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Quantifying plant species diversity in a *Natura 2000* network: Old ideas and new proposals

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A B S T R A C T

Assessing the effects of the spatial components on species diversity in a network of protected areas represents an important step for assessing its conservation "capacity". A clear evaluation on how α-, β-, and γ-diversity are partitioned among and within spatial scales can help to drive manager decisions and provide method for monitoring species diversity. Moving from these concepts, a probabilistic sample of plant species composition was here applied for quantifying plant species diversity within the Sites of Community Importance (SCIs) of the *Natura 2000* network in the Siena Province. All analyses were performed separately for all species and those species defined as "focal" (included in regional, national or continental "red" lists). The results indicated that species richness of the SCIs differed from one location to another one independently from the sampling efforts. Diversity partitioning indicated that most of the flora diversity within the network was given by larger-scale β-diversity, i.e. the differences in species composition among SCIs. β-diversity was then decomposed in two components: β_{Area} (due to the differences in area among SCIs) and $\beta_{Replacement}$ (due to the compositional differences across SCIs). β_{Area} was particularly important for all species, while $\beta_{Replacement}$ was the most important factor for focal species. The consequent implications for monitoring and nature conservation strategies are discussed.

1. Introduction

Due to the ever-growing impact of human activities, the biodiversity of natural habitats is rapidly being eroded, with the 13% loss estimate by Reid (1992), from 1990 to 2015, likely to be conservative (Nagendra and Gadgil, 1999). Concrete efforts for biodiversity conservation have been urged (WSSD of Johannesburg, Convention on Biological Diversity, UN Environment Programme and UN Development Programme). The objective to "*achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level*" has been set by the convention on biological diversity and many resources are devoted to this aim. The implementation of the EU directives 92/43/EEC (Habitats Directive) and 79/409/EEC (Birds Directive) in the *Natura 2000* network is a major step towards a European strategy for nature conservation, and makes biodiversity monitoring legally binding (Bock et al., 2005). The sites of community importance (SCIs) are the main elements of the *Natura 2000* and the harmonisation of management and monitoring activities in these sites is an important challenge for local managers even though it still needs much effort (Devictor et al., 2007). Meanwhile, Habitats Directive (articles 11 and 17) focuses on monitoring of the conservation status of habitats and species of community importance, throughout the territories of all European Member States. In fact, the assessment of species diversity is crucial, since it represents a fundamental property of ecological communities and provides a tool to compare assemblages in time and space, independently from species identities (Colwell and Coddington, 1994; Olszewski, 2004). The assessment

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of species diversity could then provide useful information about the status of the *Natura 2000* network and the effects of its management, but criteria are still lacking.

Quantifying the partitioning of species diversity across spatial or ecological scales is fundamental to understand the processes structuring the biological communities (Wagner et al., 2000). Whittaker (1977) proposed a multiplicative way to link the diversity across scales, with the total diversity in a region given by the local scale diversity multiplied by the compositional change ($\gamma = \alpha * \beta$). Then, Allan (1975) introduced the additive partitioning of species diversity calculated by the Shannon index ($\gamma = \alpha + \beta$). Lande (1996) extended this latter approach to species richness and Simpson index, proposing this as a unifying way to assess the partitioning of species diversity at different organisation levels, with the advantage of using the same unit (e.g. the number of species) for quantifying the contribution of each component. Recent developments related this approach to classical techniques such as species–area curves (Crist and Veech, 2006) or rarefaction curves (Olszewski, 2004).

In order to achieve comparable results, standardized techniques are urgently needed for assessing and monitoring of biodiversity (Stohlgren et al., 1995). Probabilistic methods (Elzinga et al., 2001; Legg and Nagy, 2006) are then needed to provide a reliable inference about the species populating a large area or a network of protected areas. This is particularly true for plants, for which methods are available for assessing species diversity at a local scale (see e.g. Stohlgren, 2007), but not at a larger scale, such as a large protected area or a whole network of protected areas. At these scales, floristic data are often collected subjectively and the lists of species may be adequate for some aims (e.g. description of local habitats) but not for quantitative ones (Palmer et al., 2002). In addition, it is unlikely that one will ever get complete species lists in a large region (Robinson et al., 1994; McCollin et al., 2000). With respect to the *Natura 2000* network, even if monitoring programs single focused on animal species are ongoing, much remains to be done especially for plant species and total biodiversity.

Here, the results of a probabilistic sampling approach developed for assessing and monitoring plant species diversity within the network of SCIs of the Siena Province, Italy, are used to answer the following questions: (1) what is the relative contribution to the species diversity of the different spatial components, from the local to the regional one? (2) is the diversity partitioning of all species the same of that of focal species for which the reserve network was set up?

2. Survey sites

Seventeen SCIs are present in the Siena Province, Italy, and they range in size from 483 ha (Lago di Montepulciano) to 13,744 ha (Montagnola Senese), for a total of 58,969 ha. They range from low elevation (65 m a.s.l.) to high mountain (1,685 m a.s.l.), and host many different habitats: from open habitats to almost unmanaged forests. This network of SCIs is expected to host high plant species diversity, but the presently available floristic data are uneven.

The development phase of the monitoring program was conducted in 2005 and 2006, in eight SCIs with a variety of ecological conditions (Table 1). These SCIs host diverse plant communities, from thermophile forests dominated by *Quercus ilex*, *Quercus pubescens* or *Quercus cerris*, to mountain forests dominated by *Fagus sylvatica* or *Castanea sativa* (all the nomenclature is in accordance to Pignatti, 1982). Croplands, pastures, shrublands and conifer plantations are also present. These SCIs represent more than 35% of the *Natura 2000* surface in the Siena Province.

3. Methods

3.1. *Rationale and sampling design*

The sampling design adopted in this project was the same used for the Italian Inventory of Forests and Forest Carbon Stocks (INFC, Fattorini and Tabacchi, 2004). The sampling points were located by a restricted random selection, as follows: the whole Italy was covered by a grid of 1 × 1 km cells and one random point was selected within each cell. In the INFC project, these points were used for a three-stage sampling of forest data (De Natale et al., 2005). Here, the set of points of the INFC first sampling stage (one point per

Table 1 – Descriptive data for the eight investigated SCIs

SCI	Acronim	Area (km^2)	Altitudinal range (m)	Number of plots	All species		Focal species	
					Plot scale (mean and range)	SCI scale	Plot scale (mean and range)	SCI scale
Cono Vulcanico del Monte Amiata	AMI	17.68	782–1685	16	13.5 (4–40)	90	1.3 (0–5)	10
Alta Val di Merse	AVM	94.85	196–498	90	26.6 (6–119)	499	1.4 (0–6)	32
Bassa Val di Merse	BVM	41.40	123–459	44	29.4 (0–78)	394	0.7 (0–4)	20
Castel Vecchio	CAS	11.15	315–668	11	41.5 (12–62)	186	1.2 (0–3)	7
Valle del torrente Farma	FAR	26.29	196–498	26	30.2 (0–77)	316	1.6 (0–5)	21
Lucciolabella	LUC	14.17	315–668		25.5 (0–57)	151	1.9 (0–5)	11
Foreste del Siele e Pigelleto di Piancastagnaio	PIG	11.72	494–968	11	39.3 (16–59)	174	1.7 (1–3)	6
Ripa d'Orcia	RIP	8.31	205–522	8	29.8 (0–81)	130	1.4 (0–5)	7
All the SCIs	NETWORK	225.57	123–1685	219	28.2 (0–119)	778	1.3 (0–6)	65