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A gap analysis comparing Natura 2000 vs National Protected Area network with potential natural vegetation

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Abstract: We performed a gap analysis of protected area networks in Italy to assess the representativeness of potential natural vegetation (PNV) types of the European Natura 2000 network compared with the National Protected Area network. In this context, the PNV map, reflecting the diversity and spatial arrangement of the natural terrestrial ecosystems, can be considered as an appropriate proxy of environmental and biogeographical diversity of Italy. In this country, 775 protected areas are registered in the Official List of Protected Areas (OLPA), 2281 sites are listed as Sites of Community Interest and 590 as Special Protection Areas, constituting the Natura 2000 network. The adopted conservation target considered that any PNV type included for less than the 10% in the PAs network (OLPA, Natura 2000) was defined as a gap in the system. In particular we defined four categories of PNV protection: any PNV types with a representation of less than 10% in both the OLPA and N2000 was defined as a "total gap" (i.e., under-protected); any PNV type with a representation of less than 10% in either the OLPA or the N2000 was defined as a "partial gap"; any PNV type with a representation of between 10 and 50% in both the OLPA and N2000 was defined as "protected"; lastly, any PNV type with a representation of more than 50% in both the OLPA and N2000 was defined as "widely-protected". Digital overlays of PNV and PAs networks were separately performed and statistics produced, indicating the current state of protection of Potential Natural Vegetation types in the two networks (OLPA and Natura 2000). We found that more than 59% of PNV types recognized on the Italian territory is not protected by the OLPA network. On the contrary, regarding Natura 2000 network, 68% of PNV types are protected, accounting for 27% more than OLPA. Compared to the National network of OLPA, the European network Natura 2000 is characterized by a larger percentage of territory in terms of area (18% of the Italian territory for Natura 2000 vs 10% of OLPA) but also by a smaller size of the sites, allowing for a more coherent distribution and efficiency in the protection of habitat remnants (68% PNV types protected by Natura 2000 vs 41% by OLPA). The proposed PNV approach can help guiding decisions on where and how to spend scarce conservation management resources.

Abbreviations: N2000 – European Natura 200 Network, OLPA – Official List of Protected Areas, PNV– Potential Natural Vegetation.

Introduction

To propose and develop effective conservation strategies in the Mediterranean basin and–more generally–where a human impact has over the millennia transformed much of the land (Blasi et al. 2000, Miller and Hobbs 2002, Falcucci et al. 2007), it is essential to consider the current situation together with the ecological potential of the territory (Wildi and Krüsi 1992, Ricotta et al. 2000, 2002, Bohn 2004). Several studies demonstrate that the existing protected area network often does not represent and protect the biodiversity of a country or a region (Rodrigues et al. 1999, Margules and Pressey 2000). Gap analysis methods are widely applied and documented as useful instruments to identify elements (e.g., species, ecosystems, ecoregions) that need greater protection (Jennings 2000, Scott et al. 2001, Oldfield et al. 2004, Dietz and Czech 2005, O'Dea et al. 2006).

According to Westhoff and van der Maarel (1973), the potential natural vegetation (PNV) is "the vegetation that would finally develop in a given habitat if all human influences on the site and its immediate surroundings would stop at once and if the terminal stage would be reached at once" (see also Tüxen 1956, for an early and probably the first definition of PNV).

In Europe, the PNV concept of was developed principally for vegetation mapping purposes in cultural landscapes (Zerbe 1998, Blasi et al. 2000). Indeed, by recognizing vegetation as the leading factor in a terrestrial ecosystem, PNV integrates abiotic factors and phytogeographic information combined with structure, dynamics and ecology of plant communities. PNV has been used in landscape planning and management (Chytrý 1998, del Rio et al. 2005), to test and develop climate change scenarios (Lexer et al. 2002) and to define a biogeographical classification at regional level (Gallizia Vuerich et al. 2001).

This paper proposes PNV as a useful tool that contributes to select conservation priorities on a national scale. We performed a gap analysis to assess how many and which potential natural vegetation types are included in protected areas in Italy, and compared the contribution of the national network

with the European Natura 2000 network (EU Directive 92/43/EEC).

Materials and methods

Study area

Italy is located in a central position in the Mediterranean basin that is considered one of the 25 global biodiversity hotspots (Medail and Quezel 1999, Myers et al. 2000). It covers an area of approximately 300.000 square kilometers, with the current land cover characterized predominantly by agricultural land use (53%), though approximately 40% is natural or seminatural, of which a considerable proportion (35%) is covered by forests that are growing at a rate of 0.3% per year (1990/2000, Corona et al. 2004).

Potential natural vegetation (PNV) map

The PNV map illustrates the distribution of the main natural potential plant communities in Italy, showing the current abiotic factors as well as the biogeographic features and the most important ecological characteristics, such as latitudinal zones, oceanic/continental gradients and altitudinal variations (i.e., vegetation belts). The map was integrated into a hierarchical land classification approach (Blasi et al. 2000) which identifies land units that are homogeneous in their bioclimatic and litho-morphological characteristics. A panel of regional experts from throughout the country contributed to produce the map on a scale of 1:250.000 (Blasi et al. 2004). The potential natural vegetation map was constructed on existing remnants of natural vegetation and their relationship to specific abiotic site conditions (climate, lithology, geomorphology, soil properties, etc). A hierarchical legend shows bioclimatic, physiognomic, ecological and geographical features (Table 1) and the syntaxonomical classification is specified for each unit (PNV type). The PNV map divides the Italian territory into 277 units each of which corresponds to one PNV type: 161 types belonging to temperate macrobioclimate and 116 to Mediterranean macrobioclimate, subdivided into 9 main vegetation belts (9 PNV types included in the Nival-criorotemperate; 15 in the Oro-temperate; 65 in the Supra-temperate; 72 in the Meso-temperate; 60 in the Meso-mediterranean; two in the Oro-mediterranean; 20 in the Supra-mediterranean; 32 in the Thermo-mediterranean and two in the Infra- Mediterranean. Climate definitions follow Rivas-Martŭnez (2004) and Blasi and Michetti (2007). PNV map is available on GIS Natura (Italian Ministry for the Environment – Politecnico di Milano, 2005); to perform the analyses, we revised and updated the PNV map, considering a minimum mapping unit of 50 ha.

Protected areas: national network and European Natura 2000 network

The first step in GAP analysis is to verify the level to which biodiversity elements are represented in existing protected areas, followed by the identification of the elements that need further protection. We considered the Italian national network of protected areas and Natura 2000 network, in order to assess the separate contribution of each of these two protection networks.

Table 1. Hierarchical structure of the Potential Natural Vegetation types.

Hierarchical levels	*Example*
Macro Bioclimatic region	Temperate
Vegetation belt	Mesotemperate
Physiognomic type	*Quercus cerris* (Turkey oak) forests
Ecological attribute	Sub-acidophilous
Phytogeographic feature	Southern Apennine
PNV type	*Lathyro digitati-Quercetum cerridis*

The Italian national network of protected areas is composed of 775 sites that are registered in the Official List of Protected Areas (OLPA) and include national parks, regional parks, natural reserves, biotopes and natural monuments. According to the World Conservation Union - IUCN classification, most of these areas are included in protected areas management categories III, IV and V (World Resources Institute, 2006).

The Natura 2000 network (N2000) was proposed under the European Habitat Directive (EU Directive 92/43/EEC) for the conservation of particular habitats and species. In Italy, 2281 sites were listed as sites of community interest and 590 as special protection areas. The Italian Ministry for the Environment (Directorate for Nature Protection) provided the OLPA and N2000 data sets (last update: October 2006).

We excluded all marine protected areas and analyzed the terrestrial reserves only, which account for 96% of the total number of protected areas in the OLPA and 98% in the N2000 network. The size of the terrestrial reserves varied (OLPA: mean 4055.6 ha, SD 15731.5 ha; N2000: mean 1788.8 ha, SD 9763.5 ha). We excluded from the analysis all sites smaller than 50 ha, i.e., smaller than the PNV minimum mapping unit: the OLPA sites <50 ha accounted for less than 1% of national territory, while the N2000 sites <50 ha accounted for less than 0.03% of the national territory. Natura 2000 network sites often overlapped with existing protected areas (OLPA): to avoid overestimation of the protected territory in Italy, we performed the analyses separately for the two analyzed networks (OLPA and N2000).

Representation of Potential Natural Vegetation in the protected areas network

We analyzed how many of the PNV types were represented in N2000 network and OLPA network. The first step in conservation assessment and planning is to identify objectives (Margules and Pressey 2000, Myers et al. 2000, Maiorano et al. 2006).The "10% target" is one of the most widely applied conservation goals (Rodrigues et al. 2004, Dietz and Czech 2005): it means that at least 10% of the ecosystem coverage is set aside for conservation purposes or included in a

protected area. Yet, research has shown that no single threshold value can be broadly applied to conserve all species and ecosystems (Dietz and Czech 2005, Maiorano et al. 2006). Moreover, to our knowledge, no studies have been conducted on PNV and conservation threshold levels. Hence, in this study we performed two level analyses, setting arbitrary levels of 10% and 50% as conservation targets. We defined four categories of PNV protection: any PNV types with a representation of less than 10% in both the OLPA and N2000 was defined as a "total gap" (i.e., under-protected); any PNV with a representation of less than 10% in either the OLPA or the N2000 was defined as a "partial gap"; any PNV with a representation of between 10 and 50% in both the OLPA and N2000 was defined as "protected"; lastly, any PNV with a representation of more than 50% in both the OLPA and N2000 was defined as "widely-protected".

It is worth bearing in mind that one protected site may have multiple designations which may considerably exaggerate the apparent level of protection in the country (see Oldfield et al. 2004). The definition of "total gap" adopted in this paper, i.e., PNV protected for less than 10% in both protected area systems, avoids overlapping of types of protected areas and yields a comprehensive and accurate picture of the gaps in the Italian protected areas network.

OLPA and N2000 maps have been compared on the basis of the numbers and percentage of potential vegetation types present in the respective PAs: to perform the analysis, we overlaid the boundaries of the OLPA over the PNV map and calculated the number and percentage of each PNV type included in the protected areas. We performed the same analysis separately for the N2000 network. We analyzed the differences between the percentages of PNV areas protected by the OLPA and N2000 using analysis of variance (Kruskal-Wallis ANOVA). Analyses were performed with ArcView 3.2 GIS software (ESRI 1999) and STATISTICA 6 (StatSoft, 2001).

Results

We analyzed 553 OLPA terrestrial reserves covering approximately 30 thousand square kilometers, i.e., 10% of the Italian territory. Within the N2000 terrestrial network, we analyzed 1835 sites of community interest and 543 special protection areas, covering approximately 18% of the area of Italy. The overall percentage of protection in Italy, as calculated by combining the terrestrial OLPA and N2000 network sites, was 20.35%, which indicates that the two protection systems largely overlapped (Fig. 1).

As regards the 10% threshold, there was a marked decrease in the PNV gap along an altitudinal gradient from lowland to higher mountain in the temperate and Mediterranean macroclimate in both protected areas networks (Fig. 2; OLPA KW-$H_{(8,277)}$ =58.23, $p<0.001$; N2000 KW-$H_{(8,277)}$ = 62.73, $p<0.001$).

There were "total gaps" for 78 PNV types (28.2%): 48 of these "total gaps" (62%) belonged to the temperate macroclimate while the remaining 30 (38%) belonged to the Mediterranean macroclimate. The spatial distribution of the protec-

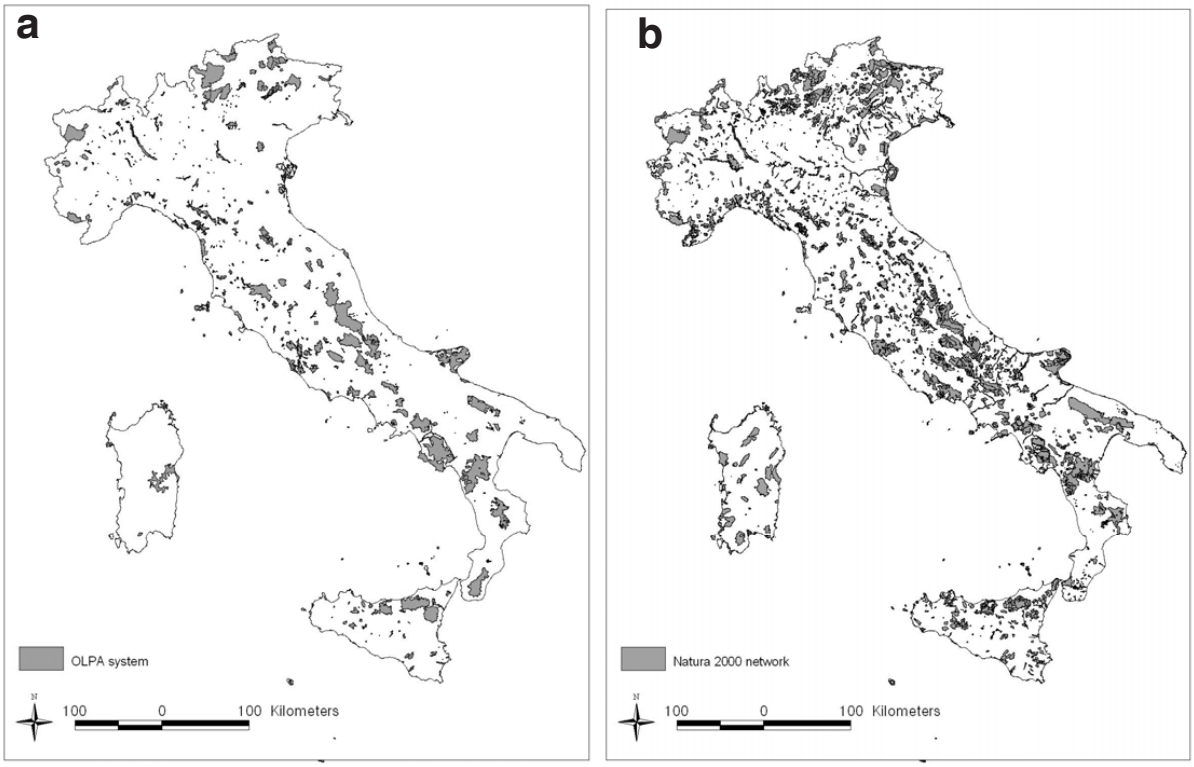

Figure 1. Distribution of the protected areas in Italy. **a:** the National System of Protected Areas (OLPA), **b:** Natura 2000 network (N2000).

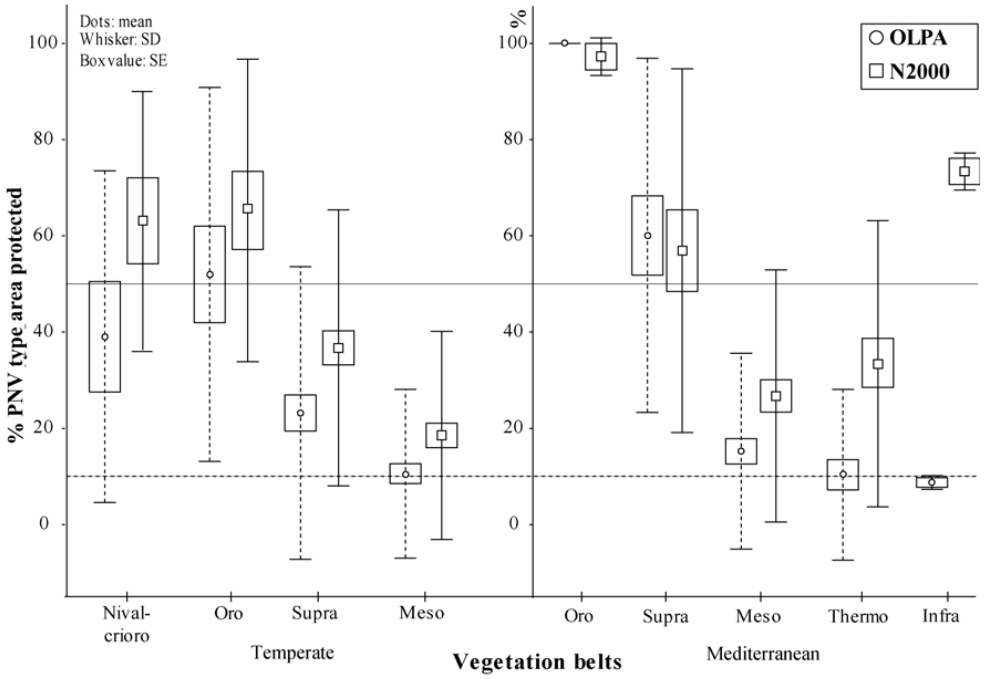

Figure 2. Percentage of PNV type's area protected by OLPA and N2000, presented according to the vegetation belts. The dashed line indicates the 10% target, the solid black line shows the 50% target.

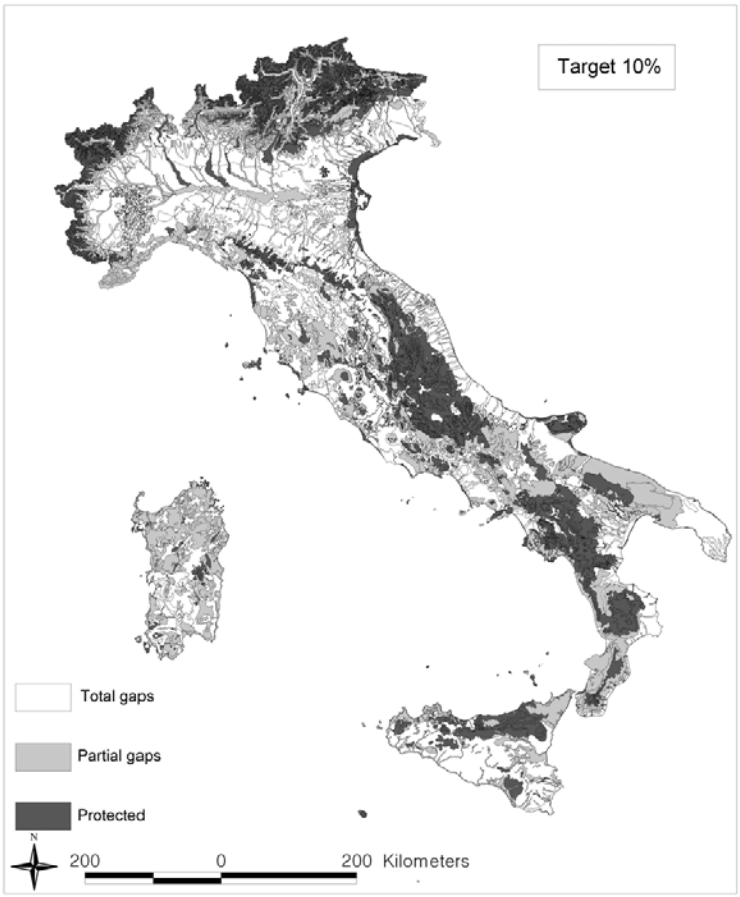

Figure 3. Conservation target 10%. Distribution of the 277 PNV types protected and not protected (total gaps and partial gaps) by the National Network of Protected Areas (OLPA) and Natura 2000 Network (N2000) in Italy.

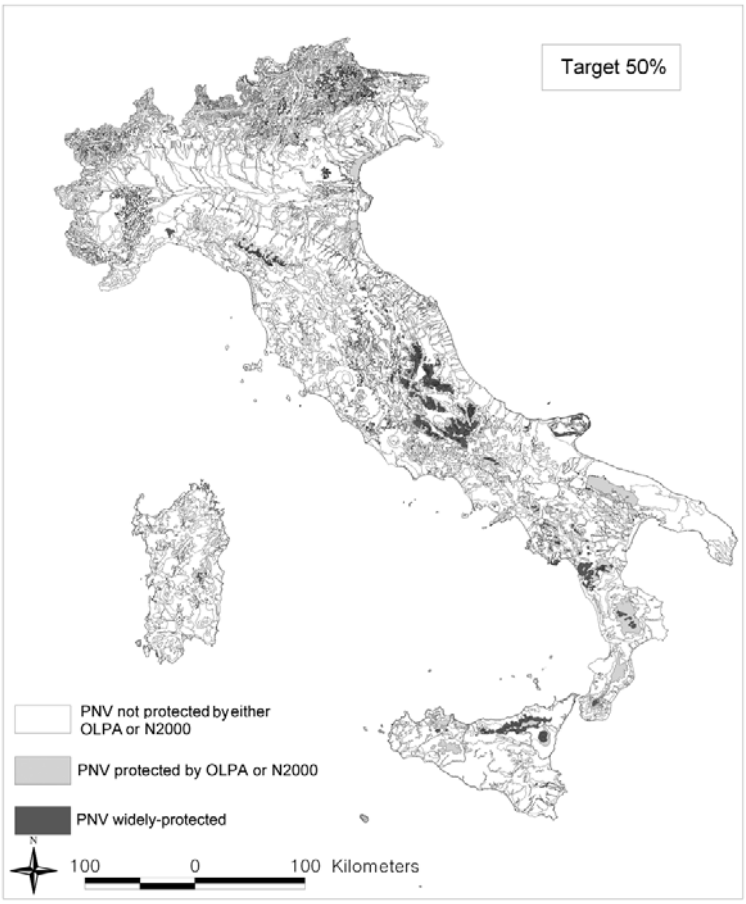

Figure 4. Conservation target 50%. Distribution of the 277 PNV types protected by both systems (widely-protected) and not protected or partially protected (PNV not protected by either OLPA or N2000; PNV protected by OLPA or N2000) by the National Network of Protected Areas (OLPA) and the Natura 2000 network in Italy.

tion gaps of the two protected areas networks was quite different, particularly in the islands of Sardinia and Sicily, in coastal areas and in the Po river floodplain (Figs. 1 and 3). Most of the PNV gaps were located in the hilly and lowland vegetation belts, from the mesotemperate to thermomediterranean bioclimate (Figs. 2 and 3). By contrast, according to the two protection levels analyzed (10 and 50%), the mountain and the upper belts of the Apennines and Alps were "widely-protected" as regards both the extension of the protected surface and the protection networks (Figs. 3 and 4). Despite this general trend, a detailed analysis of the phytogeographic information contained in the PNV types revealed marked differences in the conservation status of PNV types whose physiognomy and ecology are similar. For example, in the mesotemperate belt, the PNV types described as *Quercus cerris* forest (physiognomic level, Table 1) were "protected" (11% in the OLPA and 15% in the N2000), though not all types were equally represented (10 out of 24 PNV types protected in the OLPA, 16 out of 24 in the N2000). Indeed, the southern Apennine sub-acidophilous *Quercus cerris* forests (*Lathyro digitati-Quercetum cerridis*) were "protected" according to both networks in more than 20% of the potential area, while the central Preapennine sub-acidophilous *Quercus cerris* forests *(Carpino orientalis-Quercetum cerridis)* were defined as a "total gap" in both networks (8 % in the OLPA; approx. 4% in the N2000).

Similar findings emerged as regards the Alpine xerophytic coniferous forests of *Pinus nigra* and *Pinus sylvestris* (for syntaxonomical classification, Poldini et al. 2004), whose conservation status differed in the Eastern and Western sectors of the Alps: while all the Eastern Alpine PNV types were "protected", in the Central and Western alpine regions 4 out of 6 PNV types were "total gaps". By contrast, the *Pinus nigra s.l.* and *P. leucodermis* xerophytic coniferous forests in the Southern Apennines were "widely-protected" in the OLPA network (96% and 100%, respectively). Considering the 50% conservation target, 38 out of 277 PNV types reached the target in both the OLPA and N2000 (widely-protected): 47 reached the target in the OLPA and 70 in the N2000 (Figs. 2 and 4).

Discussion

The used PNV map represent the most complete and updated document available regarding the distribution of PNV in Italy (Blasi et al. 2000, 2004). Nevertheless, results may be biased by inaccuracies due to a lack of uniformity in the vegetation data across the country; moreover, PNV types and biodiversity hotspots recognizable on a more detailed scale

(i.e., grain finer than 50 ha) were not considered in the analysis. However, the PNV approach detected gaps in the protection networks analyzed: neither the national network of protected areas nor the Natura 2000 network completely preserved the Potential Natural Vegetation diversity of Italy. Theoretically, since the Italian OLPA network protects an overall percentage of 10% throughout Italy, an "optimal protected areas network" (i.e., a network of protected areas that preserves the highest potential diversity of ecosystems) should protect each PNV type and in particular the 10% of PNV type's area . At present, more than 55% of PNV types are classified as gaps in the OLPA network, partly due to the fact that several PNV types largely exceed the 10% coverage threshold; similar considerations can be made for the Natura 2000 network, using the 18% coverage threshold. Our results show that a change in the conservation target (from 10 to 50%) markedly reduces the level of protection; indeed, only 14% of the PNV types exceed the 50% threshold.

The proposed approach using PNV appears a useful instrument to identify the priorities to fill the conservation gaps on a national scale; nevertheless, we acknowledge that to define conservation strategies and propose coherent management actions, we have to assess the conservation status (Machado, 2004) of "total gap" and "widely-protected" PNV types using actual land cover data. In fact, in "total gaps" that have almost completely been transformed by human impact, conservation interventions should promote, when feasible, the restoration of lost ecosystems and sustain low-intensity farming (see e.g., the recent trend in the European Union for environmental objectives to be incorporated into agriculture policy). The "total gaps" in areas in which a high percentage of natural vegetation persists, are ideal candidates either for the institution of new protected areas or for the promotion of low impact use of natural resources. Furthermore, not only total gap areas require conservation actions, but also the management of "widely-protected" PNV types should address conservation issues. For example, long-term strategies to monitor and protect ecosystem diversity should be planned e.g., to initiate old growth forests (Humphrey 2005) or to maintain, through active management, the natural heterogeneity in open areas and heathlands (Svenning 2002, Rocchini et al. 2006, Maccherini et al. 2007).

In any case, even the conservation of a high portion of PNV types may not preserve the complete range of diversity (e.g., genetic, structural and functional) within that ecosystem (Scott et al. 2001, Dietz and Czech 2005). In addition, no studies are available regarding the PNV and threshold debate: for example, species-area relationships suggest that conserving a given percentage of remaining fragments may not be enough to ensure long-term viability of ecosystem type and its components (Soulè and Sanjayan 1998). The issue of how much of any ecosystem's distribution needs to be protected is still unresolved (Dietz and Czech 2005, Maiorano et al. 2006).

We demonstrated that the spatial distribution of the national network of protected areas was rarely consistent with the environmental heterogeneity found in the country, with only 42% of PNV types being protected by the network. The results restate the point that protected areas have been concentrated historically on lands at high altitude, relatively unproductive (Dietz and Czech 2005, Maiorano et al. 2006). By contrast, the designation of sites within the European Natura 2000 network is based on more recent conservation biology criteria (EU Directive 92/43/EEC). Studies concerning the effectiveness of the Natura 2000 have yielded contrasting results, indicating poor results for the conservation of plant diversity (Dimitrakopoulos et al. 2004), but encouraging results for lichens (Martinez et al. 2006) and coleoptera (Chefaoui et al. 2005). PNV analyses showed that, when compared with the national OLPA network, the European Natura 2000 network covers a larger area (18% of the Italian territory for N2000 vs 10% for OLPA), though, at the same time, a smaller size of the sites (a median size of 31 ha for N2000 vs 261 ha for OLPA). The characteristics of the N2000 network ensure a more coherent distribution and higher degree of efficiency in the protection of habitat remnants than the OLPA; in this context, the PNV approach sustains the results reported in studies on the conservation of groups of 'non-charismatic' species (Chefaoui et al. 2005, Martinez et al. 2006).

The results show that conservation priorities in Italy are concentrated where human influence is most intense: future management in the lowlands, hilly areas and coastal plains of the peninsula should preserve and restore the remnants of natural habitats.

The PNV approach proposed in this study is an instrument that integrates and supports species, habitat and phytogeographic data so as to prioritize conservation efforts. The Potential Natural Vegetation protection goal should be set according to national and ecoregional conservation management programs, on an appropriate scale. In fact, we believe that PNV gap analyses can guide national conservation strategy by prioritizing ecosystem types on a national scale; though we also argue that on a finer scale, the conservation of each PNV type should be determined specifically and separately, taking into account other factors that operate at a more detailed scale, such as urban impact, degree of fragmentation and disturbance regimes. In addition, at local scale the real diversity of the territory , i.e., land cover, strongly affects the conservation strategies and the PNV approach can only be pragmatically applied to address managers' choices for biodiversity conservation and planning purposes.

Nevertheless, in times of changing environments the proposed approach aims to contribute to the discussion of national and broad scale biodiversity strategies.

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