Testing the Value of Six Taxonomic Groups as Biodiversity Indicators at a Local Scale

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Abstract: *We examined six groups of taxa—woody plants, aquatic and terrestrial herpetofauna, small terrestrial birds, orchids, and Orthoptera—to determine their efficiency as biodiversity indicators in the Dadia Reserve in northern Greece. We investigated the indicator value of each group by examining the degree of congruence of its species-richness pattern with that of the other groups and the efficiency of its complementary network in conserving the other groups and biodiversity. The two techniques differed in many respects in their outputs, but they both showed woody plants as the best biodiversity indicator. There was in general low congruence in the species richness patterns across the different groups. Significant relationships were found between woody plants and birds, Orthoptera and terrestrial herpetofauna, and birds and aquatic herpetofauna. None of the optimal complementary networks of the groups we examined protected all species of the other groups. Nevertheless, the complementary network of woody plants adequately conserved all groups except orchids. We conclude that the principle of complementarity must be integrated into the methodology of evaluating an indicator. In an applied context, our results provide a scientific background on which to base a biomonitoring program for the Dadia Reserve. In a wider scope, if the group of woody plants prove an adequate biodiversity indicator for other Mediterranean areas as well, this will be important because it will facilitate conservation-related decisions for the entire Mediterranean region.*

Key Words: biodiversity, biomonitoring, indicators, Mediterranean, reserve

Probando el Valor de Seis Grupos Taxonómicos como Indicadores de Biodiversidad en una Escala Local

Resumen: *Examinamos seis grupos de taxones – plantas leñosas, herpetofauna acuática, herpetofauna terrestre, aves terrestres pequeñas, orquídeas y Orthoptera – para determinar su eficiencia como indicadores de biodiversidad en la Reserva Dadia en el norte de Grecia. Investigamos el valor de cada grupo como indicador examinando el grado de congruencia de su patrón de riqueza de especies con el de otros grupos y la eficiencia de su red complementaria para conservar a los otros grupos y a la biodiversidad. Las dos técnicas difirieron en muchos aspectos de sus resultados, pero ambos mostraron a las plantas leñosas como el mejor indicador de biodiversidad. Hubo poca congruencia en los patrones de riqueza de especies en los diferentes grupos. Se encontraron relaciones significativas entre plantas leñosas y aves, Orthoptera y herpetofauna terrestre, y aves y herpetofauna acuática. Ninguna de las redes complementarias óptimas de los grupos que examinamos protegió a todas las especies de los otros grupos. Sin embargo, la red complementaria de plantas leñosas*

conservó adecuadamente a todos los grupos excepto las orquídeas. Concluimos que se debe integrar el principio de complementariedad a la metodología para evaluar un indicador. En un contexto aplicado, nuestros resultados proporcionan un antecedente científico sobre el cual basar un programa de biomonitoreo para la Reserva Dadia. En una visión más amplia, si el grupo de plantas leñosas también resulta un indicador de biodiversidad adecuado para otras áreas Mediterráneas, esto será importante porque facilitará las decisiones relacionadas con la conservación de toda la región Mediterránea.

Palabras Clave: biodiversidad, biomonitoreo, indicadores, Mediterráneo, reserva

Introduction

One of the major tasks of conservation biologists is to restrain the alarming rate of species extinction stemming from the overuse and misuse of space and natural resources (Meffe & Carroll 1994; Cincotta et al. 2000). In many cases, the magnitude and urgency of the problem require immediate action. However, the resources, appropriate techniques, and adequate expertise needed to survey the biodiversity of an area are often lacking. Consequently, there is an urgent need for special methods and tools to be developed that will help conservationists and managers of reserve areas make decisions, particularly in emergency cases and with limited resources.

The use of biodiversity indicators constitutes one of the basic tools of conservationists for quick action against biodiversity loss (Caro & O'Doherty 1999; Lindenmayer et al. 2000; Soberón et al. 2000). Conservation practitioners attempt to identify taxa that are well known, are readily surveyed, and have the potential to be used as indicators of the distribution patterns of other unsurveyed taxa or of overall biodiversity at different spatial scales (Noss 1990; McGeoch 1998). Given that more than 80% of the species on Earth remain unknown (Hawksworth & Kalin-Arroyo 1995), the importance of biodiversity indicators in conservation is pivotal. If such indicators become available, full biodiversity surveys, which are expensive and time-consuming, particularly in cases where the biota are not well known or described, would not be an absolute requirement for making good management decisions.

The idea of biodiversity indicators is based mainly on the assumption that different taxa have congruent patterns of species richness, which is currently widely debated. Several researchers have proven positive species turnover across taxa and propose vascular plants, tiger beetles, or butterflies as biodiversity indicators (Pearson & Cassola 1992; Crisp et al. 1998; Pearson & Carroll 1998; Pharo et al. 1999). In contrast, many other researchers have found only weak indicator relationships across different taxa (e.g., Saetersdal et al. 1993; van Jaarsveld et al. 1998; Pärt & Söderström 1999; Ricketts et al. 1999; Vessby et al. 2002), which does not allow for use of a specific group as an indicator.

Because of these contrasting results, the practical value of biodiversity indicators requires rigorous testing before implementation (Gustafsson 2000). In testing, the value of complementary networks should be considered. Complementarity (Vane-Wright et al. 1991) is a key principle in conservation planning (Pressey et al. 1993; Margules & Pressey 2000). It implies selection of sites complementary to an existing reserve system that contribute new unprotected attributes (e.g., species, habitats). In spite of their importance, the value of complementary networks is rarely tested when indicator relationships are examined (e.g., van Jaarsveld et al. 1998).

We attempted to identify and evaluate biodiversity indicators in the Dadia Reserve (northeastern Greece), an area of great natural beauty that has been protected since 1980 because of its high ornithological value. Our study has both a theoretical and a practical scope. On the theoretical level, we aimed at contributing to the current debate regarding the issue of biodiversity surrogates, particularly focusing on their importance in the Mediterranean environment. We explored the efficiency of six groups of taxa, some of which have not been examined before (Orthoptera and orchids), as indicators for the species richness of other groups. In this context, we also examined two different techniques of indicator evaluation and investigated potential ecological reasons for their surrogate value. In an applied context, we aimed to provide guidelines for an efficient biomonitoring of the Dadia Reserve. More precisely, we wanted to demonstrate the best biodiversity indicator of the studied groups that would over time provide an inexpensive, reliable, and rapid biodiversity assessment in the study area.

We selected and assessed groups of taxa that represent different taxonomic, functional, and spatial aspects of local biodiversity (Noss 1990; Pearson 1995). We estimated the degree of congruence of their species-richness patterns and the efficiency of each complementary network selected to protect all species of each group at conserving species of the other groups.

Methods

Study Area

The study area is situated in northeastern Greece (40°59′–41°15′N, 26°00′–26°19′E) (Fig. 1). It covers 430 km²,
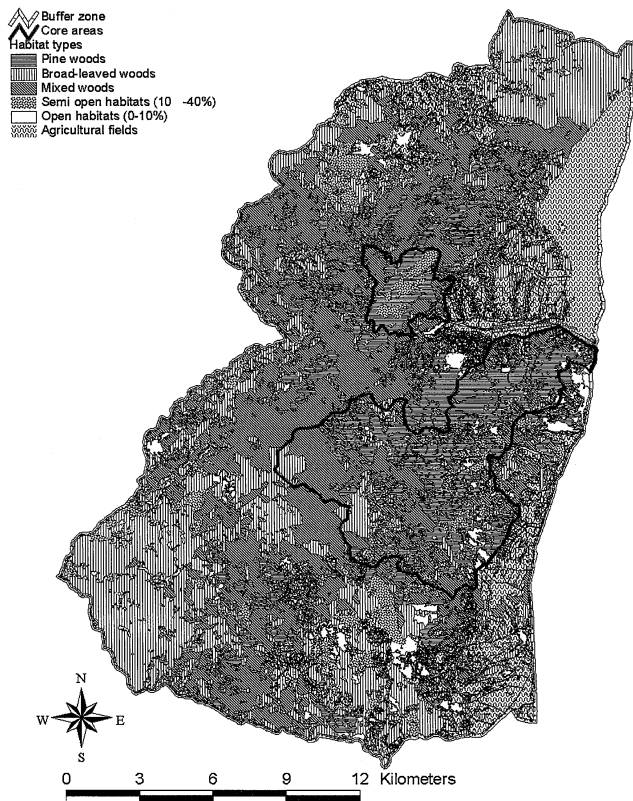
Figure 1. Location of the Dadia Reserve in northeastern Greece and map of land cover of the main habitat types.

almost all of which belongs to the reserve of Dadia-Lefkimmi-Soufli Forest, hereafter the Dadia Reserve. The reserve includes two strictly protected zones (72.9 km²) and one buffer zone (351.7 km²). The elevation in the study area varies from 10 to 650 m. The climate is submediterranean. Temperature ranges from −19° to 40° C. Mean annual rainfall ranges between 556 and 916 mm (Adamakopoulos et al. 1995). *Quercion frainetto* forests cover 75% of the reserve. Aegean pinewoods *(Pinus brutia)* form the dominant vegetation type. The ornithological value of the reserve is high because it hosts 36 out of the 38 European species of raptors (Poirazidis et al. 2002). We selected 36 sites at random, preferring the most easily accessible, to represent the 21 habitat types of the Corine typology system (Devillers et al. 1996) in the study area (Table 1).

Sampling

To measure diversity within each sampling site, we conducted random sampling, applying sampling techniques appropriate for each group under study, including woody plants, orchids, Orthoptera, aquatic herpetofauna (amphibians and water tortoises), terrestrial herpetofauna (lizards and terrestrial tortoises), and small terrestrial birds (Passeriformes, Columbiformes, Coraciformes, Piciformes). We tested the thoroughness of sampling with software that drew a species-accumulation curve randomized 50 times (option of species richness estimator; Colwell 1997). When the species-accumulation curve for a group reached a plateau, our sampling was considered to be thorough for this group.

We sampled woody plants within quadrats of 25 × 25 m (Kent & Coker 1994). All woody plants occurring within the quadrats were recorded and identified in situ. In each site, we sampled three random quadrats, for a total of 108 quadrats (Table 2). We sampled in spring, April 1999 to 30 May 1999. The species-accumulation curve reached the plateau at 99 out of the 108 quadrats sampled.

We sampled orchids in a qualitative way with site visits of fixed duration (1 hour each site) (Table 2). We searched sites twice per year at the peak of orchid flowering (15 April–15 June) for 2 successive years (1998 and 1999). Sampling took place first at low-elevation and open sites. We sampled high-elevation and shaded sites a month later. We used an orchid key to identify specimens in situ (Delforge 1994). The species-accumulation curve reached the plateau at 136 out of the 144 visits.

Orthoptera sampling was semiquantitative (Table 2). We sampled each site by two random transects 2 m in width. The length of the open transects (<60% shade) was fixed at 30 m. Because of the scarcity of specimens in shady forested sites, we tripled (90 m) the length of the shaded transects (>60% shade). We sampled three times in 1999, in spring (June), summer (July–August), and autumn (September–October), when air temperatures were between 20° and 30° C, for a total of 216 samples (Table 2). We caught adult specimens of Orthoptera with a sweep net and counted and identified them ex situ with Willemse's (1985) guide. The species-accumulation curve reached the plateau at 103 of the 114 open transects and at 52 of the 102 shaded transects.

To collect presence and absence data for aquatic herpetofauna, we made time-constrained visits (Crump & Scott 1994) for both acoustic and visual sampling (Table 2). Acoustic sampling, 30 minutes in each site, was carried out at sunset during early spring in 1999 (15 March–15 April). Every site was sampled three more times, in early spring (30 March–15 April), mid-spring (15 April–15 May) and late spring (15 May–15 June) to record species presence visually (adult specimens, larvae, and egg masses). The early spring visit lasted 120 minutes, whereas the mid- and late-spring visits lasted 30 minutes. The species-accumulation curve reached the plateau at 89 of the 144 visits.

We counted lizards and tortoises along standardized transects 300 × 6 m in size (Krebs 1989). At each site we sampled one transect, located at random, crossing all the microhabitats of terrestrial herpetofauna in the study area (Strijbosch et al. 1989). The sampling was repeated

Table 1. Habitat types and sites sampled in the Dadia Reserve of northeastern Greece.

Vegetation type	Corine code	Habitat description	No. of sites sampled	Site area (ba)
Forest	41.1B × 41.19311	beech wood	2	20
	41.76	oakwoods (*Quercus frainetto/cerris*)	2	20
	41.733	oakwoods (*Quercus pubescens*)	2	20
	41.733	oakwoods (*Quercus pubescens*) with bush undergrowth	2	20
	43.7	mixed pine-oak woods	2	20
	42.661(C)	pinewoods (*Pinus nigra*)	1	3
	42.85 A	pinewoods (*Pinus brutia*)	1	20
	42.85 A	pinewoods (*Pinus brutia*) with bush undergrowth	2	5,10
	44.514	riparian vegetation (*Alnus glutinosa*)	2	20
	44.615	riparian vegetation (*Populus sp.*)	2	20
Shrubs	32.313	high maquis (*Arbutus sp.*)	2	15
	32.161	deciduous oak mattoral	1	20
	32.21A4 × 34.53	bushes (*Phyllirea latifolia.*)	1	10
Heaths	32.32	low ericaceous maquis (*Erica arborea*)	2	10
Grasslands	37.4 (×41.8221)	humid grasslands	2	3,10
	34.53	xeric grasslands	2	5,10
	34.2	heavy-metal grasslands	1	2
Agricultural land	84.4	rural mosaics	2	20
	82.11	field crops	2	20
Mosaics	32.71 × 38.1	pseudomaquis × pastures	2	20
	32.71 × 38.1 37.1 × 44.12 × 41.733	pseudomaquis × pastures × humid grassland × willow shrubs × oakwood	1	10
Total	23	21	36	568

three times in 1999, in mid-spring (15 April–11 May), late spring (16 May–31 May), and summer (1 June–15 June). To standardize sampling efficiency, we conducted samplings only when air temperatures were between 16° and 30° C. The species-accumulation curve reached the plateau at 77 of 108 transects.

We used the point-count method of unlimited distance (Blondel et al. 1970; Bibby et al. 1992) to identify small terrestrial birds acoustically. All birds seen or heard within 10 minutes were counted within a circle with a radius of 100 ± 20 m. Hearing distance was 100–120 m in five open sites (Table 1: grasslands and field crops) and 80–100 m in two closed sites (Table 1: riparian vegetation of *Alnus glutinosa*). We considered singing males to be representative of a pair of birds. We sampled most of the sites (20 ha) with 5 point counts. Smaller sites were sampled with two, three, or four point counts (Table 1). Sampling

points were at least 200 m away from one another and 100 m away from the site edge. We conducted point counts from 30 minutes before sunrise to 4 hours after, the peak of bird calling activity. We repeated point counts twice in the spring of 1999 (15 April–15 May and 15 May–15 June) to sample both sedentary and late immigrant species. The species-accumulation curve reached its plateau at 278 out of 310 point counts.

Data Analysis

We tested the value of each group, hereafter called an indicator group, as a surrogate for the conservation of each of the other groups examined, hereafter called a target group. We also tested the value of each indicator group for the conservation of biodiversity (BD). We defined the parameter BD as the total number of species found at a

Table 2. Sampling procedure applied to record the species richness of the six groups of taxa studied in the Dadia Reserve.

Taxonomic group	Type of data	Sampling method	Size of sample unit (m)	Number of sample units	Number of replicates	Number of samples	Number of species recorded
Woody plants	qualitative	quadrats	25 × 25	108	1	108	55
Orchids	qualitative	time-constrained visits	—	36	4	144	25
Orthoptera	semi-quantitative	transects	30 or 90	72	3	216	39
Aquatic herpetofauna	qualitative	time-constrained visits	—	1	4	144	10
Terrestrial herpetofauna	semi-quantitative	transects	300	36	3	108	10
Birds	semi-quantitative	point counts	radius 70–120	155	2	310	72

site (of all six groups examined) minus the number of species belonging to the indicator group.

We used two techniques to evaluate the indicator value of each group. First, we estimated the degree of congruence of the species-richness patterns across the different groups and BD with Pearson correlation coefficients. We also examined how the habitat factor affected the significant relationships produced by analyzing subsets of the data for different habitat categories (forests and nonforests, mosaic and nonmosaic habitat types) and calculating Pearson correlation coefficients within them. Finally, we determined whether the number of species in groups influenced results—whether the multispecies groups were better biodiversity indicators than less speciose groups.

Second, we estimated the efficiency of the optimal network of every indicator group at conserving every target group and BD. The optimal network for the conservation of the indicator group was defined as the network that maximizes conservation of the species of this group within the minimum land surface. The networks were created after an optimal random-selection algorithm was run (SAS Institute 1985), which produced 20,000 random combinations for a given number of sites, λ, and pinpointed the combination that maintained the maximum number of species (Kati 2001). Six optimal complementary networks were formed (one for each of the six groups examined), with a maximum number of sites for each group, $\lambda_{\max}$, in which all species of the indicator group were maintained.

We examined relative species loss (L) to assess the surrogate value of the complementary network of each indicator group. This parameter is independent of the number of sites selected to form the network and is calculated on the basis of the following equations:

$$L_{it} = \frac{1}{\Lambda} \sum_{\lambda=1}^{\Lambda_i} (\mathrm{SI}_{i\lambda} - \mathrm{ST}_{it\lambda}) \text{ and}$$

$$L_{i\mathrm{Bd}} = \frac{1}{\Lambda_i} \sum_{\lambda=1}^{\Lambda_i} \left(\mathrm{SI}_{i\lambda} - \mathrm{BD}_{it\lambda}^5\right),$$

where $\mathrm{SI}_{i\lambda}$ is the percentage of species of the indicator group i conserved in the complementary network consisting of λ sites; $\mathrm{ST}_{it\lambda}$ is the percentage of species from the target group t conserved by this λ-site complementary network of indicator group i; $\mathrm{BD}_{i\lambda}$ is the percentage of biodiversity conserved in the λ-site complementary network of indicator group i; $\Lambda_i = \lambda_{\max}$ for indicator group i, which is the number of sites forming its complementary network in which all its species are conserved. Thus, L_{it} is the average percentage of species of the target group t that are not conserved in the optimal complementary network of indicator group i for one to $\lambda_{\max}$ sites, and $L_{i\mathrm{Bd}}$ is the corresponding average for biodiversity not conserved.

The smaller the L value, the lower the percentage of species of the target group not contained within the complementary network of the indicator group and thus the greater the surrogate value of the indicator group. Ideally, L becomes zero when the complementary network of the indicator group conserves the same percentage of species of both the indicator and the target groups. In this case, the indicator group has an excellent surrogate value for the conservation of the target group. The L values were analyzed by one-way analysis of variance (ANOVA). Significant differences among groups were estimated with the Waller-Duncan t test.

Results

Species Richness

We recorded 211 indigenous species in the 36 sites of the Dadia Reserve. There were 55 species of woody plants (Kati 2001), 25 orchid species (Kati et al. 2000), 39 Orthoptera species (Kati & Willemse 2001), 20 herpetofauna species (8 amphibians, 2 terrapins, 8 lizards, and 2 terrestrial tortoises) (Kati 2001), and 72 bird species (61 Passeriformes, 2 Columbiformes, 3 Coraciformes, and 6 Piciformes) (Kati 2001) (Table 2).

Woody plants, Orthoptera, birds, and terrestrial herpetofauna were widespread in the study area. Species in the first three groups were detected in all 36 sites, whereas terrestrial herpetofauna species were missing in two sites. Aquatic herpetofauna and orchid species were less widespread; they were absent in 14 and 18 sites, respectively.

Congruence of Species-Richness Patterns

The strongest pairwise correlation was between the species-richness patterns of woody plants and small terrestrial birds ($r = 0.759$; $p < 0.01$) (Table 3). Species-richness patterns were significantly correlated between woody plants and aquatic herpetofauna ($r = 0.357$; $p < 0.05$), aquatic herpetofauna and birds ($r = 0.452$; $p < 0.05$), and terrestrial herpetofauna and Orthoptera fauna ($r = 0.394$; $p < 0.05$) (Table 3).

The above pairwise relationships explained why woody plants were the best indicator of biodiversity in the study area ($r = 0.647$; $p < 0.01$). The second best indicator was small terrestrial birds ($r = 0.604$; $p < 0.01$), followed by aquatic herpetofauna ($r = 0.356$; $p < 0.05$).

Explanation of Congruent Species-Richness Patterns

The congruence of the species-richness patterns between woody plants and aquatic herpetofauna and between aquatic herpetofauna and birds is explained in terms of environmental heterogeneity. When we did not include the five highly heterogeneous sites of mosaics and rural

Table 3. Results of pairwise correlations (Pearson correlation coefficients) of the species richness of the six groups of taxa studied in the Dadia Reserve (in 36 sampling sites).

Taxonomic group	Woody species	Orchids	Orthoptera	Aquatic herpetofauna	Terrestrial herpetofauna	Birds	BD[a]
Woody plants	1	0.217	0.215	0.357[b]	−0.23	0.759[c]	0.647[c]
Orchids		1	0.256	−0.038	0.016	0.077	0.194
Orthoptera			1	0.158	0.394[b]	0.226	0.324
Aquatic herpetofauna				1	−0.176	0.452[b]	0.356[b]
Terrestrial herpetofauna					1	−0.013	0.083
Birds						1	0.604[c]

[a] *Conservation of biodiversity value.*
[b] *$p \leq 0.05$ level (two tailed).*
[c] *$p \leq 0.01$ level (two tailed).*

mosaics in our analysis (Table 1), no relationship was significant. The most species-rich sites for these two groups were those characterized as mosaic.

The relationship between Orhoptera and terrestrial herpetofauna was explained to some extent by their common requirement for light. Separate analysis of data from forest and nonforest sites (Table 1) gave different results. For forest sites, the pairwise correlation between Orthoptera and terrestrial herpetofauna was more pronounced ($r = 0.647$; $p < 0.01$) because shade was their common limiting resource. The correlation was not significant in nonforest sites.

The highly significant relationship between woody plants and birds was not maintained when forests alone were examined. In other words, the diversity of woody plants had no indicator value for the diversity of forest birds. On the contrary, their species-richness patterns were highly congruent in nonforest habitats ($r = 0.906$; $p < 0.01$).

Finally, we found a significant positive correlation between the Pearson values of correlated groups (Table 3) and the sum of their species ($r = 0.651$; $p < 0.05$).

Efficiency of Optimal Networks

The selection of the indicator group affected the efficiency of the complementary network in conserving the species of each target group or of biodiversity (one-way ANOVA: $F_{BD} = 20.389$, $F_{\text{woody plants}} = 52.823$, $F_{\text{ochids}} = 19.591$, $F_{\text{orthoptera}} = 21.445$, $F_{\text{aq. herpetofauna}} = 38.665$, $F_{\text{ter. herpetofauna}} = 36.377$, $F_{\text{birds}} = 38.3872$, $p < 0.001$).

The values of L (Table 4) represent how many fewer species, on average, of the target group relative to the species of the indicator group are maintained in the indicator complementary networks. Therefore, the smaller the value of L, the greater the surrogate value of the indicator group. Taking as a threshold $L = 25$, a group has an important indicator value if $L \leq 25$, which means the complementary networks of this indicator group miss, on average, $\leq 25\%$ of the species of the target group.

Woody plants were a good indicator group ($L \leq 25$) for the conservation of four target groups: aquatic herpetofauna ($L = -4$), birds ($L = 4$), Orthoptera ($L = 18$), and terrestrial herpetofauna ($L = 25$). Also, the optimal network of woody plants was the only good surrogate for the conservation of the biodiversity of the study area ($L = 17$). Its indicator value was poor only for the conservation of orchids ($L = 45$). The bird group was a good indicator for the conservation of three groups: woody plants ($L = 21$), Orthoptera ($L = 21$), and aquatic herpetofauna ($L = 16$). Orchids, Orthoptera, and aquatic herpetofauna were good indicators for the conservation of only one target group each, whereas the terrestrial herpetofauna

Table 4. Average difference (L) between percentage of species of the indicator group and percentage of species of the target group or of biodiversity, contained in the complementary networks of the indicator group, for the different groups examined.

Indicator group	No. of sites	L[a] BD[b]	woody plants	orchids	orthoptera	aquatic herpetofauna	terrestrial herpetofauna	birds
Woody plants	9	17	0	45	18	−4	25	4
Orchids	4	41	58	0	31	55	23	41
Orthoptera	6	38	54	30	0	56	19	31
Aquatic herpetofauna	4	37	24	67	40	0	38	19
Terrestrial herpetofauna	2	61	65	69	50	80	0	40
Birds	8	44	21	67	21	16	82	0

[a] *Calculated for a number of sites, 1 to λ_{max} (in which all species of the indicator group are conserved); L values of ≤ 25 mean the group is a good indicator.*
[b] *Conservation of biodiversity value.*

Table 5. Hierarchy of groups based on their indicator value from Waller-Duncan *t* test (at $\alpha = 0.01$).*

Target group	Range of indicator means and homogeneous subset
Woody plants	woody plants>(birds, aq. herpetofauna)>(Orthoptera, orchids, ter. herpetofauna)
Orchids	orchids (Orthoptera, woody plants)>(aq. herpetofauna, ter. herpetofauna, birds)
Orthoptera	Orthoptera>(woody plants, birds, orchids, aq. herpetofauna, ter. herpetofauna)
Aquatic (aq.) herpetofauna	woody plants, aq. herpetofauna>birds>orchids, Orthoptera>ter. herpetofauna
Terrestrial (ter.) herpetofauna	ter. herpetofauna>Orthoptera, orchids, woody plants, aq. herpetofauna>birds
Birds	birds, woody plants,>aq. herpetofauana>Orthoptera>ter. herpetofauna, orchids
BD	woody plants>aq. herpetofauna, Orthoptera, orchids, birds>ter. herpetofauna

*Dashed lines indicate homogeneous subsets at $\alpha = 0.01$.

group was not a good indicator for any of the groups examined.

Focusing on each target group separately, we ranked the efficiency of complementary networks in conserving each group (Table 5). The complementary network of the target group itself maximized its conservation. However, in two cases—aquatic herpetofauna and birds—the complementary network of woody plants proved as efficient as their own complementary networks. The complementary network of woody plants was therefore an excellent indicator for these two groups. This is another reason why the complementary network of woody plants was the best indicator of the biodiversity in the study area (Table 5).

Discussion

We found little congruence of species-richness patterns among the six indicator groups studied; only one correlation was highly significant (Table 3). Researchers from the tropics (Lawton et al. 1998), the boreal forests of North Europe (Jonsson & Jonsell 1999), and the rainforests of Australia (Oliver & Beattie 1996) found similarly low congruence of species-richness patterns at a small scale. Weak correlations of species-richness patterns have also been found at broader scales in studies of North America (Ricketts et al. 1999) and the tropics (Howard et al. 1998).

Examining the congruence of species-richness patterns is only one of the possible ways to evaluate biodiversity indicators. Another technique is to examine the efficiency of their complementary networks in conserving biodiversity. In our study, both techniques showed that woody plants were the best biodiversity indicator group, but they differed in their outputs concerning the indicator value of the other groups we examined. Reyers and Jaarsveld

(2000) also discuss the fact that different techniques can produce dissimilar and even contrasting results for the same data set.

In our study, although the congruence of species-richness patterns was low, the indicator complementary networks examined missed, on average, ≤25% of species of the target group in 12 out of 30 cases. In other words, the complementary networks of several groups considered indicators adequately conserved groups considered targets. We argue, therefore, in favor of applying the principle of complementarity when examining the value of possible biodiversity indicators rather than using the more traditional technique of cross-taxon congruence of species richness, particularly when working at a local scale. In broad-scale studies, the conclusion of Howard et al. (1998) for the tropics was similar to ours, unlike that of van Jaarsveld et al. (1998) for South Africa.

Both of the techniques we used to examine the value of different species groups as biodiversity indicators showed that woody plants were the best local biodiversity indicator. For the first technique, which examined the cross-taxon congruence of species richness, this result was primarily due to the strong correlation of woody-plant species richness with that of birds and aquatic herpetofauna. For the second technique, examining the efficiency of complementary networks, this result was primarily due to the fact that the complementary network of woody plants was as efficient at conserving birds and aquatic herpetofauna as the optimal networks designed especially for these two groups and succeeded in sufficiently conserving the species of Orthoptera and terrestrial herpetofauna.

Broad-scale studies show that vegetation is a good biodiversity surrogate (Dobson et al. 1997; Osborn et al. 1999; Ricketts et al. 1999), given its keystone character for a number of taxonomic groups dependent on vegetation (Peck 1989; Crisp et al. 1998; Ferris & Humphrey 1999).

This was not always the case in small-scale studies: herbaceous plants proved inadequate to predict the species richness of farmland birds or endangered species in Sweden (Pärt & Söderström 1999; Vessby et al. 2002).

The indicator value of woody plants has not been examined in the Mediterranean. Little study has been done of potential biodiversity indicators in this area. Woody plants proved an adequate biodiversity surrogate for other groups and for biodiversity. If this result holds for other Mediterranean areas, it will provide a powerful tool for the design of reserve networks in the region using only woody plants.

For the bird group, our results showed a significant predictive power of biodiversity, which is in agreement with findings of studies at broader scales (Prendergast et al. 1993; Lombard 1995). Nevertheless, we did not show that bird complementary networks conserve biodiversity as adequately as woody plants.

Similarity of species-richness patterns can be interpreted in terms of common responses to local environmental factors. For instance, the main ecological factor affecting the species distribution of terrestrial herpetofauna (Strijbosch et al. 1989) and Orthoptera fauna (Kati et al. 2004) in the study area is aridity. The good indicator value of the complementary network of woody plants can be explained in an analogous way. In terms of biomass, woody plants dominate the Mediterranean environment and constitute the basic structural characteristics of landscape, defining the different habitat types (Blondel & Aronson 1999). Given that environmental heterogeneity is one of the main factors generating biological diversity (Huston 1994), we argue that to a large extent the complementary network of woody plants captures the gradient of environmental heterogeneity and thus constitutes a reliable local biodiversity surrogate in Mediterranean areas.

In practical terms, our results suggest that a conservation scheme targeting maintenance of the diversity of woody plants would also guarantee maintenance of small terrestrial birds and aquatic herpetofauna. Additional protection of the richest in terrestrial herpetofauna sites would also result in protection of Orthoptera fauna, and vice versa. In the applied context, our results also provide a scientific background on which the pilot biomonitoring program of the Dadia Reserve, currently under development, could be based. This program will monitor ecological values of the reserve over time. Because the black vulture (*Aegipius monachus)* and other breeding raptor populations are recognized as the conservation targets, the program is aimed primarily at monitoring vegetation, which is important as nesting ground for raptors (Poirazidis et al. 2002). Our results suggest that woody plants, being an adequate local biodiversity indicator, can be used for rapid and rather inexpensive monitoring of many biodiversity values of the Dadia Reserve, not only raptors.

Our results showed the importance of applying the principle of complementarity instead of only testing the congruence of species-richness patterns when assessing the value of potential biodiversity indicators. For the first time, the indicator value of Orthoptera and orchids was examined, and Orthoptera were good indicators of terrestrial herpetofauna, particularly in forest sites. Woody plants were an adequate biodiversity indicator for the particular Mediterranean area we studied. If this were to prove true in general, it would greatly facilitate conservation efforts and related decision making in the Mediterranean region.

Acknowledgments

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