected Areas and in the country.

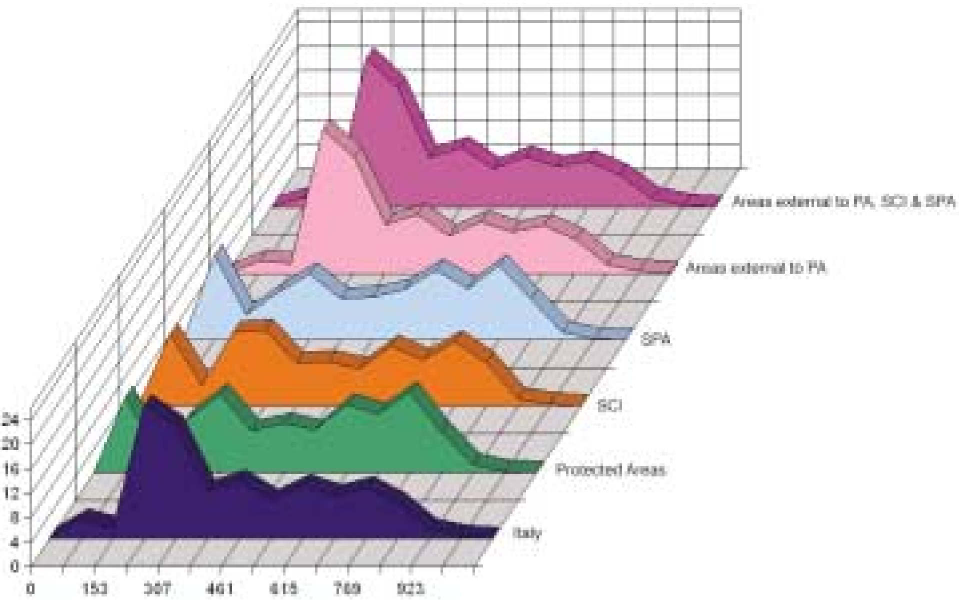


Fig. 29b. Biodiversity Index frequency pattern (see par. 4.5) for Amphibians in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas, and in the areas outside the whole system of SCI, SPA and Protected Areas.

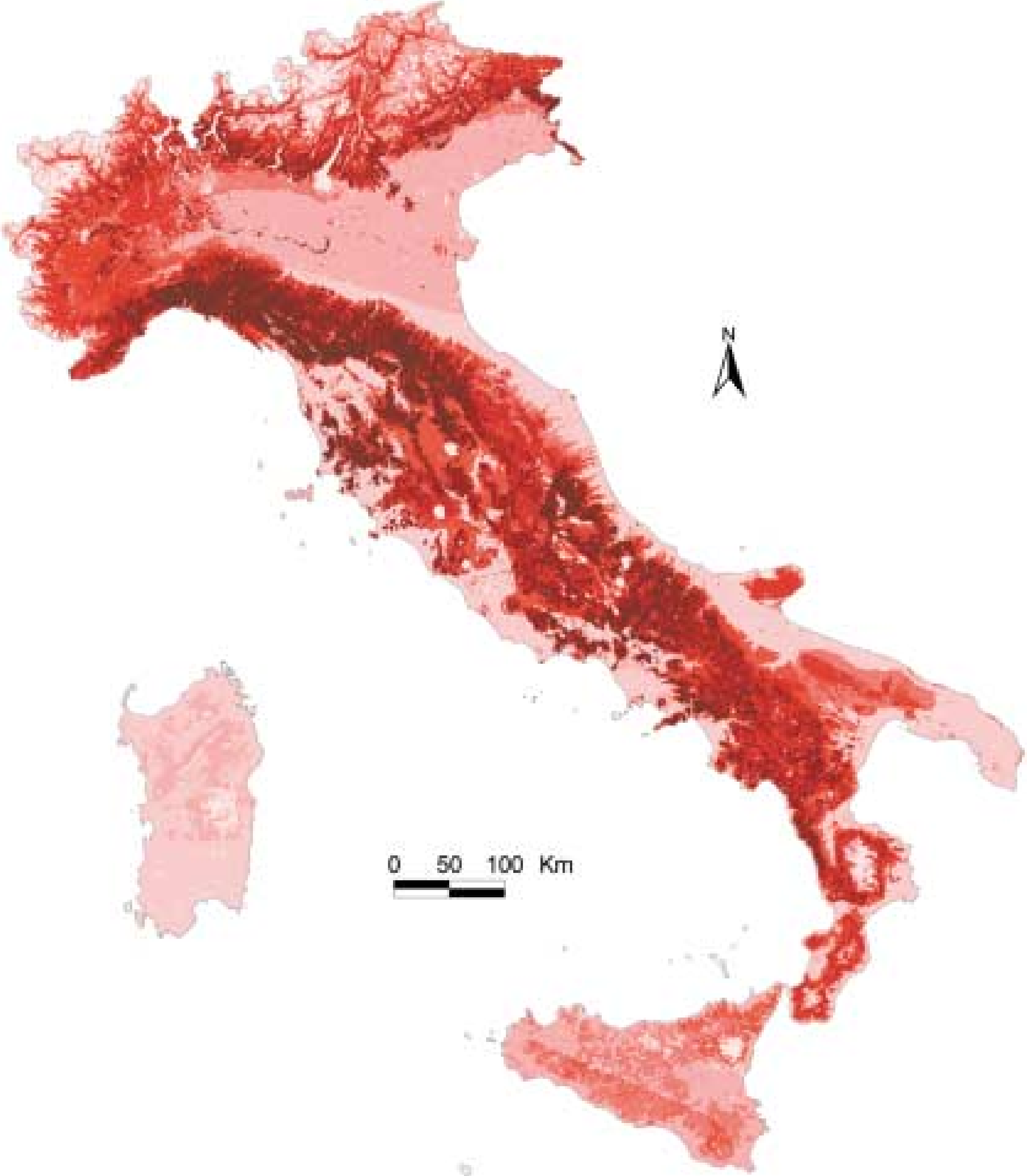


Fig. 29c. Ecological Network of Italian Amphibians (darker shades of red indicate suitability for a greater number of species, up to a maximum of 13).

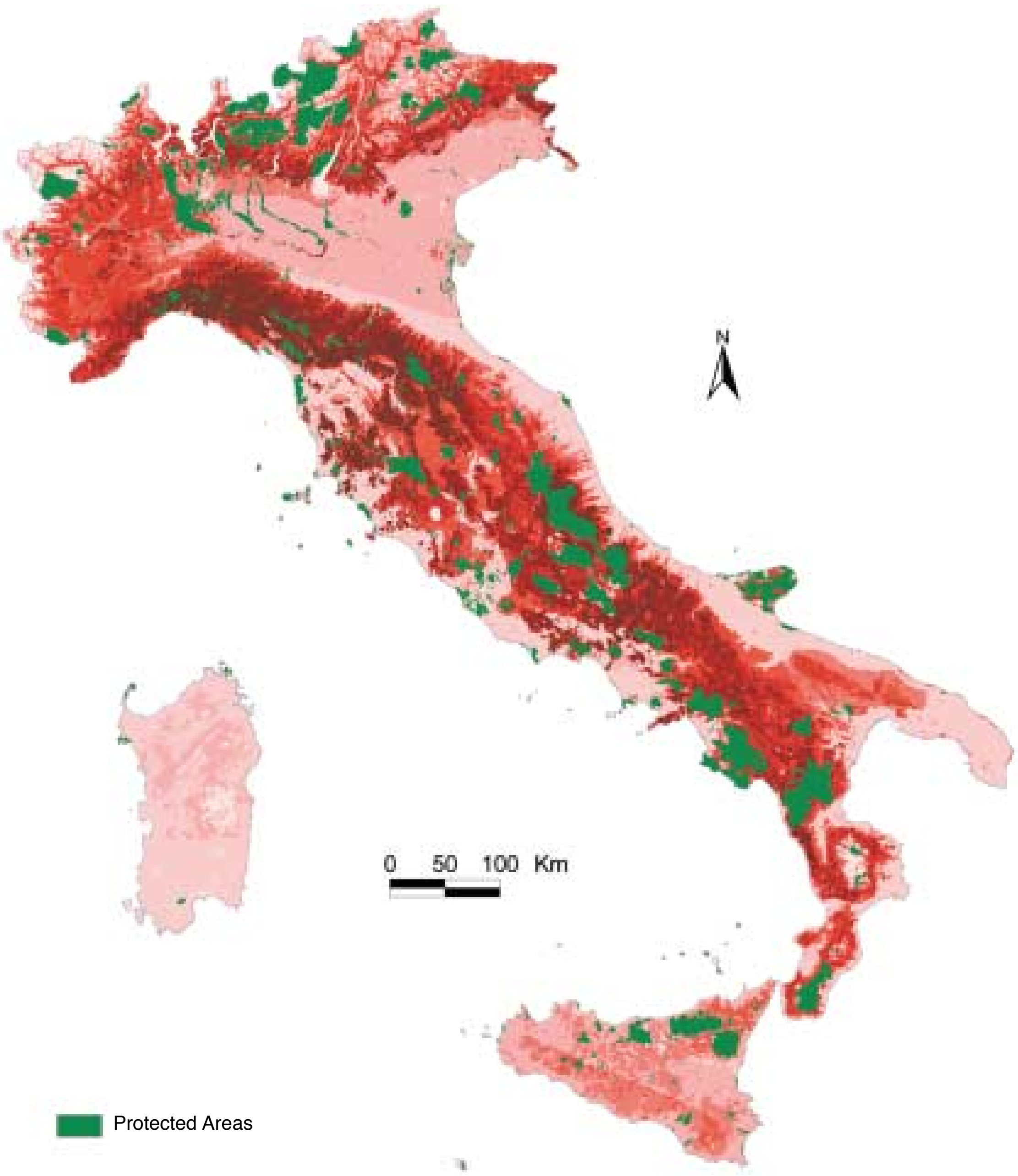


Fig. 29d. Potential number of amphibian species present in Italy, outside the Protected Areas.

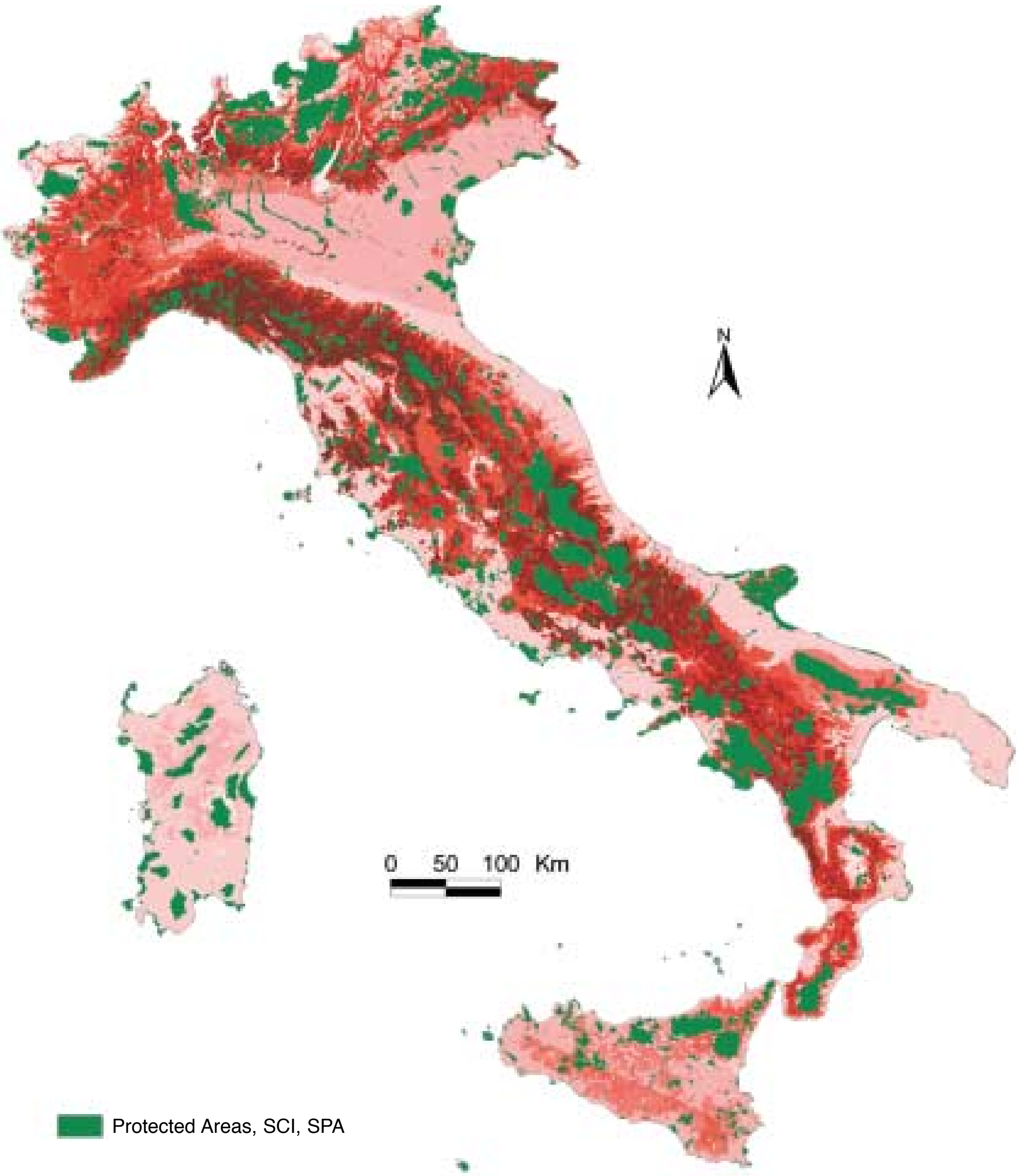


Fig. 29e. Potential number of amphibian species present in Italy, outside the Protected Areas, SCI and SPA.

5.6 Fish

It is difficult to examine fish using the same methods that are found useful for other vertebrates, and the observations that can be made for this class are so general that more detailed analyses are necessary in order to develop directly applicable guidelines. The graph illustrating the pattern of biodiversity indices for fish shows a trend which, with a few variations, covers all the values of the index in an almost uniform fashion, indicating that there is a wide variety of situations, from the simplest where only a few species are present to those with a greater number of species (Figs. 30a, 30b. 30c). In the system of PA, there seems to be a clear preference only for areas with low diversity, while the system fails to protect the most significant part of the territory for this class of vertebrates. Even the National Parks and SCI do not modify this situation, and only one category, Other Protected Areas, shows a peak corresponding to the highest diversity values. It would seem clear that, apart from the difficulty of interpreting these figures, fish have not been given adequate consideration in planning and creating protected areas in Italy, not even in the SCI.

The distribution map shows, despite the obvious fragmentation of the hydrographical networks, that the areas of greatest diversity are to be found in the Po plain and in the basins of Tuscany and Latium, which should be the object of a renewed conservation strategy (Figs. 30d, 30e): while it is possible to achieve this objective by means of legislation and action that does not necessarily make reference to territorial institutions such as protected areas, it is nevertheless desirable to develop the utmost synergy with the PA system; territorial coverage should therefore be adapted where possible to take account of the diversity of fish species, too, so as to promote their conservation.

Chub *(Leuciscus cephalus)*

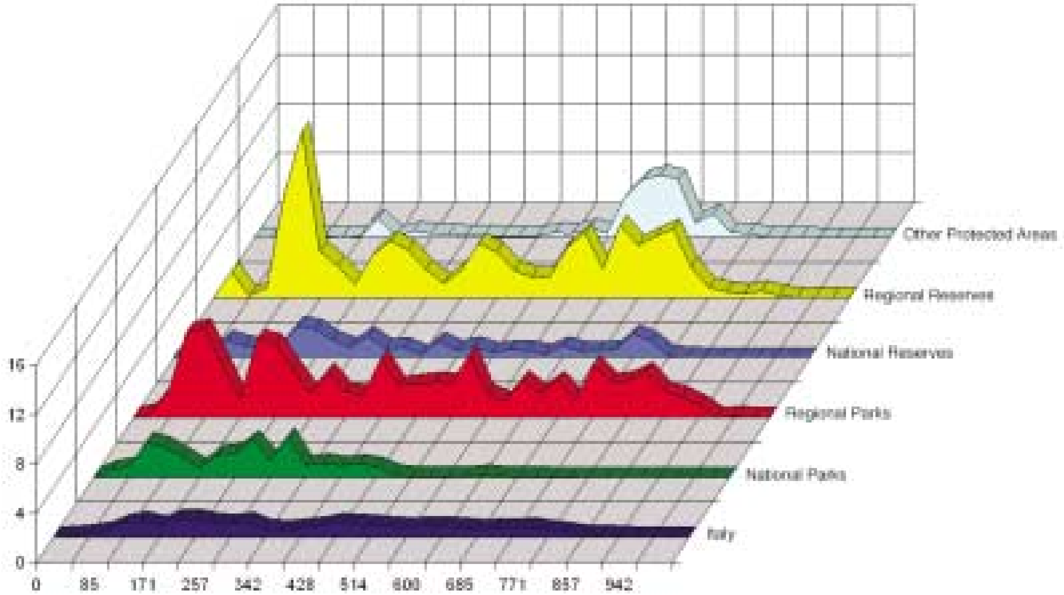


Fig. 30a. Biodiversity Index frequency pattern (see par. 4.5) for Fish in the various types of Protected Areas and in the country.

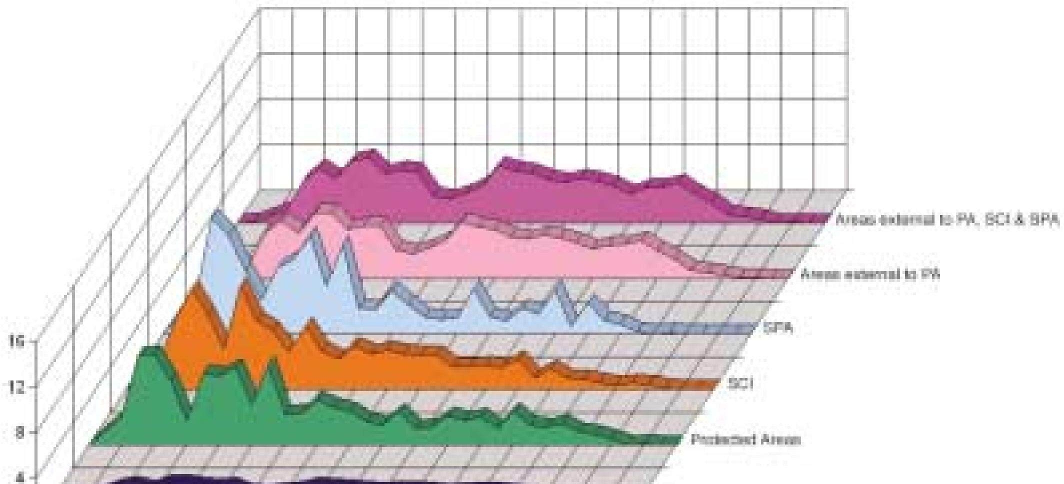


Fig. 30b. Biodiversity Index frequency pattern (see par. 4.5) for Fish in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas, and in the areas outside the whole system of SCI, SPA and Protected Areas.

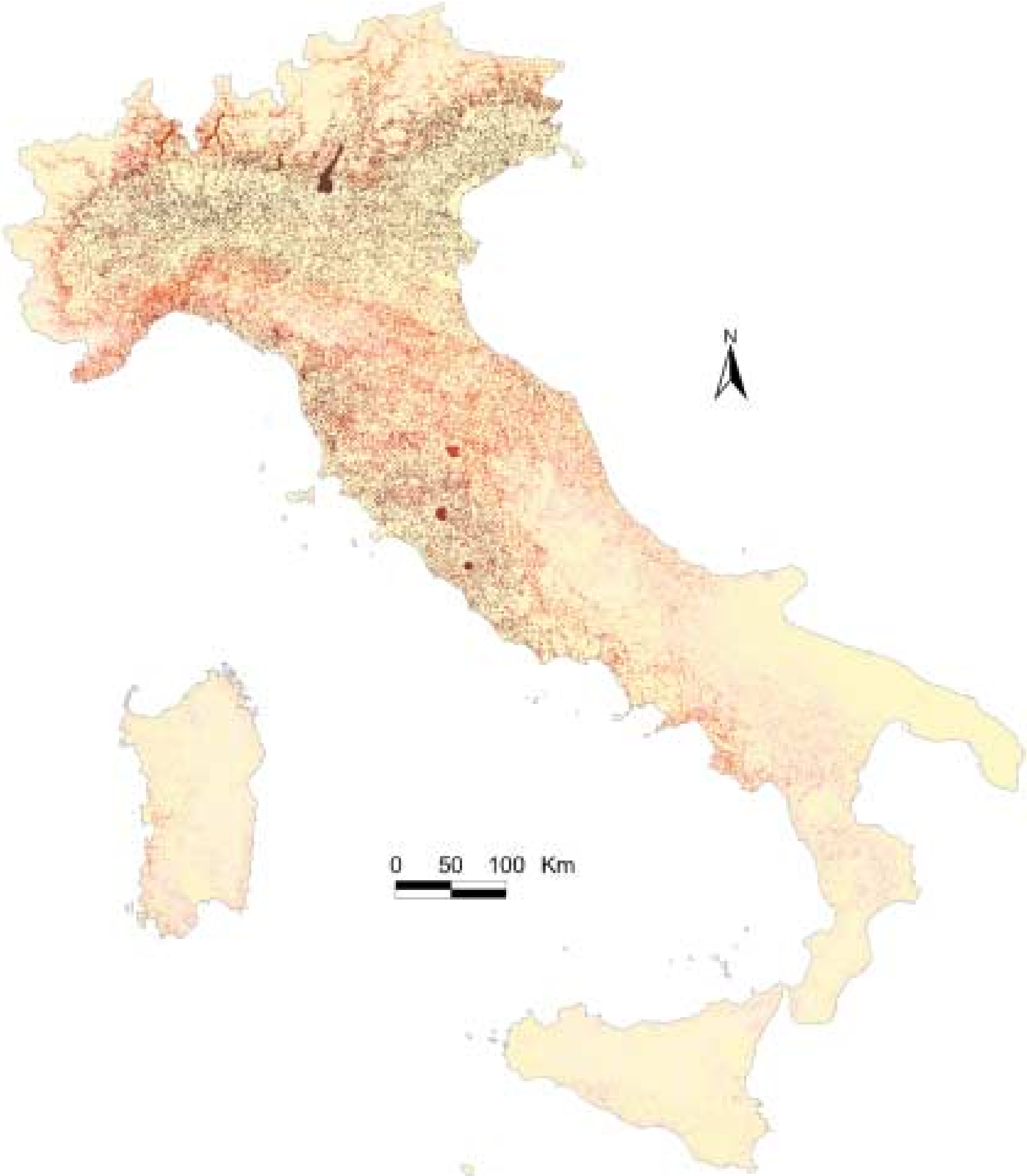


Fig. 30c. Ecological Network of Italian Fish (darker shades of red indicate suitability for a greater number of species, up to a maximum of 35).

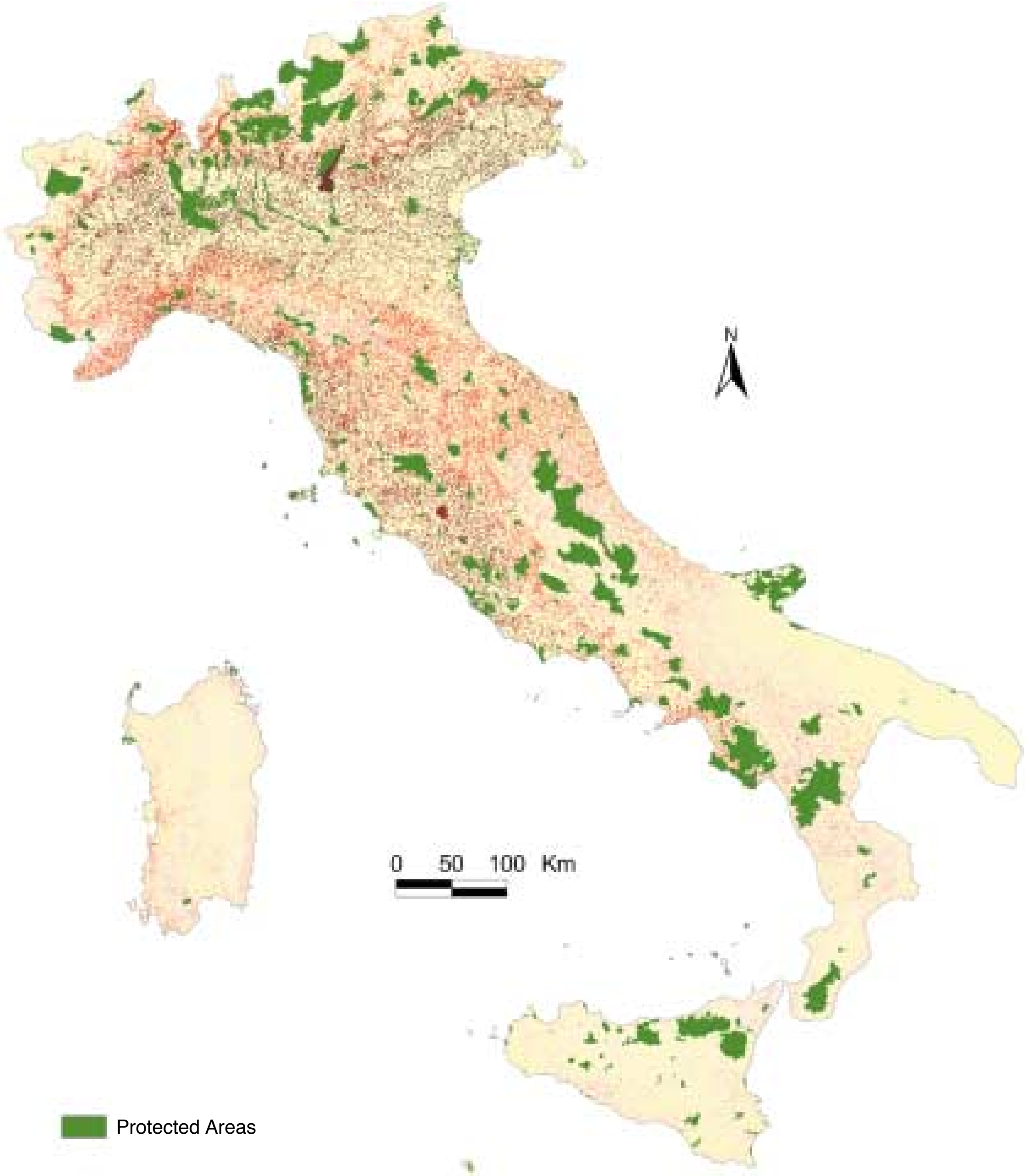


Fig. 30d. Potential number of fish species present in Italy, outside the Protected Areas.

Fig. 30e. Potential number of fish species present in Italy, outside the Protected Areas, SCI and SPA.

5.7 Endangered species

The network of endangered species (149 species) is of critical importance for biodiversity conservation. Special attention should be paid to these species in drawing up the system of PA and the legislation intended to protect them, because their vulnerable state means that fewer options are available in choosing protected areas and corridors between them. For this reason, the analysis of graphs and maps must be still further refined. The pattern of the diversity index of endangered species shows two peaks corresponding to low and average diversity values, together with a less pronounced peak for high diversity values (Figs. 31a, 31b, 31c). This poses a problem with regard to the distribution of the protected areas, not only in the zones with the greatest diversity but also in those with low diversity values, because in the case of endangered species, under national and European legislation, no possible means of conservation can be ignored. The system of PA, both existing and proposed, seems to answer the protection requirement of this group of species relatively well and an interesting synergy can be seen between the role played by National Parks, SCI and SPA on the one hand and that of Regional Parks and reserves on the other: the former are concentrated in the areas of greatest diversity while the latter also cover areas with low diversity indices. Although the general structure of the system appears to be valid, however, an examination of the distribution maps reveals incongruities of considerable magnitude. There is confirmation of the three macro-areas with the highest diversity values where there are still large portions of territory outside the system of PA (Figs. 31d, 31e): the eastern Alps, central and western Liguria, the Apennines of central Italy. In these priority areas, the system of PA must become a more efficient network as far as the biological needs of the endangered species are concerned; corridors between the protected areas must be created and maintained so that the system effectively constitutes a network and not just a collection of protected areas in the most critical places. In Friuli, it is urgently necessary to maintain an efficient link between Slovenia and the Belluno area, and not only at high altitudes. In Liguria, it is the hinterland of Savona and Imperia that deserves particular attention, while in the central Apennines the critical areas are those that are not yet protected, especially the areas north of the Simbruini range in Latium and the corridors in Molise linking the great National Parks to the Regional Parks and reserves located further to the south.

Besides these three macro-areas, we must also mention a few other situations which require immediate intervention in order to strengthen the system and form a network (Figs. 31d, 31e): the link between the Cilento and Vallo di Diano National Park and the Pollino National Park can wait no longer, and the same is true of the completion of the protection of the coastal chain, a factor that is essential for maintaining the vitality of the protected areas of Calabria, from Mount Sila to Aspromonte. Careful observation of this map reveals other situations, too, that could be rectified with a minimum of effort: better protection could be given to the foothills of Lombardia and Piedmont, the lower slopes of the Apennines in Tuscany, the Metalliferous Hills and a few critical fragments in the Gargano, Sicily and Sardinia.

Taking into account the limitations imposed by the type of data utilized with regard to scale, these guidelines seem sufficiently robust to demand careful verification in the field, in order to identify the best operational solutions for conservation, whether by extending and correcting the existing/proposed system or by introducing regulations and laws specifically covering the endangered species.

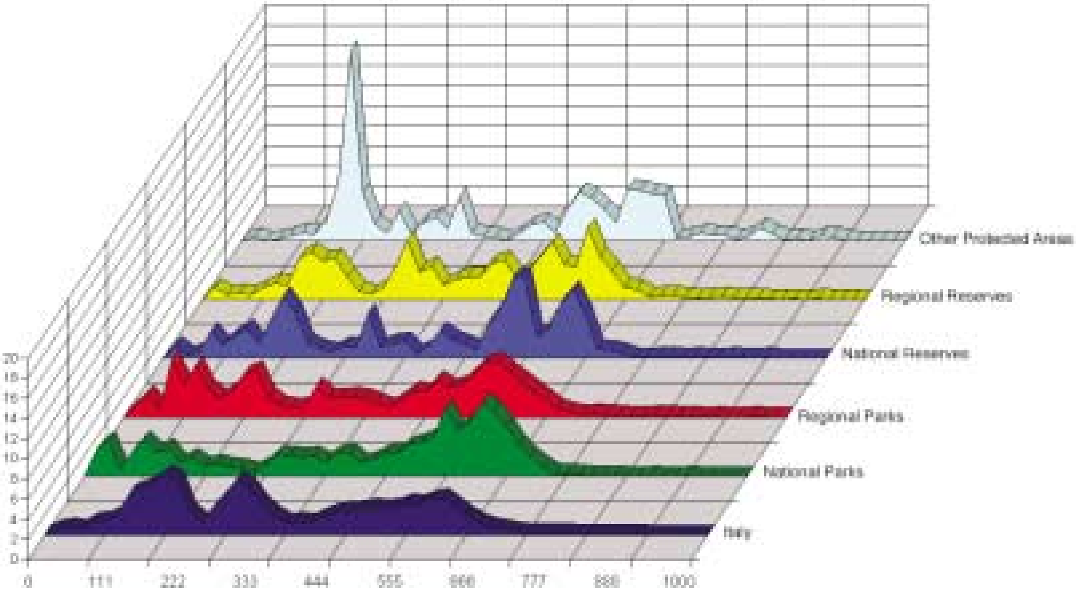


Fig. 31a. Biodiversity Index frequency pattern (see par. 4.5) for endangered species (Bulgarini et al., 1998) in the various types of Protected Areas and in the country.

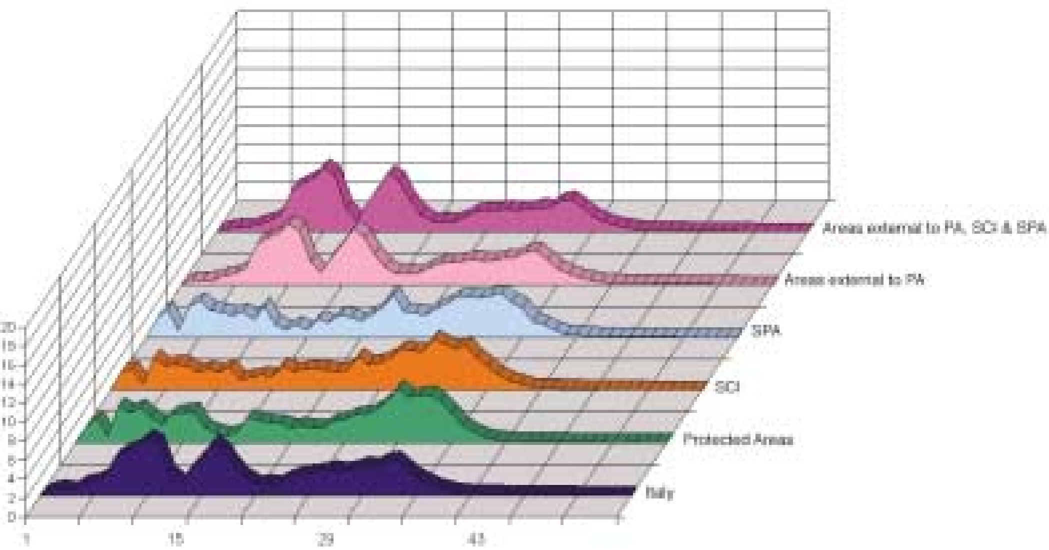


Fig. 31b. Biodiversity Index frequency pattern (see par. 4.5) for endangered species (Bulgarini et al., 1998) in the country, in the Protected Areas, in the SCI, in the SPA, in the areas outside the Protected Areas, and in the areas outside the whole system of SCI, SPA and Protected Areas.

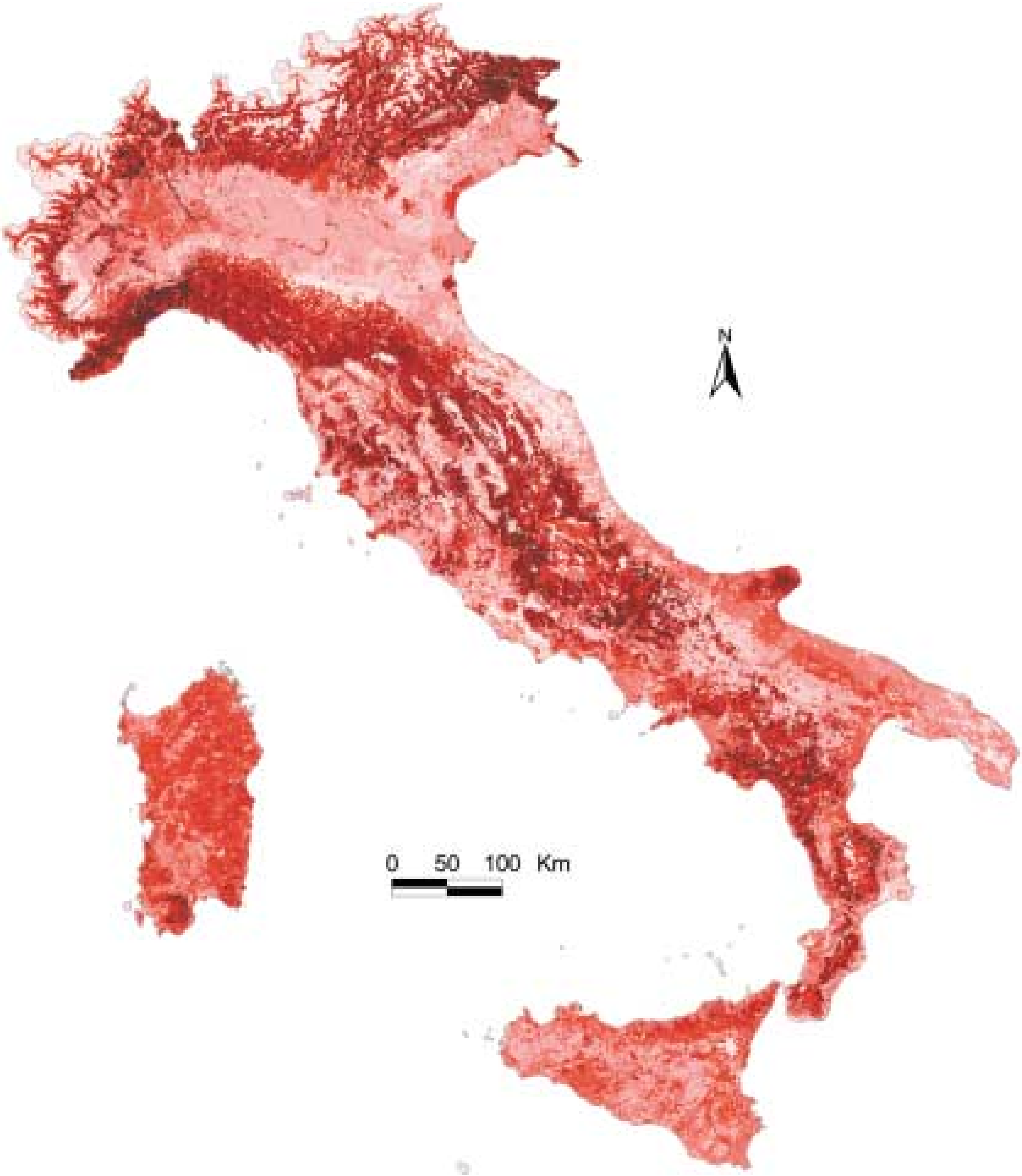


Fig. 31c. Ecological Network of Italian endangered species (Bulgarini et al., 1998) (darker shades of red indicate suitability for a greater number of species, up to a maximum of 54).

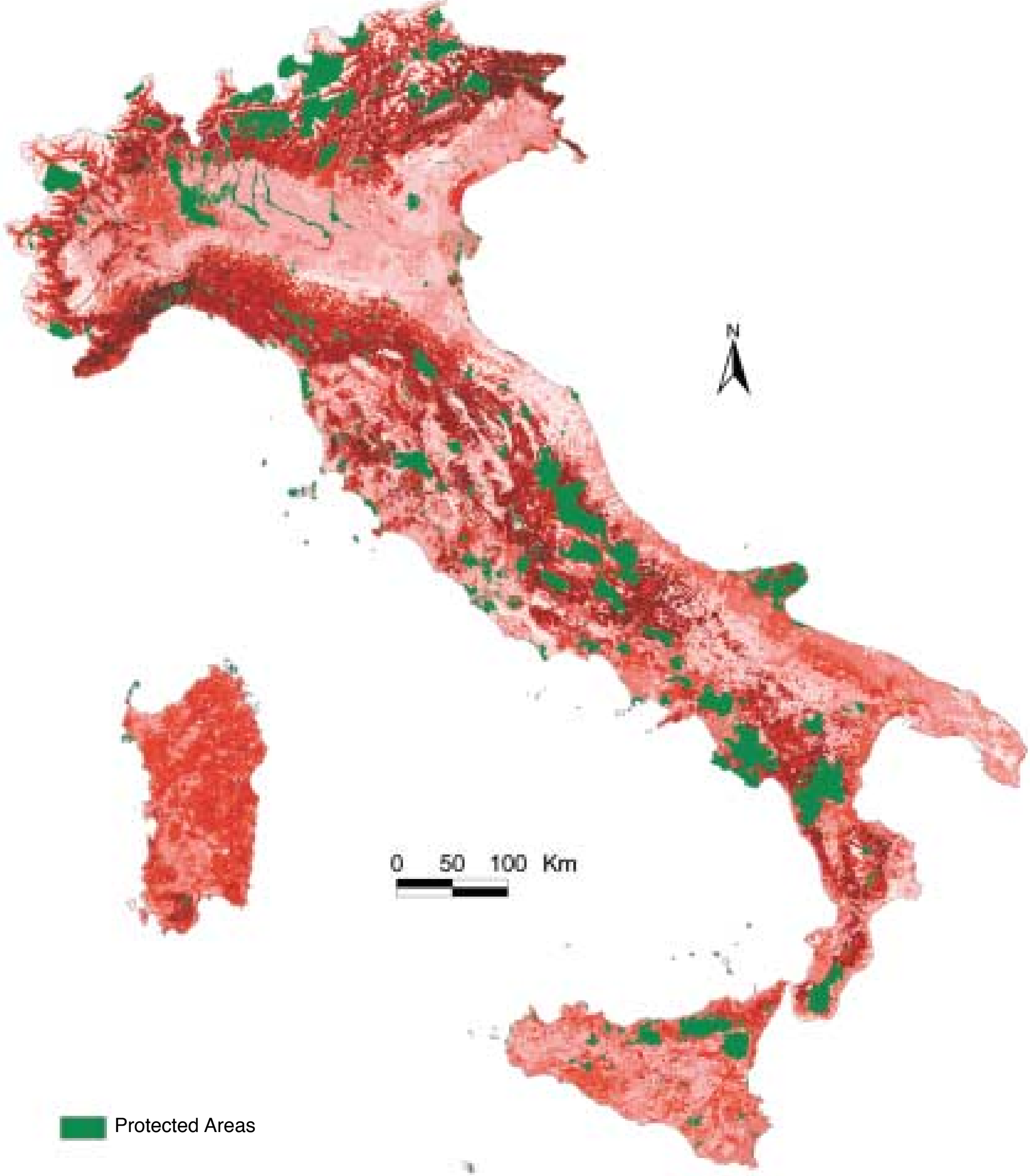


Fig. 31d. Potential number of endangered species (Bulgarini et al., 1998) present in Italy, outside the Protected Areas.

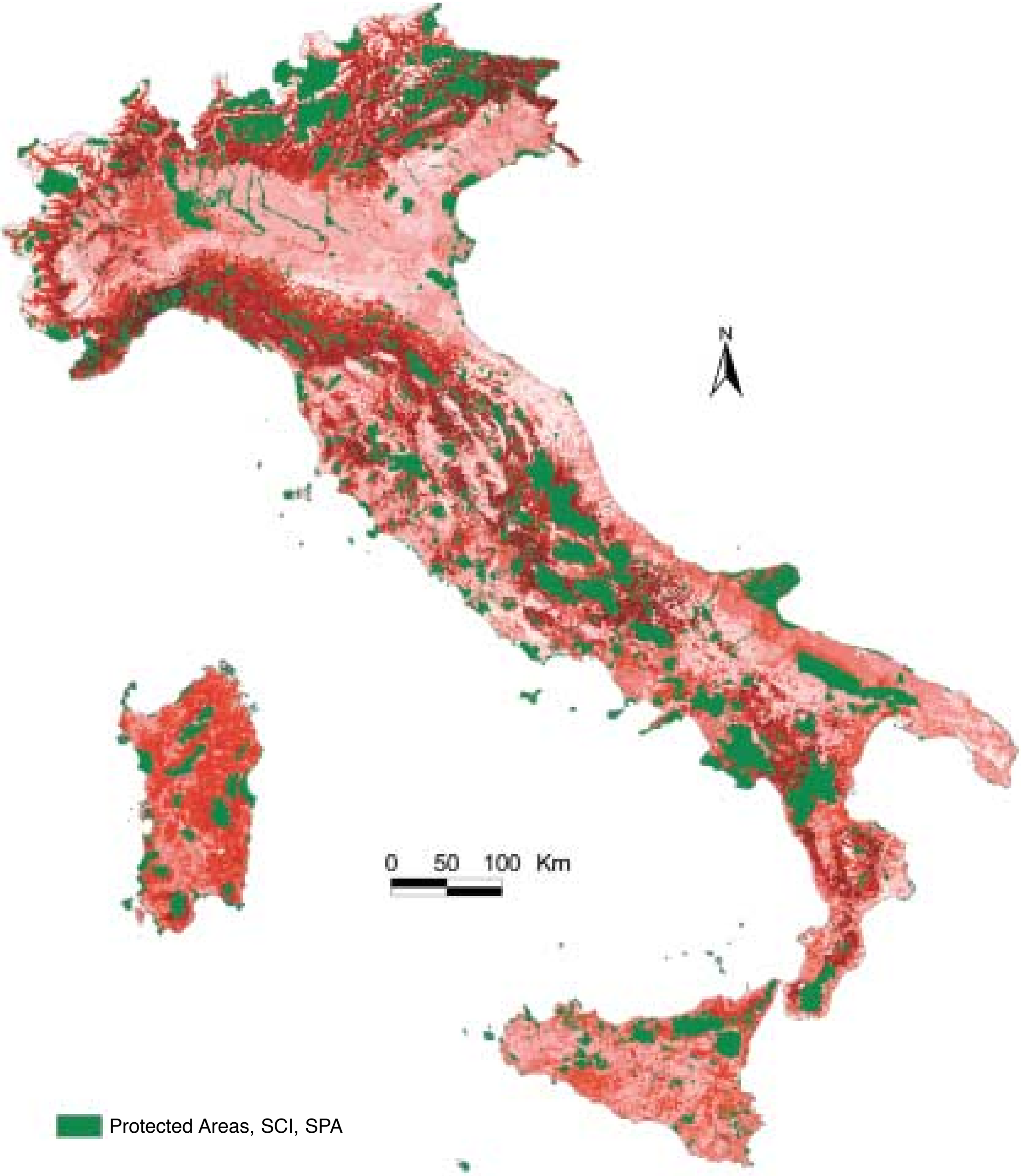


Fig. 31e. Potential number of endangered species (Bulgarini et al., 1998) present in Italy, outside the Protected Areas, SCI and SPA.

6 Congruency analysis of Protected Areas based on irreplaceability

The efficacy of protected areas (PA) for the protection of vertebrate biodiversity has been evaluated in the first part of this work through the examination of the contents of the PA system. In particular, a presence – absence analysis for both species and habitat types inside and outside the protected areas system (see Chapter 4 and 5) has been done. The results obtained are very encouraging and underline the overall importance of the Italian PA system.

More sophisticated techniques have been used in the second part of this work to carry out the same type of analysis. In particular, the first application of the irreplaceability concept to the Italian context has been tested. Irreplaceability is a measure strictly linked to the importance of an area for the conservation of natural resources. In fact, if an area has no substitute or a small number of substitutes in the conservation plan, then it is characterized by high irreplaceability values. Conversely, low irreplaceability values indicate that the area is relatively unimportant for reaching the conservation goal considered for a given region.

In this sense, irreplaceability is the measure given to an area (terrestrial or marine) that reflects the importance of that area in the context of the considered region, and within the limits of the conservation target that have been set. Briefly, the concept of irreplaceability can be explained as the probability that the protection of a given area is classified as necessary in order to reach an established conservation target. This definition gives us the opportunity to use a quantitative approach to conservation, considering the different features that characterize each site (habitat types, suitability for a species, presence or absence of a species).

Pressey and colleagues (1994, 1995) proposed the proportion of all the possible combinations of sites that are able to reach the target and that contain a given site as a measure for the irreplaceability of that site. For example, consider the situation where the PA system is made by selecting a combination of n sites from a total of t sites. The number, C, of possible combinations of n sites that can be drawn is calculated using the formula:

$$C = t! / n!(t-n)!$$

The number C groups all the possible combinations, but only a small sub-group of C meets the needs linked to the conservation target. All the other sites do not meet the conservation target for one or more features. Moreover, for each site x, the possible combinations of sites can be divided into two sets, one groups all the combinations that include the site x while the other groups all the combinations that do not include the site x. According to Pressey et al. (1994), the irreplaceability of a site can be calculated as the ratio between the number of combinations of sites that include site x and the number of all the possible representative combinations.

Further investigations (Pressey et al. 1994, New South Wales National Parks and Wildlife Service, 2001) have suggested different possible improvements of the irreplaceability measures. In fact, the set of combinations that include the site x can be subdivided in two groups: those combinations that would not be any more representative if site x would have been excluded and those combinations that would still be representative even if the site x would have been excluded (i.e. those combinations for which the site x is redundant). A better measure of irreplaceability can then be calculated using the ratio between the number of combinations that contain the site x (and that would not be representative if the site x would have been excluded) and the number of all representative combinations.

However, the above definitions are difficult to be used when calculating the irreplaceability for a regional or national data set because of the exponential nature of the problem: if the number of sites considered increases, the number of possible combinations increases exponentially, rapidly reaching numbers that are impossible to manage even with the fastest and newest supercomputers. For these reasons the irreplaceability values are calculated using a statistical approach, in particular using the methods described in Ferrier et al. (2000).

All the analysis have been done using the software C-Plan 3.20 (New South Wales National Parks and

Wildlife Service, 2001), that, together with a Geographic Information System, allows to map all possible options necessary to reach an established conservation target. All calculations are based on the sites by features matrix, where the rows represent the sites and the columns represent the environmental features. The latter being represented by the habitat suitability models and the distribution ranges for the Italian vertebrates described in Chapter 4. It should be clearly reminded that some species do not have a habitat suitability model and this should be considered when interpreting the results obtained, especially in the case of reptiles, amphibians, and breeding birds. In fact, for these three groups some of the species that have no habitat suitability model are endemic and hold a great conservation value.

In order to calculate the irreplaceability values, C-Plan requires the study area to be divided into planning units (the spatial elements that constitute the basis for all the analysis). Since there is no possibility to design meaningful planning units, the entire national territory has been divided into more than 13,000 square cells (5 km by 5 km) and for each cell the areas occupied by the distribution range of each species and by the highly suitable territory for each species have been calculated. The matrix of data (Tab. V) has been used to estimate the irreplaceability for each planning unit and the results has been imported into ArcGis 8.3 software in order to produce the final maps.

PUID	S473	S448	S478
1	0	299	2.333
2	0	919	498
3	0	532	...
...	...	...	...

Tab. V. Example of matrix of data used for the analysis in C-Plan. PUID indicate the planning units' number, all the following columns indicate the species of vertebrates, and the numbers in the matrix indicate the number of hectares of highly suitable territory in each planning unit.

C-Plan 3.20 is able to calculate irreplaceability values also considering each species of vertebrate with a different weight, calculated according to its degree of vulnerability. Thus, a number of international and national conventions, treaties and laws, together with biological indexes (Tab. VI) have been considered for each species in order to rank all species, according to their degree of vulnerability.

	National Law 157/92 art. 1 (1)	National Law 157/92	EU Birds Directive 79/409/EEC Ann.1	Berne Convention 1979 Ann.2	Berne Convention 1979 Ann.3	Washington Convention (CITES) App. A	Washington Convention (CITES) App. B	Bonn Convention 1979 Ann.1	Bonn Convention 1979 Ann.2	EU Habitats Directive 92/43/EEC Ann.2	EU Habitats Directive 92/43/EEC Ann.4	Barcelona Convention App. 2	Endemic taxon (2)	Intrinsic value (3)	% of population in range (4)	Trend in Italy (5)	Threat category (6)	Species of European Conservation Concern (SPEC) (7)
Mammals	X	X		X	X	X	X		X	X	X		X		X	X	X	
Birds	X	X	X	X	X	X	X	X	X					X			X	X
Reptiles				X	X	X	X			X	X		X		X	X	X	
Amphibians				X	X	X	X			X	X		X		X	X	X	
Fish				X	X	X	X			X	X	X	X		X	X	X	

Tab. VI. List of variables considered for each taxonomic class. (1) Special protected species; (2) According to Bulgarini et al. 1998, Amori et al. 1999, Societas Herpetologica Italiana 1996, Gandolfi et al. 1991; (3) According to Brichetti & Gariboldi 1997; (4) According to Bulgarini et al. 1998; (5) According to Bulgarini et al. 1998; (6) According to IUCN 2001, Amori et al. 1999, Bulgarini et al. 1998; (7) According to Tucker & Heath 1994.

The international and national conventions, treaties and laws have been considered all together to give each species a score scaled between 0 and 100 depending on the number of conventions in which the species has been listed. The points deriving from the conventions have been summed to all the other values and the final values have been scaled between 0 and 100. The ranking resulting from these operations seems to satisfactorily reflect the conservation values of each species. In fact, species like *Pelobates fuscus, Euproctus platycephalus, Podarcis wagleriana, Vipera ursinii, Aythya nyroca, Cervus elaphus corsicanus, Lampetra zanandreai, Rupicapra pyrenaica ornata* resulted having the highest values, and species like *Sylvilagus floridanus, Mustela vison, Anguilla anguilla* and *Cyprinus carpio* having the lowest values. Obviously, some species appear to rank with a value higher or lower than expected. This is the case of the wild boar (*Sus scrofa*) that occupy a position in the central lower part of the ranking because, even though it is considered a pest in Italy and the number of animals is extremely high, there is the possibility of an endemic subspecies still surviving in some areas of the Italian peninsula. The same kind of considerations can be done for species like the wolf (*Canis lupus*) and the peregrine falcon (*Falco peregrinus*) that have a very high position in the ranking; these two species have seen a great increase in their number in the last ten years for many different reasons, but all the international and national conventions/laws have not been updated, thus both species are still considered very endangered. Conversely, species like *Lepus corsicanus* was re-discovered only very recently and so is not considered in many conservation treaties or in the IUCN red list. This made that such species occupies a low position in the ranking.

The list created in this way has been split into five groups, each group containing 20 points: the first group going from 81 to 100, the second from 61 to 80, the third from 41 to 60, the fourth from 21 to 40, and the fifth all the remaining values. Each of the five groups correspond to a vulnerability degree, with the first group (species with point between 100 and 81) being the most endangered, and the fifth group (species with point between 0 and 20) being the least endangered. The number of groups to consider has been chosen according to the specifications of the software C-Plan, which is not able to manage more than 5 vulnerability groups.

One of the most important elements for the analysis is the conservation target that is used by C-Plan to calculate the irreplaceability index. The conservation target can be seen as the result that should be obtained for a given region and it can be established following many different criteria. In particular, it is possible to establish a single target for all the elements considered in the analysis (the species of vertebrates) or a different target for each feature (New South Wales National Parks and Wildlife Service, 2001). The first hypothesis (a fixed target for all species) has been chosen in this project, because the intent of the analyses is to depict a general vision for the Italian situation. Moreover, there is no possibility with the current knowledge of the Italian fauna to establish a biologically meaningful conservation target for each species. The general conservation target has been set at 20% of the highly suitable habitat or of the distribution range for each species, because 20% of the Italian territory is currently interested by existing or proposed protected areas (see Chapters 2 and 3).

All analyses previously described have been carried out also considering the already existing protected areas. C-Plan is able to consider the existence of protected areas in the analysis and in this way it is possible to identify all the areas that are not protected but should be so in the future possible scenarios. To carry out this type of analysis a planning unit has been considered as protected only if at least 50% of its area is covered by protected areas.

All analyses considered have been carried out for all the vertebrates together and for the single taxonomic groups (mammals, birds, reptiles and amphibians, freshwater fish). The values of irreplaceability have been subdivided into 5 classes in order to facilitate the visualization and the interpretation of the maps. In particular, the irreplaceability values have been standardized (the mean has been subtracted from each value and the difference has been divided by the standard deviation); in this way each irreplaceability value has been transformed in a negative number (if the original value is less than the mean) or a positive number (if the original value is greater than the mean) that give a measure of the difference (in standard deviation units) among each value and the mean value. The classes used in the maps show an important division: the first class (in yellow) has all values smaller or equal to 0 (that is all the values smaller than the mean), while the four subsequent classes (shaded in red hues) have the values among 0 and 1 (irreplaceability values greater than the mean and smaller than the mean plus one standard deviation), among 1 and 2 (irreplaceability values greater than the mean plus one standard deviation and smaller than the mean plus two standard deviations), among 2 and 3 (irreplaceability values greater than the mean plus 2 standard deviations and smaller than the mean plus three standard deviations), and greater than 3 (irreplaceability values greater than the mean plus three standard deviations). In this way it is possible to clearly show on a map the planning units that more than others are important for the conservation of the vertebrates.

6.1 All species of vertebrates

Figure 32a (that consider the distribution range for all the vertebrates) shows the most important areas for the Italian vertebrates. The eastern Alps are one of the most interesting locations in the entire Italian peninsula, and extremely important are also some areas of the Padana plain, the Apennines, the Apulia region and Sardinia. This map, however should be considered carefully, since it is greatly influenced by the birds (that constitute great part of the species) and by some other species of the different groups (like some amphibians in Sardinia, some bats in the Padana plain and some freshwater fish in relation to some lakes). Moreover, Fig. 32a presents the results obtained considering the distribution range of the species of vertebrates, and so it is probably influenced by the low precision that characterize some of these ranges. The picture outlined with this analysis is very different from that built using just the number of species, in particular in correspondence to the Apennines, which is considered as no important even if it hosts a great number of species.

The situation outlined in Fig. 32b is completely different. In this case the analyses have been done considering the habitat suitability models for all the vertebrates. The results are much more detailed, and the areas considered as important have a spatial distribution that seems to be much more meaningful from a landscape point of view. Also in this case the eastern Alps can be considered as one of the most important areas for the Italian vertebrates, but in this map also the Apennines, as should be expected considering the high number of species present in the area, play an important role for biodiversity conservation. Conversely, many areas in the plains have much less importance as compared with the Fig. 32a. Some of the differences among the two maps can be explained because there is not a habitat suitability model for some high ranked species of vertebrates (like *Larus audouinii*, or *Speleomantes* spp.), but by far the most important difference is the fact that the distribution range includes many areas where the species are not really present (because those area are not suitable for the species considered), while the habitat suitability models represent a much more detailed sketch of the species actual or potential distribution.

Figure 32c shows an interesting result of the analysis carried out for all the vertebrates and also considering the presence of protected areas. In this case, the map outlines which areas still outside the existing protected areas system should be considered with greater attention. Even taking into account the limitations of an analysis that considers just the distribution ranges of the species, the result underlines the importance of Sardinia (that lacks of protected areas for great part of its territory) and also of many areas of the eastern Alps without any protection, and in many cases completely uncovered also by SCI and SPA.

Figure 32d (obtained from habitat suitability models for all vertebrates, and considering also the existing protected areas) is almost the same as Fig. 32c, even if some areas are classified differently and the most important areas are much more fragmented then those in Fig. 32c. However, once more it has been underlined the importance of the eastern Alps and of Sardinia.

Alpine Marmot *(Marmota marmota)*

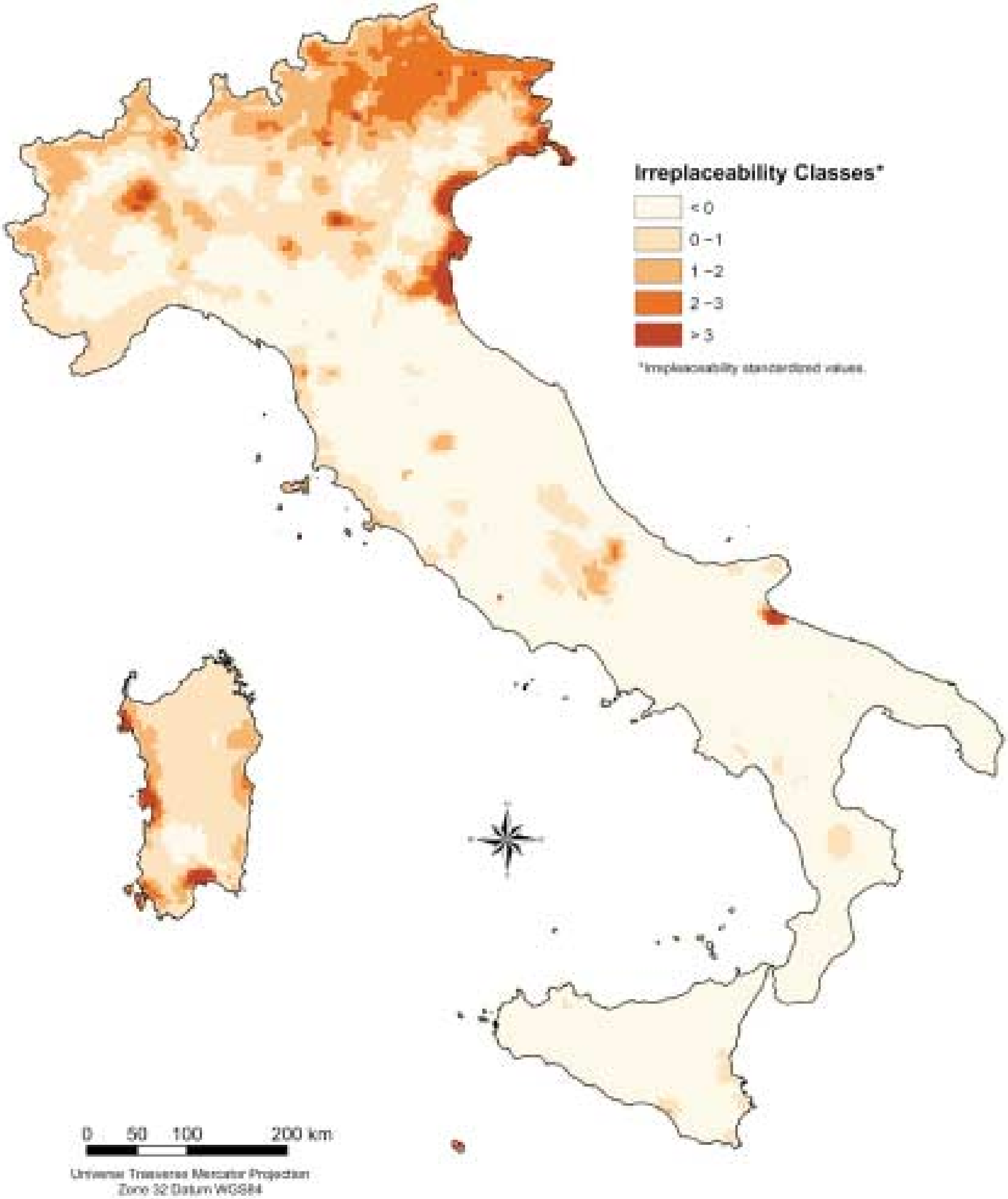


Fig. 32a. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all the Italian vertebrates.

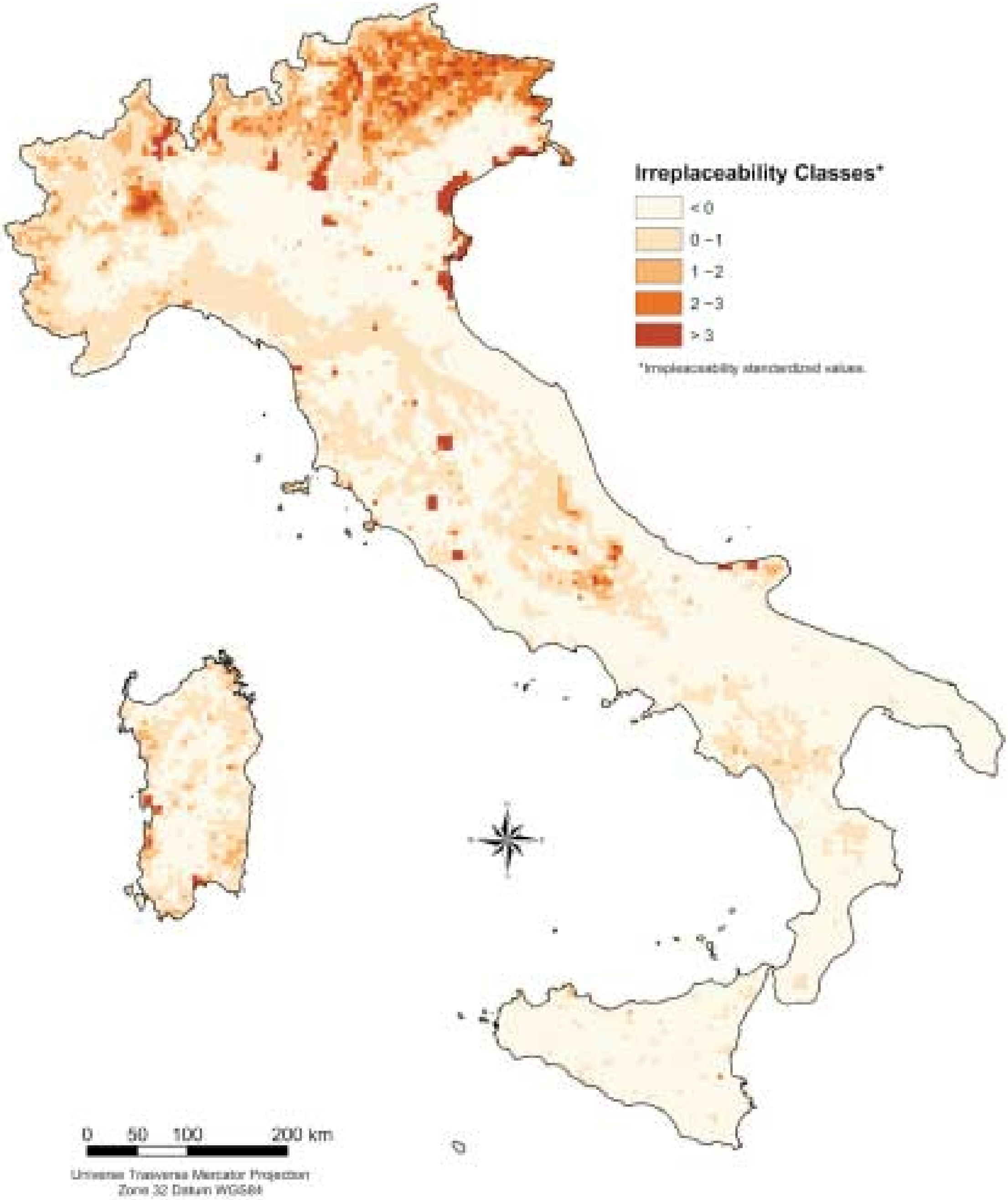


Fig. 32b. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all the Italian vertebrates.

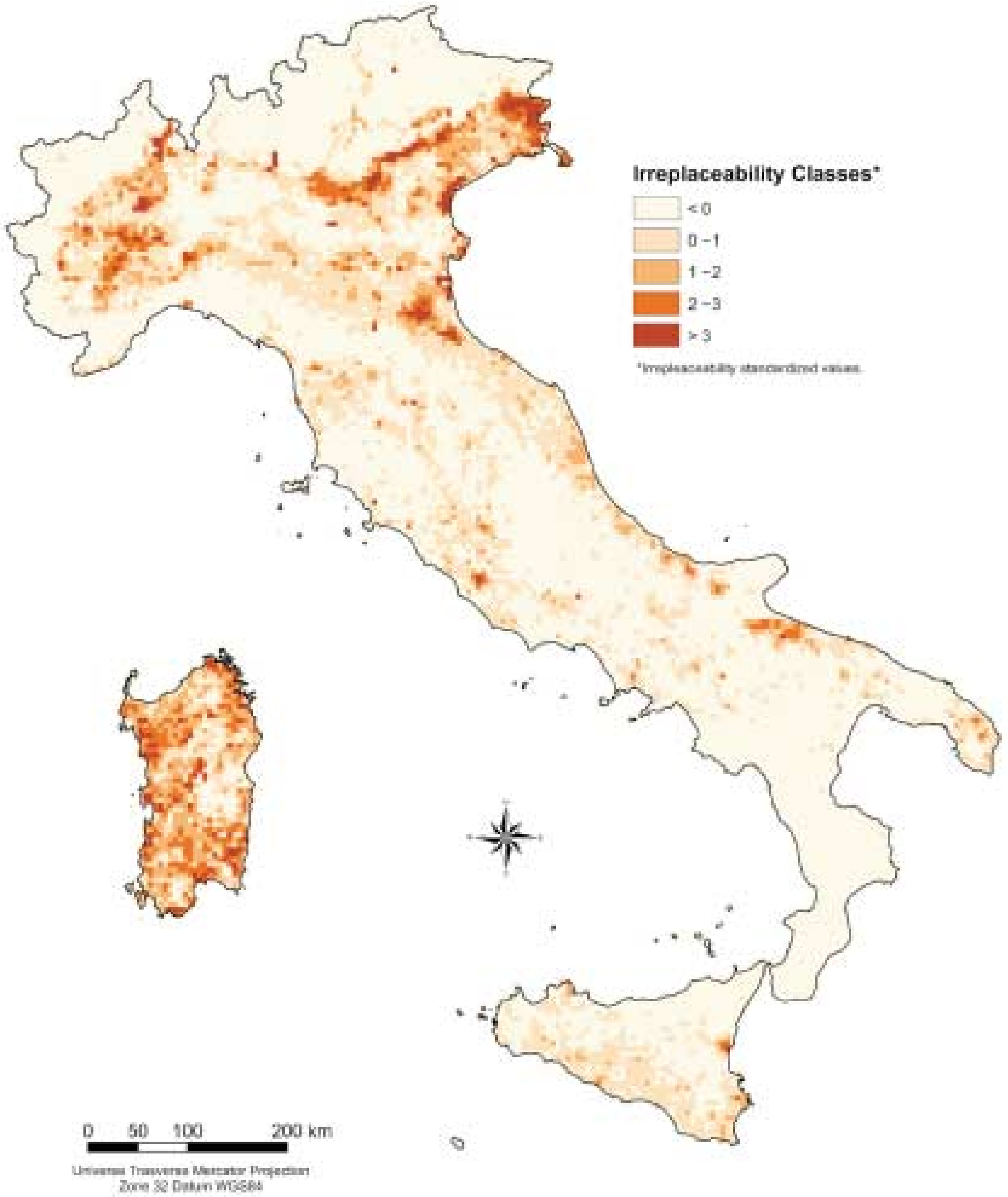


Fig. 32c. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all the Italian vertebrates and considering the existing Protected Areas.

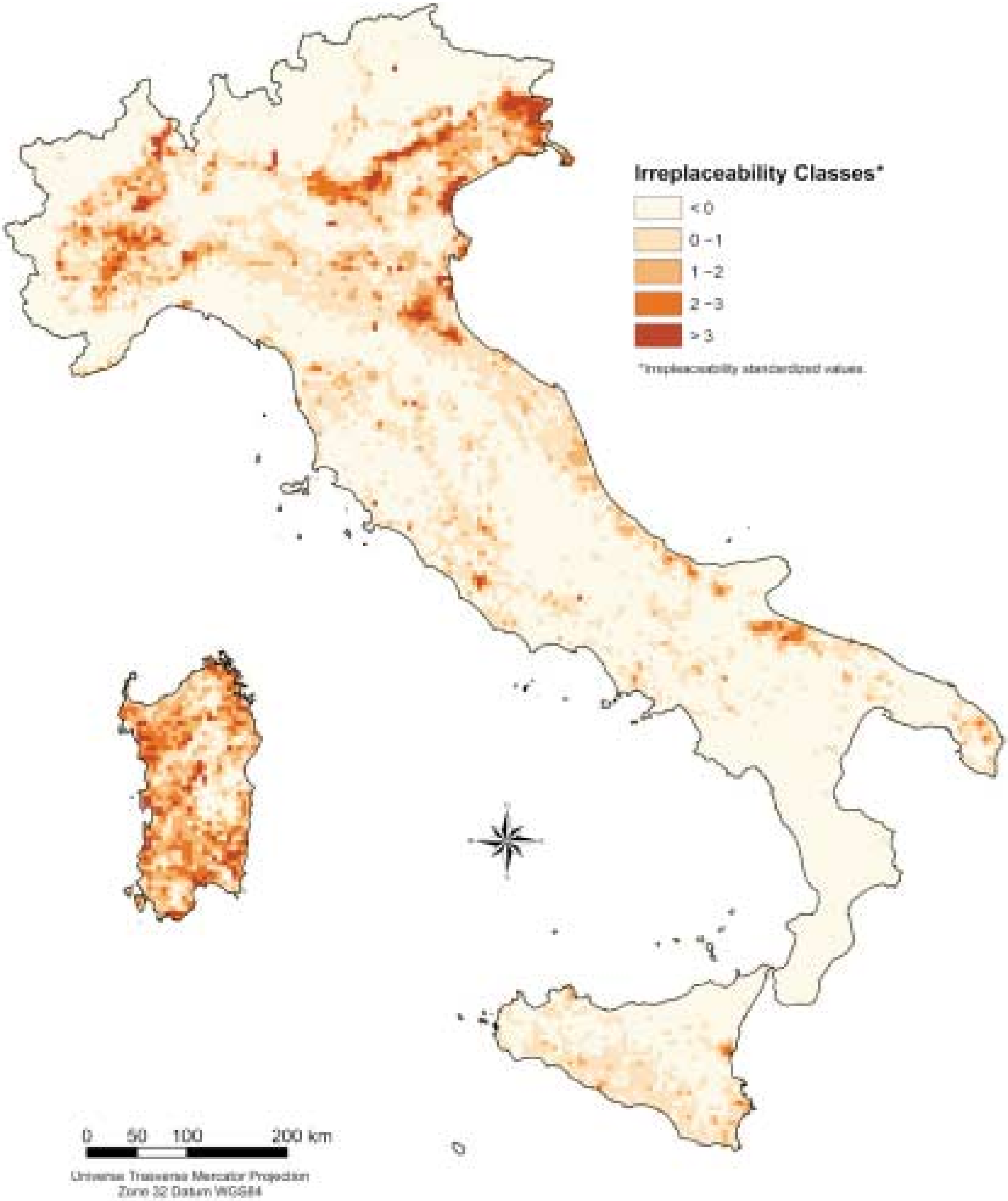


Fig. 32d. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all the Italian vertebrates and considering the existing Protected Areas.

6.2 Mammals

Mammals are probably the second best known group of Italian vertebrates after birds. In particular, the species-habitat relationships used to build their habitat suitability models are quite accurate, and the data used to build their models are particularly suited to describe mammal distribution. For this reason the results obtained for the mammals are probably of great utility.

Figure 33a provides a first cut of the conservation status of the Italian mammals (analysis carried out using the distribution ranges of mammals). In this case the most important areas are localized in correspondence to the eastern Alps. Particularly important is the boundary area among Italy, Austria and Slovenia (corresponding at least in part with the areas of presence of the bear) that is not covered by any existing protected areas, and is covered only for a very small portion by SCI. Also in the eastern Alps there are many other important areas, and most of them are not covered by any protected area. The situation improves greatly considering also the SCI that cover with greater efficacy some of the areas classified as important by the analysis. In the western alpine range, the situation is slightly different, since there are a few protected areas that effectively cover important areas. Once more, some of the SCI (especially in Piedmont) seem to be extremely important, since they cover areas important for the Italian mammals, but with no protection. The Apennine range has been classified as relatively important, with areas, like Mount Amiata and the Abruzzi mountains, of great interest and relatively well covered by the existing PA system (at least in Abruzzi). Quite different is the situation in Sardinia, where the areas important for the mammals (in the southern part of the island) are not covered by any protected areas (except for the small Reserve of Monte Arcosu), either existing or proposed.

Figure 33b depicts a general sketch for the conservation of Italian mammals using the habitat suitability models. The eastern Alps are still among the most important areas in the whole peninsula, but the areas of greatest importance are much more restricted. Again, in this case nor PA cover the most important areas for the eastern Alps, neither SCI and SPA are located accordingly to the important areas. Conversely, for the Apennines the situation outlined by Fig. 33b is completely different from that of Fig. 33a. In fact, Fig. 33b outlines that almost all Apennines are important for the Italian mammals, especially in the central and northern part of the chain, but also in the southern part as well as in some areas of Sicily. In Sardinia the eastern part of the island is classified as important (contrary to what outlined by the analysis done using just the distribution range), and once more the existing protected areas do not cover almost any important area. In this case SCI are of great importance because they cover great part of the gaps in the protected areas system

Hedgehog *(Erinaceus europaeus)*

of the region. Moreover, Fig. 33b outlines the importance of some planes, especially in Sicily, Apulia and in the Padana plain, especially for micro-mammals like *Neomys fodiensis, Suncus etruscus, Crocidura sicula, Lepus europaeus* and other rodents.

The map presented in Fig. 33c shows the results obtained considering not only the distribution range of the Italian mammals, but also the already existing protected areas. The first important consideration is that the distribution ranges for the mammals are quite general and are not able to depict a particularly meaningful picture in this analysis. However, it is possible to note that Sardinia is by far the most important part of Italy still outside the protected areas system.

The situation outlined in Fig. 33d is completely different. In this case the analysis considers the presence of the protected areas already existing and the habitat suitability models for the mammals. The detail of the map is much greater and also the areas considered as important change in extent and location. In this picture the important areas outside the protected areas systems are located in correspondence to the plains, to the medium altitude mountains, and in Sardinia, where virtually no PA exist.

Brown Bear (Ursus arctos)

Fig. 33a. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian mammals.

Fig. 33b. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian mammals.

Fig. 33c. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian mammals and considering the existing Protected Areas.

Fig. 33d. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian mammals and considering the existing Protected Areas.

6.3 Birds

Birds are with no doubt the most best group of vertebrates in Italy, thus the results obtained should be considered extremely useful. The high number of species considered, and their great diversity of ecological niches, make them one of the most interesting groups to analyze.

Figure 34a shows the results obtained using the distribution ranges for the Italian breeding birds. Among the important areas there are the eastern Alps, the Apennines, and the Tyrrhenian coast, that were considered important also for the mammals. The analysis gives particularly great importance to the lagoons (e.g., in Apulia, in the Padana plain, and in Sardinia) and to some lakes. In general, the PA system covers quite well all the areas important for the breeding birds, but in some cases, like in Sardinia, there is no protected area at all covering the most important areas.

Figure 34b (built upon the breeding bird habitat suitability models) depicts quite a different situation. The spatial structure of the important areas is the same as in Fig. 34a but their number and spatial extent change. The importance of eastern Alps is once more confirmed, even if the important areas are now much more localized and fragmented. Also, in the Apennines the number and the extent of the areas considered important is lower than in Fig. 34a, but the most significant change among the two maps is that some of the lagoons are not considered important any more, probably because they are so small that cannot be detected in the habitat suitability models. It is important to outline also that some of the most important areas for the Italian breeding birds are not covered by existing protected areas, but this gap is mostly covered by SCI and SPA.

Figure 34c shows the results obtained considering the distribution range of the breeding birds and the existing protected areas. It is extremely clear that the most important areas outside the protected area systems are mostly plains, both in northern and southern Italy. In fact, almost no Italian PA is located in flat areas, although many of them are extremely important for aquatic birds. Sardinia is indicated as probably the most important Italian region in this map , even if its territory is almost unprotected. It should be noted that most of the areas outlined as important in this picture are covered by SCI and SPA, which are well located to cover to bird biodiversity.

Figure 34d shows the same general picture as Fig. 34c, but the details are different. In particular, the Padana plain has less important areas, while central and southern Italy, and the two largest islands (Sicily and Sardinia) are considered of great importance. It is important to underline that some of these areas are not covered by any proposed protected areas, especially in northern Apulia.

Scops Owl *(Otus scops)*

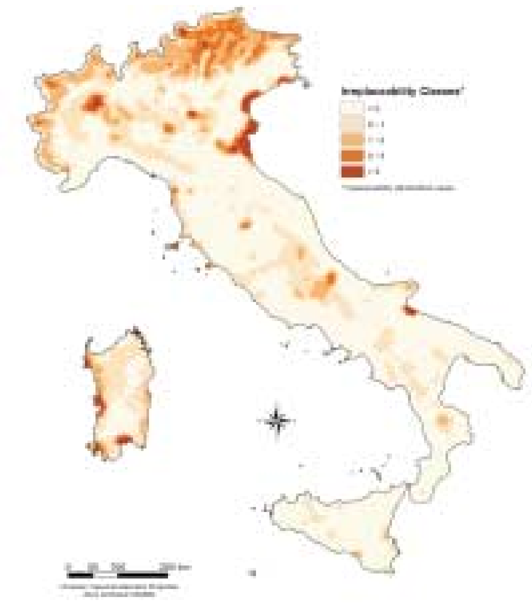


Fig. 34a. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian breeding birds.

Fig. 34b. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian breeding birds.

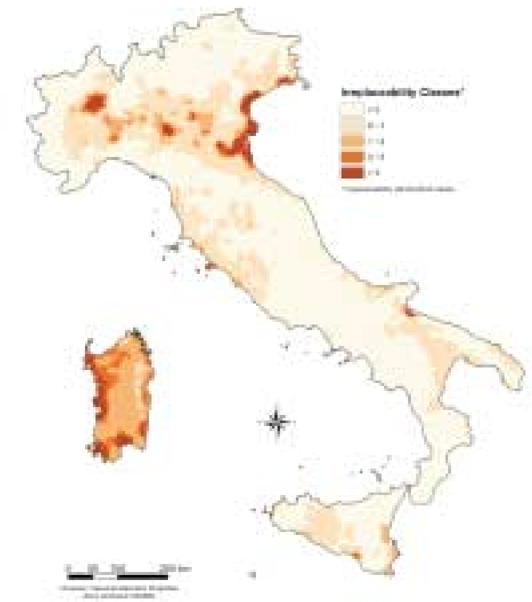


Fig. 34c. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian breeding birds and considering the existing Protected Areas.

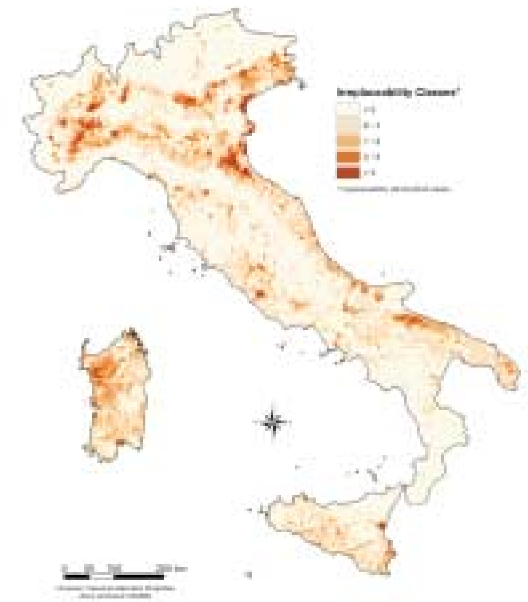


Fig. 34d. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian breeding birds and considering the existing Protected Areas.

6.4 Reptiles and Amphibians

Information on reptiles and amphibians is often limited, especially concerning their distribution. At the same time, many species of these two groups are endangered and/or endemic of some part of the Italian peninsula. This implies that the results obtained on these groups should be considered with great attention and that further investigations on their ecology and distribution should be considered before giving any conclusive statement.

Figure 35a depicts the results obtained from the analysis of the distribution ranges. The situation outlined by the map is unclear because of the coarseness of the distribution maps considered. The only consideration that can be done is that Sardinia, Liguria and the most eastern part of Friuli are the most important areas for Italian reptiles and amphibians.

Quite different is the situation outlined by Fig. 35b that shows the results obtained from the habitat suitability models for amphibians and reptiles. The differences existing between the results obtained from the distribution ranges and those obtained from the habitat suitability models are greater than those of any other group. In fact, Fig 35b shows a much greater detail than Fig. 35a, and also the spatial distribution of the important areas is different. The importance of Sardinia, Liguria and eastern Friuli is confirmed once more, but also many areas in the Apennine chain are classified as fundamental for amphibians and reptiles.

The results shown in Figs. 35c and 35d (from analysis that consider the presence of protected areas) simply confirm what has been noted above: the results obtained from the distribution ranges (Fig. 35c) cannot be considered really meaningful (at least for a detailed interpretation) because of the lack of information, but once more the importance of Sardinia, Liguria and eastern Friuli should be underlined. On the other hand, the results obtained from the habitat suitability models (Fig. 35d) offer a much better vision of both the general picture and of the details, but the main conclusion is still that Sardinia should be urgently considered in the conservation areas of Italy.

Western Whip Snake *(Coluber viridiflavus)*

Spectacled Salamander (Salamandrina terdigitata)

Fig. 35a. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian reptiles and amphibians.

Fig. 35b. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian reptiles and amphibians.

Fig. 35c. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian reptiles and amphibians and considering the existing Protected Areas.

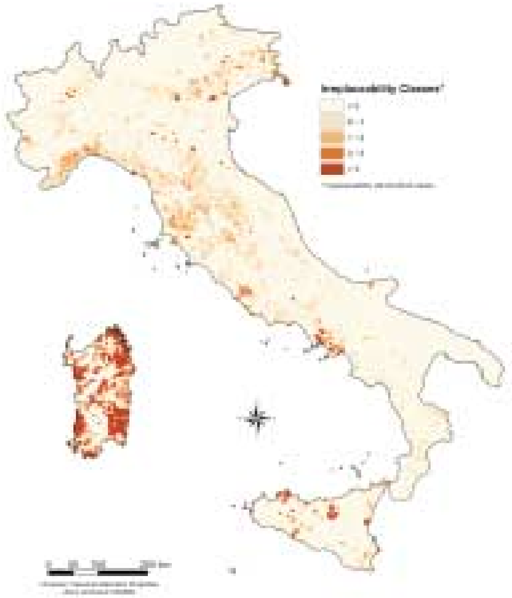


Fig. 35d. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian reptiles and amphibians and considering the existing Protected Areas.

6.5 Fish

Freshwater fish suffer the same limitations (lack of knowledge, in this case also taxonomically) of amphibians and reptiles, with the further limitation that correctly representing the distribution range of a fish is really difficult, as well as to build a habitat suitability model for this group of vertebrates. Thus, any conclusion that could be drawn from the analysis presented in this paragraph should be considered with great caution.

Figure 36a presents the results of the analysis carried out using the distribution ranges. The map does not allow any really useful interpretation. The only consideration (quite obvious) is that the most important areas for fishes in Italy are the Padana plain and some other catchments in northern and central Italy. Southern Italy, together with Sicily and Sardinia, has no importance for fishes, as should be expected considering the scarcity of water bodies in those areas.

Figure 36b (results obtained using habitat suitability models) shows quite a different view. In particular the Adriatic region is now considered much more important, while the detail and the spatial structure of the important areas in the Padana plain are much more interesting. Furthermore, the Alps, Sicily, Sardinia and southern Italy, seem to have no importance for freshwater fishes.

It is quite interesting to note that Fig. 36c (that shows the results obtained from protected areas and distribution ranges) is extremely similar to Fig. 36a; and Fig. 36d (results obtained from protected areas and habitat suitability models) is similar to Fig. 36b. This indicates that the protected areas in the Italian peninsula do not adeguately cover at all freshwater fish biodiversity.

Fig. 36a. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian freshwater fish.

Fig. 36b. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian freshwater fish.

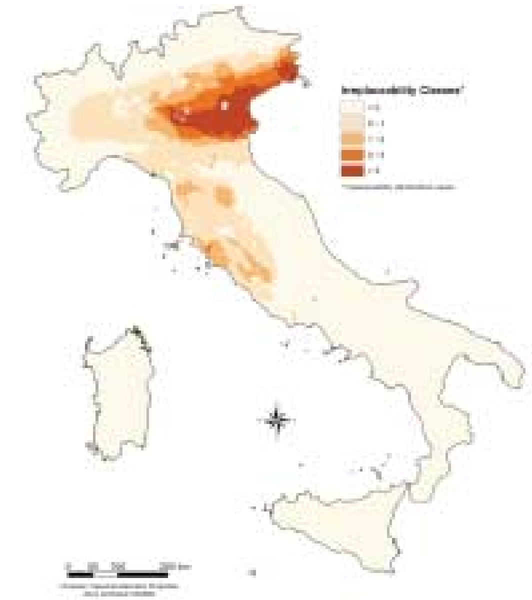


Fig. 36c. Distribution of the irreplaceability values in Italy. Values calculated using the distribution ranges of all Italian freshwater fish and considering the existing Protected Areas.

Fig. 36d. Distribution of the irreplaceability values in Italy. Values calculated using the habitat suitability models for all Italian freshwater fish and considering the existing Protected Areas.

7 Conclusions

The overall consideration of the analyses is that the results are of great interest for the conservation of vertebrates and Italian nature in general.

1) The method used to define the distribution models made it possible to base the global analyses of the ecological network on premises that are sound and objective. The species-specific models were constructed using explicit, transparent methodological procedures, which can be reiterated in the future with ever better data sets provided by more accurate field research. It should be underlined, once again, that one of the chief advantages of using models such as those proposed is that the results obtained are never, even in the worst hypothesis, inferior to those of the classic distribution ranges and, if all goes well, can substantially improve our knowledge of the distribution of species. Furthermore, model validation, mostly with positive results, has made it possible to lay a solid, reliable foundation for the conceptual constructions created in drawing up the modelling process and in assessing the system of protected areas.

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2) For the first time in Italy, we now have a single database, covering all species of Italian vertebrates, which gives a few items of basic ecological information for each, together with ranges and distribution models: the collection, organization and standardization of the data in digital form has resulted in a tool of great importance, not only for ecologists but also for administrative bodies, at both central and local levels. All the data are immediately utilizable in the IT systems most commonly used by national, regional and provincial administrations, and can be processed more extensively and in greater detail according to the planning needs of each institution.

3) For many species, the map of inhabited areas resulting from the models shows worrying fragmentation of suitable habitats and the existence of vast unsuitable areas, which greatly reduce or prevent the continuity of the various components of the metapopulations. The brief comments given for each species constitute a starting point for more detailed analyses aimed at obtaining results that can be directly utilized in strategies and action plans targeting the species of greatest interest for the purposes of conservation.

4) The concept of an ecological network as a dynamic entity and as a reference for calibrating individual studies and plans for geographic areas, groups of species or protected areas has found confirmation and support in the analyses. The study illustrates, both graphically and numerically, the irregular pattern of diversity for Italian vertebrates throughout the country, identifying the areas with the greatest richness, both for all species taken together and for individual taxa.

5) The clear-cut characterization of Apennine Park of Europe (APE) as a key factor for the conservation of a large number of species represents an objective confirmation of the role played by the Apennines as a great ecological corridor running through the peninsula and of the ministerial programme aimed at giving priority to this large area and ensuring unified intervention.

6) The fracture of environmental continuity in the band of territory between the provinces of Matese and Benevento has been clearly confirmed, as has the critical importance of many areas of the pre-Alps and Apennine spurs. On the whole, the greatest diversity is to be found in the north-eastern Alps and the northern Apennines, but there are also areas of enormous interest spread over the central and southern parts of the country and in the great wetlands.

7) A proper analysis of how the various species or groups of species help to define these areas can provide information that will prove very useful in managing the protected areas and the connecting corridors, making a valuable contribution towards the concrete creation of the various components of the ecological network (core areas, corridors, buffer zones), which can be planned according to a dynamic, unified overview of the national network but must then be created at a local level.

8) Our analyses show the pattern of biodiversity values for Italian vertebrates as a process of continuous, fertile irradiation from the mountains to the plains; the Alps and Apennines represent a non-metaphoric backbone which alone sustains much of the biodiversity of vertebrates. From the point of view of fauna management, this observation means two things: conservation efforts must be concentrated on the mountainous areas and more attention must be paid to building and managing the lines of irradiation from the mountain heights towards the plains.

9) The comparative analysis of the networks has also led to the interesting result of showing that the network of a few taxonomic groups or, better still, the network of endangered species, is a good surrogate for the global network of species. In this context, the network of endangered species could be used as an indicator for the global network, helping to focus attention on top-priority species without losing sight of the overall picture of vertebrate biodiversity.

10) The system of existing protected areas in Italy represents the various environmental categories (CORINE Land Cover) and the various elevation belts in a very irregular fashion, leaving important components of Italian environmental diversity, such as hilly areas and foothills, with little or no protection.

11) Over the last 20 years, the system of protected areas has seen exceptional growth in the area covered; in order to conserve biodiversity, it now needs to be consolidated within the perspective of a system integrated into the surrounding territorial matrix. To this end, it is urgently necessary to do various things: a) to analyse the contribution made by each area to the effectiveness of the whole system, b) to extend the analyses to include consideration of the spatial patterns of the animal populations, so as to go beyond the simple paradigm of the presence/absence of a species and to tackle the more complex theme of the temporal and spatial patterns of the metapopulations, c) to ascertain and ensure effective links between different areas, especially in the macro-areas that are most critical for endangered species.

12) By identifying the high-diversity zones that are excluded from the current system of protected areas it

Abruzzi Chamois *(Rupicapra pyrenaica ornata)*

is possible to plan an assessment of the entire system and if necessary its reorganization, so as to optimise its effectiveness, especially bearing in mind the final stages of approval of the SCI system. In particular, the SCI should preferably be utilized for two functions that are critical in the context of the ecological network: a) as corridors between the largest protected areas, or between these and zones with lower diversity (e.g. between mountains and plains), b) as buffer zones surrounding protected areas.

13) Many important areas (as outlined by the irreplaceability analysis) are not covered by the existing protected areas or by the SCI and ZPS system. This implies that the system should be revised for some areas like the eastern Alps or part of Sardinia, in order to consider the ecological necessities of particular species.

14) It should be remembered that all the analysis carried on during the project consider many species in order to give a general picture of the Italian situation. However some species (e.g. endangered wildfowl)

require a particular protection and should be considered singularly.

The above analyses therefore seem to give the National Ecological Network a strong foundation, with regard to both method and content, as a tool for planning and implementing a combination of initiatives in the political, economic, social and territorial spheres, aimed at a type of development that is compatible with biodiversity conservation; this scientific basis constitutes an excellent framework for renewed efforts to develop the protected areas policy into a territorial strategy that also includes the surrounding matrix. We hope that the present study can represent a useful contribution towards its creation.

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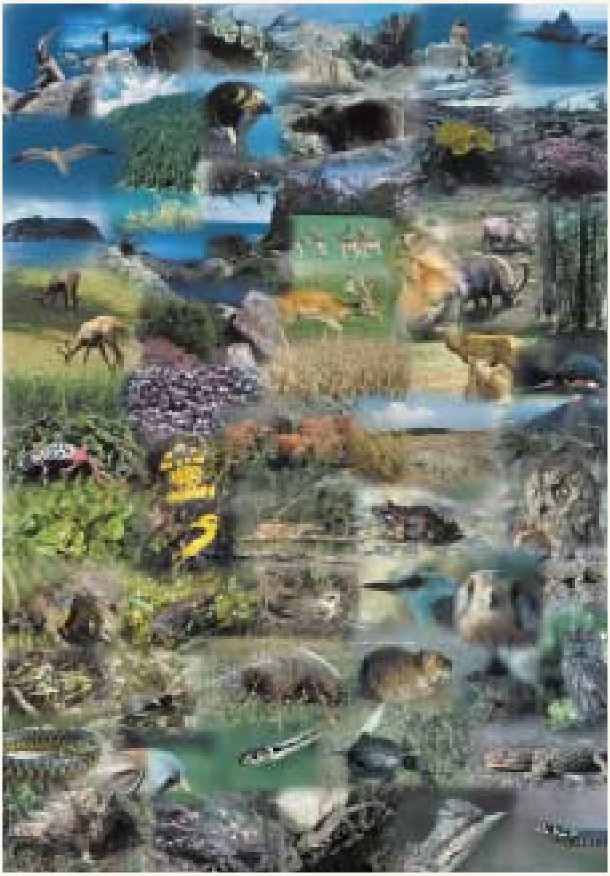

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