

Status and changes of ground vegetation at the CONECOFOR plots, 1999 - 2005

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Abstract – The vegetation dataset (1999-2005) of the CONECOFOR network is analyzed in the paper, to produce a present-day status and evaluation of changes in a sub-set of Permanent Monitoring Plots (PMPs). Descriptors such as mean number of species (community and population scale), diversity indices and species turnover were selected. Each PMP was investigated to evaluate: (i) type and direction of variations; (ii) significant changes of species indicator values. At the community level, significant variations in richness occurred in sites affected by recent anthropic or natural disturbances. In few PMPs directional changes can be observed; in most of cases a typical fluctuation pattern (more or less regular) was detected. The use of *a priori* reference standard (RS) supported the interpretation of changes. At finer scale (population level), annual richness variations are frequent but of minor importance. Higher values of species turnover occurred in communities under intense dynamic processes, interested by disturbance or influenced by neighboring communities. The abundance of *nitrophilous* species was consistent in beech forests, while the contribution of *acidophilous* species was not important. Moreover, our results suggest that: (a) the data collected at the community level seem more sensitive to describe important changes at the forest stand level; (b) a strong relationship is present between plant diversity and the forest dynamical state. The inherent non-linear dynamics of forest regeneration processes emphasizes the needs of long-term datasets for detecting the plant diversity responses to environmental changes.

Key words: forest monitoring, long term studies, species diversity, Reference Standard, species richness, species turnover, species indicator values.

Riassunto – Stato e cambiamenti della vegetazione nelle aree CONECOFOR nel periodo 1999 - 2005. In questo contributo viene analizzato il set di dati sulla vegetazione (1999-2005) della rete CONECOFOR per valutare lo stato ed i cambiamenti in alcuni Plot di Monitoraggio Permanenti (PMP). A tale scopo si sono selezionati descrittori quali il numero medio di specie (sia a scala di comunità che di popolazione) indici di diversità e di turnover di specie. Ciascun PMP è stato analizzato per valutare (i) tipologia e tendenza delle variazioni e (ii) cambiamenti significativi dei valori indicatori delle specie. A livello di comunità, significative variazioni in ricchezza si sono rilevate in siti influenzati da recenti disturbi. In pochi PMP sono apprezzabili cambiamenti direzionali, mentre, nella maggior parte dei casi, si sono verificati dei modelli di fluttuazione (più o meno regolari). L'utilizzo di uno Standard di Riferimento (RS) definito *a priori*, ha supportato la valutazione dei cambiamenti. A scala fine (livello di popolazione), le variazioni annuali della ricchezza specifica sono frequenti, ma di minor importanza. I più alti valori di turnover delle specie si sono registrati in comunità guidate da intensi processi dinamici, interessate da disturbi o da altre comunità confinanti. L'abbondanza delle specie *nitrofile* era consistente nelle foreste di faggio, mentre il contributo delle *acidofile* non ha mostrato particolari evidenze. Inoltre, i nostri risultati suggeriscono: (a) i dati raccolti a livello di comunità sembrano più sensibili a descrivere importanti cambiamenti a livello di stand forestale; (b) una forte relazione tra diversità di piante e stato dinamico della foresta. La dinamica non lineare del processo di rigenerazione enfatizza la necessità di dataset a lungo termine per poter determinare la risposta della diversità di piante ai cambiamenti ambientali.

Parole chiave: monitoraggio foreste, studi a lungo termine, diversità specifica, Standard di Riferimento, ricchezza specifica, turnover di specie, valore indicatore delle specie.

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Abbreviations: PMP = Permanent Monitoring Plot; SU = Sampling Unit; QA = Quality Assessment; QC = Quality Control; RS = Reference Standard; T = species turnover; S = Sørensen's index Dissimilarity; N = Nitrophilous species; A = Acidophilous species;

Introduction

People, politicians and resource managers call for a basic understanding of potential hu-

man effects on forests health (ANDERSON *et al.* 2000; SPELLEMBERG 2005). Anthropic activity may influence a variety of ecological attributes including the presence of species, populations, and communities as well as

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the occurrence, rate, or scale of processes (ANGERMEIER and KARR 1994; CAMPETELLA *et al.* 2004). Understanding the implications of anthropogenic disturbances on an ecological system is complicated by variability in ecological response. Identification of indicators which capture key ecological responses to human actions provides a useful tool for improving understanding of ecological effects and for monitoring and management (DALE *et al.* 2002). Among the variables describing the forests condition, a huge amount of literature demonstrated that ground vegetation is strictly related to several ecological aspects (ELLEMBERG 1992; WILSON *et al.* 2003; PIGNATTI 2005; GRAY and AZUMA 2005; LENIÈRE and HOULE 2006; KREYER and ZERBE 2006) and sensitive to the atmospheric pollution (BRUNET *et al.* 1996; GRANDIN 2004; TAMIS *et al.* 2005, CANULLO *et al.* 2006). In fact, plant population can be used as indicators for soil acidity and nutrient availability, important factors leading to changes of site conditions (ELLEMBERG 1992; SEIDLING 2005). The availability of regional "biological floras" offers detailed datasets of species indicator values, which can be used for the interpretation of local data (BORHIDI 1993; BOHLING *et al.* 2002; PIGNATTI 2005). Ground floor vegetation also plays a key role in determining plant biodiversity of temperate forest (SEIDLING 2005), and it represents an excellent indicator of human impacts and natural processes (ZAS and ALONSO 2002; HOLESKA 2003; HANLEY 2005; ZANNE and CHAPMAN 2005; CANULLO and CAMPETELLA 2006b; GONZÁLEZ-RIVAS 2006).

The Italian intensive forest ecosystem monitoring network (CONEFOFOR) consists now of 31 permanent plots and is part of the International Co-operative Programme on Assessment and Monitoring of Air

Pollution Effects on Forests (ICP Forests) (DE VRIES *et al.* 2003). After 10 years (1996 – 2006) of vegetation assessments, the consistency of temporal information leads, at least in a subset of PMPs (11 of them, each of 0.25 ha, Table 1), to produce a present-day status and changes evaluation respect to the starting point (t_0), with a corroborated ecological meaning, as foreseen in a previous contribution (CANULLO *et al.* 2006). The primary aim of this report is to define the status of the PMPs from the point of view of plant diversity components. Secondly, the investigation on possible significant changes was performed by using the vegetation data sets. Particular attention was devoted to: (i) type and direction of variations (*i.e.* directional, cyclic, irregular variations), (ii) significant changes of species indicator values (acidophilous and nitrophilous species). To face with the above mentioned questions we selected some descriptors, such as mean number of species per sampling unit (SU), diversity indices of common use (CAMPETELLA and CANULLO 2000; CANULLO *et al.* 2006), frequency and mean cover of species sharing certain ecological indications (*sensu* ELLEMBERG 1992). Since species composition and species diversity responses are not always related, species turn-over indices as well as diversity *per se* were considered (ROBERTS and GILLIAM 1995).

Each kind of ecosystem can be characterized by strict relationships between temporal scale and processes, with a huge range distribution (FALINSKI 1986). In case of forest ecosystem, 10 years still represent a narrow window to detect important dynamics aspects (*i.e.* time series analysis). However, considering the consistency of our data set, we guess that a robust reference standard (RS) might be detected as basic

Table 1 – General information on the CONEFOFOR PMPs presenting the larger series of diachronic observations (1999-2005). The last column includes the total number of species recorded in all surveys (vascular plants, bryophytes and lichens included) at both the community and population level.
Informazioni generali sui PMP della rete CONEFOFOR dove si posseggono le più ampie serie di dati diacronici (1999-2005). L'ultima colonna include il numero complessivo di specie raccolte in tutti i rilevamenti effettuati (piante vascolari, briofite e licheni inclusi) sia a livello di popolazione che di comunità.

| N | Site name | Italian Region | Latitude | Longitude | m a.s.l. | Forest type | cumulative species number |
|----|--------------------------|-----------------------|----------|-----------|----------|------------------|---------------------------|
| 1 | ABR1 - Selvapiana | Abruzzo | +415051 | +133523 | 1500 | beech | 50 |
| 3 | CAL1 - Piano Limina | Calabria | +382538 | +161047 | 1100 | beech | 76 |
| 4 | CAM1 - Serra Nuda | Campania | +402558 | +152610 | 1175 | beech | 91 |
| 5 | EMI1 - Carrega | Emilia | +444306 | +101213 | 200 | sessile-oak | 81 |
| 7 | FRI1 - Bosco Boscat | Friuli-Venezia-Giulia | +454958 | +131004 | 6 | hornbeam-oak | 85 |
| 9 | LAZ1 - Monte Rufeno | Lazio | +424950 | +115410 | 690 | turkey-oak | 145 |
| 10 | LOM1 - Val Masino | Lombardia | +461416 | +093316 | 1190 | spruce (and fir) | 111 |
| 11 | MAR1 - Roti | Marche | +431738 | +130424 | 775 | turkey-oak | 92 |
| 16 | TOS1 - Colognole | Toscana | +433034 | +102119 | 150 | holm-oak | 59 |
| 19 | VAL1 - La Thuile | Valle d'Aosta | +454326 | +065555 | 1740 | spruce | 140 |
| 20 | VEN1 - Pian di Consiglio | Veneto | +460326 | +120156 | 1100 | beech | 70 |

aspect of monitoring activity (*i.e.* mean values related to first years of observation). Significant departures from standard reference may indicate important change (HELLAWELL 1991). Vegetation is also a complex spatial phenomenon, and its scale dependence (pattern and processes) is generally accepted, just as the mosaic nature of plant communities is well recognized at different hierarchical levels (JUHÁSZ-NAGY 1985; PODANI *et al.* 1993; BARTHA *et al.* 1998; CANULLO and CAMPETELLA 2006a). As our databank contains the vegetation records from two approaches at different scale (population level on the understorey, community level on whole plot, CAMPETELLA and CANULLO 2000), we analyzed their relative output, in order to verify if and how the same dynamical status can appear with different “indicators” variations at the investigated scales.

Methods

Data collection

In the present paper, for reasons related to data quality and sampling procedures (CANULLO *et al.* 2006), the evaluation of species composition focused on vascular plants and considered the data set originating from the surveys carried out from 1999 to 2005 (Table 1). According to the ICP-Forests Manual on Ground Vegetation Assessment (DUPOUEY 1998; AAMLID *et al.* 2002), the sampling design is related to the internal area of each PMP and it considers two different approaches (Figure 1):

- large scale, previously called “community level”;
- fine scale, or “population level”.

At the community level, twelve 10x10 m sampling units (SU) out of the 25 possible within each 50x50 m fenced PMP were systematically selected in a chess-board pattern to minimize spatial correlation (further details: CANULLO *et al.* 1999, 2001, 2006; CAMPETELLA and CANULLO 2000). The specific cover for the tree, shrub, herb and moss layers was recorded by visual cover estimates, according to the phytosociological method, assigning each species to correspondent classes (BRAUN-BLANQUET 1951), further transformed in percent median values according to VAN DER MAAREL (1979). At the population level, a systematic grid of one-hundred 50x50 cm quadrates was selected within the fenced PMP (Figure 1). Species-specific cover estimates, density of rooting functional individuals, and frequency of mechanical and parasitic damages

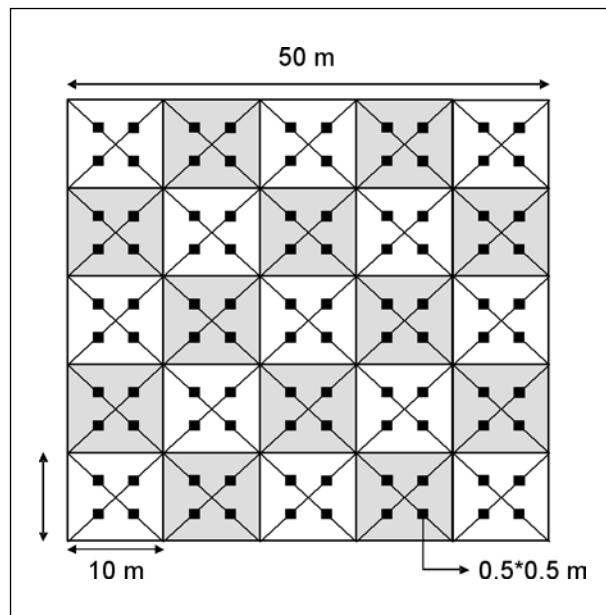


Figure 1 – Sampling design adopted for vegetation assessments within the PMPs of the Italian network (CONECOFOR). Twelve 10*10m sampling units were selected for monitoring at the community level (shaded ones). One-hundred 0.5*0.5 m quadrates were identified for the monitoring at the population level (black squares along diagonals) (based on CANULLO *et al.* 1999a).

*Disegno di campionamento adottato per le stime della vegetazione nei PMP della rete italiana (CONECOFOR). 12 unità di campionamento 10x10m sono state selezionate per il monitoraggio a livello di comunità (unità ombreggiate). Cento quadrati 0.5*0.5m sono stati utilizzati per il monitoraggio a livello di popolazione (quadrati neri lungo le diagonali) (basato su CANULLO *et al.* 1999a).*

were recorded in the understorey (up to the height of 1.3 m). In this paper, only data obtained from the summer surveys of both the approaches were used to estimate indices and descriptors. In all the initial 20 PMPs of the network (now increased to 31) the vegetation assessment began in 1996. After the validation of both the field methodology and Quality Assessment of data (QA), with the exception of SIC1, all the 19 PMPs were visited during 1999 in order to have the initial standard description of plant diversity at the various plots. On the other hand, data covering the 1999-2005 period were available only for 11 PMPs and were used to explore our hypotheses. At the population level the data of 2003 and 2004 are incomplete or missing.

Quality Assurance (QA)

In order to improve the consistency and data sets comparability, a Quality Control (QC) programme has been applied, with clearly defined quality objectives.

A Quality Assurance programme was implemented, including:

1. Field manual adoption (CANULLO *et al.* 1999) to assure harmonization.
2. Definition of Measurement Quality Objectives and Data Qualities for each parameter.
3. Annual team-training course, consisting in harmonization and field intercalibration of all the teams composed of two members including a control team; repeated observations on the same plot were also performed.
4. The control team carries out field controls on randomly chosen PMPs and a related fraction of SU; this control is used to observe the concordance between values recorded by the control team and the survey teams. Departure from expected values can be used to define the agreement with Quality Objectives thresholds (in case, refusal will be considered).
5. The data acquisition is successive to further validation executed by data-base procedures, in order to ascertain the consistency and plausibility of the data. After the taxonomical validation according to PIGNATTI's Italian flora (1982), the database performs some checks, verifying the correspondence with a set of thresholds previously defined by the system supervisor. Further inspections of data integrity for observations on both community and population levels are also performed. Finally, the automatic association between the Italian flora archive and the coded archive of *Flora Europaea* is performed (derived from the PANDORA taxonomic database system of the Royal Botanic Garden, Edinburgh; ICP-Forests-BHF 2007).

For more details on Data Quality programme, see also CANULLO *et al.* (2002).

Data analysis

Vascular plant species richness was expressed as the total number of vascular species identified in the SUs, the mean number of species *100 m² and the mean number of species *2500 cm² (± confidence interval at p=0.05). To appreciate the species turnover (*i.e.* differences in species composition) along the diachronic estimations, two descriptors of species variation were considered for data collected on 10*10 m SUs.

The species turnover score was assessed for each SU as follows

$$T = (S_{t0} + S_{t1}) - (2 \times C)$$

where S_{t0} is the number of species recorded in a reference year and S_{t1} the number of species collected in the next year, C represents the shared species number.

The Sørensen's index of dissimilarity (1-Sørensen) is frequently considered as a *beta* diversity estimator. It gives a measure of heterogeneity in plant species composition between sites or - as in our case - diachronic relevées (MAGURRAN 2003). It was assessed for each SU as follows

$$S = 1 - [(2 \times C)/(S_{t0} + S_{t1})]$$

where the symbols have the above mentioned meaning. The index ranges from 0 to 1, the latter indicating the maximum dissimilarity.

At the community level, richness-abundance relations were assessed using the Shannon index. This non-parametric estimator can be considered a good indicator of the heterogeneity level (PEET 1974), incorporating both Evenness and species richness.

The index was calculated by the following formula:

$$H' = -\sum pi \log_2 (pi)$$

where pi is the relative abundance of the species i . As suggested by the results of the previous report, only the mean cover of species was used as abundance parameter in this paper, as it gives a more realistic representation of the textural contribution of the species (CANULLO *et al.* 2006). The pi parameter is estimated using ci/C in which ci is the average relative cover of the species i in all layers of the 12 SUs, and C is the summation of the average relative cover of all species. To analyze the cover distribution level among species, the Shannon Evenness was also calculated as follows:

$$E = H'/H'_{\max}$$

where H'_{\max} represents the maximum H' at the given species richness ($H'_{\max} = \log_2 S$, where S is the total number of species).

The population level data are very suitable for the application of the diversity index based on Fisher's logarithmic series (FISHER *et al.* 1943). This is one of the most widely used indices which have a relative

stability respect to the variation of the sampled area size, has a good discriminate power, and can be calculated quite easily (MAGURRAN 2003):

$$S = \alpha \ln (1 + N/\alpha)$$

where α (specific-individual diversity) is obtained as follows:

$$\alpha = N(1-x)/x$$

in which x is derived from the iterative solution of the following equation:

$$S/N = (1-x)/x[-\ln(1-x)]$$

where S is the total number of species and N is the number of functional individuals, or ramets of modular organisms (HARPER 1977) collected in the complete sample (100 SU). In our case only the species rooting inside the SU were considered.

As the 10*10 m SUs approach collected an higher number of species, highly related to the total richness (FERRETTI *et al.* 2006), all the vascular species from summer surveys (1999-2005) within the sampling system, were assigned to widely accepted "ecological" groups (SAGE *et al.* 2005; FISCHER *et al.* 2002). Ellenberg's indicator values for the Italian flora (PIGNATTI 2005) were modified to summarize few indicators of different environmental conditions (soil pH, nitrogen and nutrient contents). The time variation of mean cover and frequency of *nitrophilous* and *acidophilous* plants species belonging to the upper fourth of the index range were considered as an additional overall ecosystem evaluation.

The repeated measurements on the same SUs (at both the scales) at more than two time-points leads to inherent autocorrelation. Therefore, in order to appreciate possible significant differences in species richness over time, the Repeated Measures ANOVA (RMA) test has been applied in each PMP, considering the variation of mean species number recorded on the 10*10m SUs (Within-Subjects Effects test); possible linear trend over time was also tested (Within-Subjects Contrasts test). In the PMPs where the Within-Subjects Effects test gives significant variation in richness ($p < 0.05$), the Bonferroni test was applied in order to compare all possible pairwise of temporal data. Significant differences of species turnover estima-

tors (T and S) and abundance of *nitrophilous* and *acidophilous* species over time were also assessed by RMA procedure.

The distribution of species richness at the population level (SUs 50*50cm) wasn't normal, thus the Friedman's non parametric test was used to assess significant differences over time. The linear regression for both Shannon and Fisher indices values vs. time were also calculated, by estimating the angular coefficient and its significant level by ANOVA.

Moreover, a baseline standard was established for each estimator (diversity indices not included). Considering the monitoring period length and data storage quantity, we *a priori* considered the first 4 years of data collection as surveillance period and its related mean value as monitoring reference (Reference Standard - RS), defined by the confidence intervals at 99%. Yearly mean values departing from such interval can be interpreted as important variations. Such possible changes are expected to have a more robust ecological meaning respect to that obtained by the traditional statistic tests. Data representing ecological values are inherently susceptible of unpredictable errors (*i.e.* interpretation), and then the confidence interval was calculated at 99.9%.

Nomenclature of species follows *Flora Europaea* (TUTIN *et al.* 1964 -1980).

Results

Community level

Species richness

The annual changes in mean number of species *100 m⁻² over the period 1999-2005 are shown in Table 2. As in the previous report, the Variation Coefficient on each PMP resulted almost stable (lower than 25%) within the observation period, indicating a good stationarity and (assuming 15% of tolerable error) the number of SUs was always adequate. Annual mean species variations are frequent and can be due to natural cycles of vegetation structure and/or recovery from previous disturbances (natural or man induced by forest management). With the only exception of CAL1, LOM1 and VAL1, the RMA test revealed significant changes in species richness over the period (Between-subjects effect). A significant linear positive trend was reported for CAM1, FRI1 and VEN1, while LAZ1 presents negative tendency (Table 2: Between-subjects contrast test). The Bonferroni *post-hoc* test

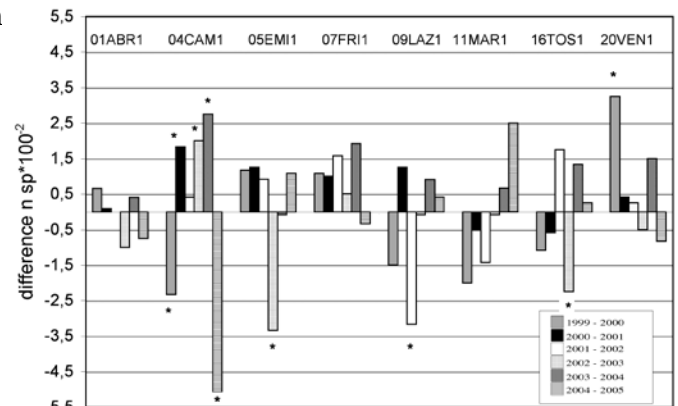
Table 2 – Annual changes in species richness. Total number of vascular species listed in the sampled area and mean number of species*100 m⁻² (and its confidence interval) in each PMP (CONECOFOR data sets range 1999-2005). Significant differences among the diachronic observations (Within-subjects effects) and significant linear trend (Within-subjects contrasts) based on Repeated Measures Anova test are in bold. A reference standard (mean values of the first four years of observation, delimited by confidence interval at 99%) was also reported. Underlined values state significant departures from RS.

*Cambiamenti annuali nella ricchezza specifica. Numero totale di specie vascolari rinvenute nell'area campionata e numero medio di specie*100 m⁻² (e suo intervallo di confidenza) in ogni PMP (CONECOFOR dataset 1999-2005). Le differenze significative tra osservazioni diacroniche (Within-subjects effects) ed i trend lineari significativi (Within-subjects contrasts) sono evidenziati in grassetto (Repeated Measures Anova). Viene inoltre riportato un riferimento standard (RS, valore medio dei primi quattro anni di osservazione, delimitati dall'intervallo di confidenza al 99%). I valori sottolineati certificano variazioni significative dal RS.*

| Plot | Indicator | Years | | | | | | | Repeated Measures Anova | | Reference Standard |
|--------|----------------------------|--------------|--------------|-------|--------------|--------------|--------------|-------------|-------------------------|----------------------------|------------------------|
| | | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Between-subj effect (p) | Between-subj contrasts (p) | |
| 01ABR1 | total number of species | 23 | 24 | 22 | 22 | 19 | 21 | 21 | 0.044 | 0.152 | 9.46 (± 0.85) |
| | n sp * 100 m ⁻² | 8.92 | 9.58 | 9.67 | 9.67 | 8.67 | 9.08 | <u>8.33</u> | | | |
| | confidence interval (±) | 1.26 | 1.30 | 1.35 | 1.35 | 1.23 | 1.28 | 1.69 | | | |
| 03CAL1 | total number of species | 34 | 31 | 35 | 34 | 31 | 32 | 37 | 0.352 | 0.425 | 17.15 (± 1.07) |
| | n sp * 100 m ⁻² | 17.41 | 17.66 | 17.25 | 16.16 | 16.75 | 17.50 | 16.83 | | | |
| | confidence interval (±) | 1.98 | 2.03 | 1.65 | 1.45 | 1.50 | 1.86 | 2.41 | | | |
| 04CAM1 | total number of species | 31 | 26 | 28 | 35 | 33 | 39 | 29 | 0.000 | 0.002 | 14.10 (± 0.99) |
| | n sp * 100 m ⁻² | 14.83 | <u>12.50</u> | 14.33 | 14.75 | <u>16.75</u> | <u>19.50</u> | 14.41 | | | |
| | confidence interval (±) | 1.92 | 1.26 | 1.37 | 1.13 | 1.13 | 1.64 | 1.06 | | | |
| 05EMI1 | total number of species | 28 | 37 | 41 | 39 | 27 | 31 | 27 | 0.000 | 0.578 | 13.23 (± 0.89) |
| | n sp * 100 m ⁻² | <u>11.41</u> | 12.58 | 13.83 | <u>14.75</u> | <u>11.41</u> | <u>11.33</u> | 12.41 | | | |
| | confidence interval (±) | 1.00 | 1.42 | 1.00 | 1.22 | 1.09 | 1.47 | 1.26 | | | |
| 07FRI1 | total number of species | 53 | 53 | 55 | 53 | 57 | 61 | 63 | 0.000 | 0.000 | 25.96 (± 1.36) |
| | n sp * 100 m ⁻² | <u>24.25</u> | 25.33 | 26.33 | <u>27.91</u> | <u>28.41</u> | <u>30.33</u> | <u>30</u> | | | |
| | confidence interval (±) | 2.31 | 1.97 | 1.88 | 1.95 | 1.62 | 1.76 | 1.34 | | | |
| 09LAZ1 | total number of species | 55 | 55 | 57 | 52 | 50 | 49 | 54 | 0.000 | 0.011 | 22.23 (± 1.75) |
| | n sp * 100 m ⁻² | 23.50 | 22.00 | 23.25 | <u>20.08</u> | <u>20.00</u> | 20.91 | 21.33 | | | |
| | confidence interval (±) | 3.14 | 2.53 | 2.47 | 2.30 | 2.43 | 2.29 | 2.12 | | | |
| 10LOM1 | total number of species | 53 | 56 | 55 | 58 | 62 | 56 | 57 | 0.654 | 0.423 | 28.93 (± 2.00) |
| | n sp * 100 m ⁻² | 29.09 | 28.54 | 29.54 | 28.54 | 29.18 | 28.45 | 27.90 | | | |
| | confidence interval (±) | 2.94 | 3.36 | 2.77 | 2.91 | 2.20 | 2.44 | 2.86 | | | |
| 11MAR1 | total number of species | 64 | 64 | 61 | 60 | 60 | 60 | 62 | 0.001 | 0.207 | 28.98 (± 1.67) |
| | n sp * 100 m ⁻² | <u>31.08</u> | 29.08 | 28.58 | <u>27.16</u> | <u>27.08</u> | 27.75 | 30.25 | | | |
| | confidence interval (±) | 1.98 | 2.62 | 2.75 | 2.52 | 2.01 | 2.25 | 2.91 | | | |
| 16TOS1 | total number of species | 37 | 34 | 33 | 35 | 33 | 35 | 36 | 0.010 | 0.534 | 15.67 (± 1.13) |
| | n sp * 100 m ⁻² | 16.33 | 15.25 | 14.66 | 16.41 | <u>14.16</u> | 15.50 | 15.75 | | | |
| | confidence interval (±) | 1.74 | 1.54 | 1.62 | 1.92 | 1.68 | 1.37 | 1.75 | | | |
| 19VAL1 | total number of species | 34 | 35 | 37 | 34 | 32 | 34 | 33 | 0.739 | 0.300 | 13.67 (± 0.82) |
| | n sp * 100 m ⁻² | 13.83 | 13.91 | 13.50 | 13.33 | 13.75 | 13.25 | 13.24 | | | |
| | confidence interval (±) | 1.40 | 1.22 | 1.26 | 1.19 | 1.56 | 1.32 | 1.40 | | | |
| 20VEN1 | total number of species | 26 | 33 | 33 | 34 | 36 | 38 | 35 | 0.000 | 0.001 | 14.92 (± 1.14) |
| | n sp * 100 m ⁻² | <u>12.16</u> | 15.41 | 15.83 | <u>16.08</u> | 15.58 | <u>17.08</u> | 16.25 | | | |
| | confidence interval (±) | 1.01 | 1.03 | 1.94 | 1.80 | 1.70 | 1.79 | 2.20 | | | |

considered all pairwise comparisons in the richness data, detecting in which surveys significant variation appears (Figure 2).

Figure 2 – Changes in mean number of species*100m⁻² occurred in each couples of consecutive years. Here are considered only the PMPs that reported significant variation (Between-subjects effect test) in the considered period (1999-2005). When appropriate, the results of Bonferroni test have been reported (p<0.05, star indicates significant variations).
*Variazioni nel numero medio di specie*100m⁻² in ciascuna coppia di anni consecutivi. Vengono considerati solo i PMP che hanno riportato variazioni significative (Between-subjects effect test) nel periodo considerato (1999-2005). I risultati del test Bonferroni sono stati riportati (p<0.05, gli asterischi indicano variazioni significative).*



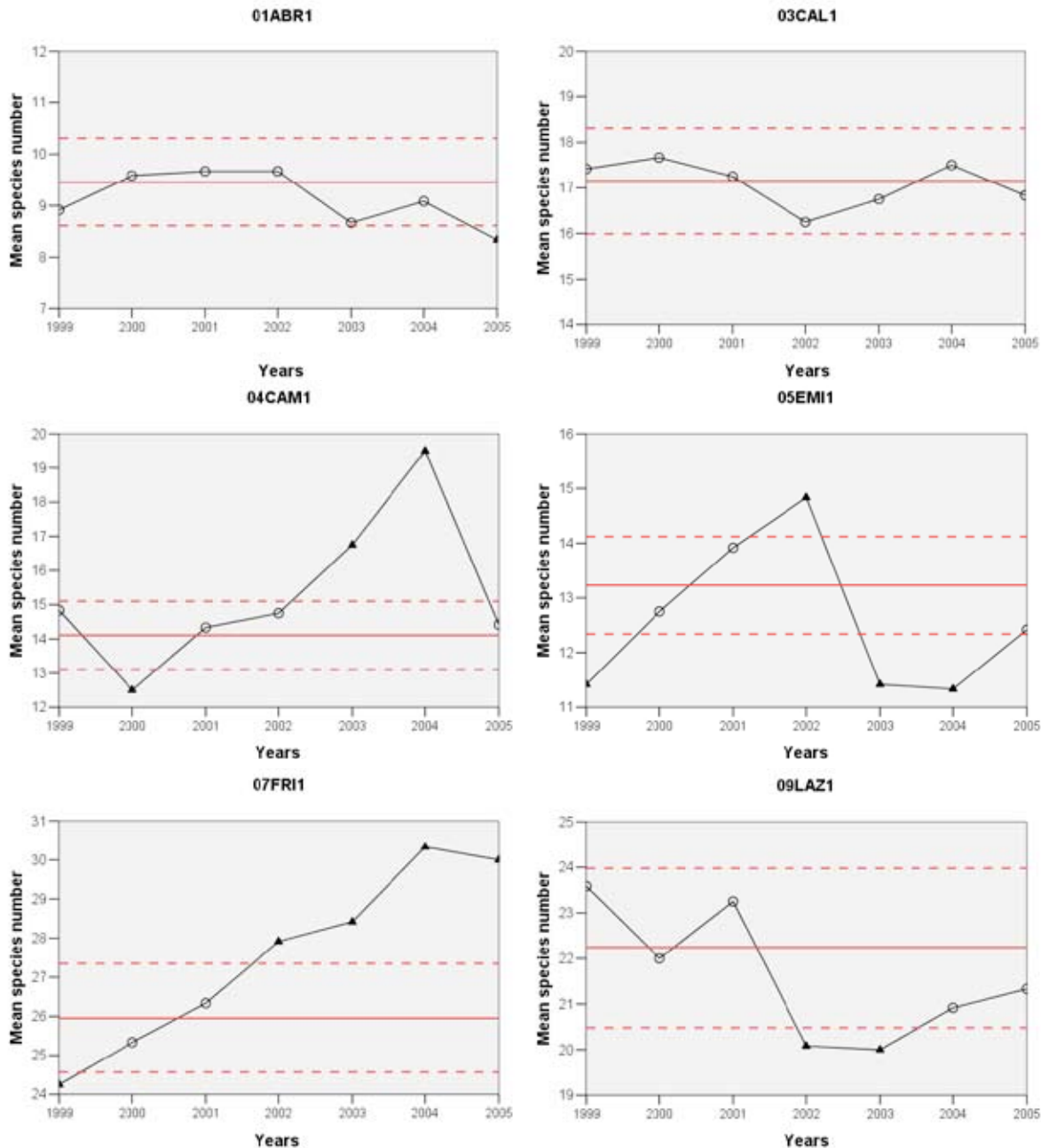


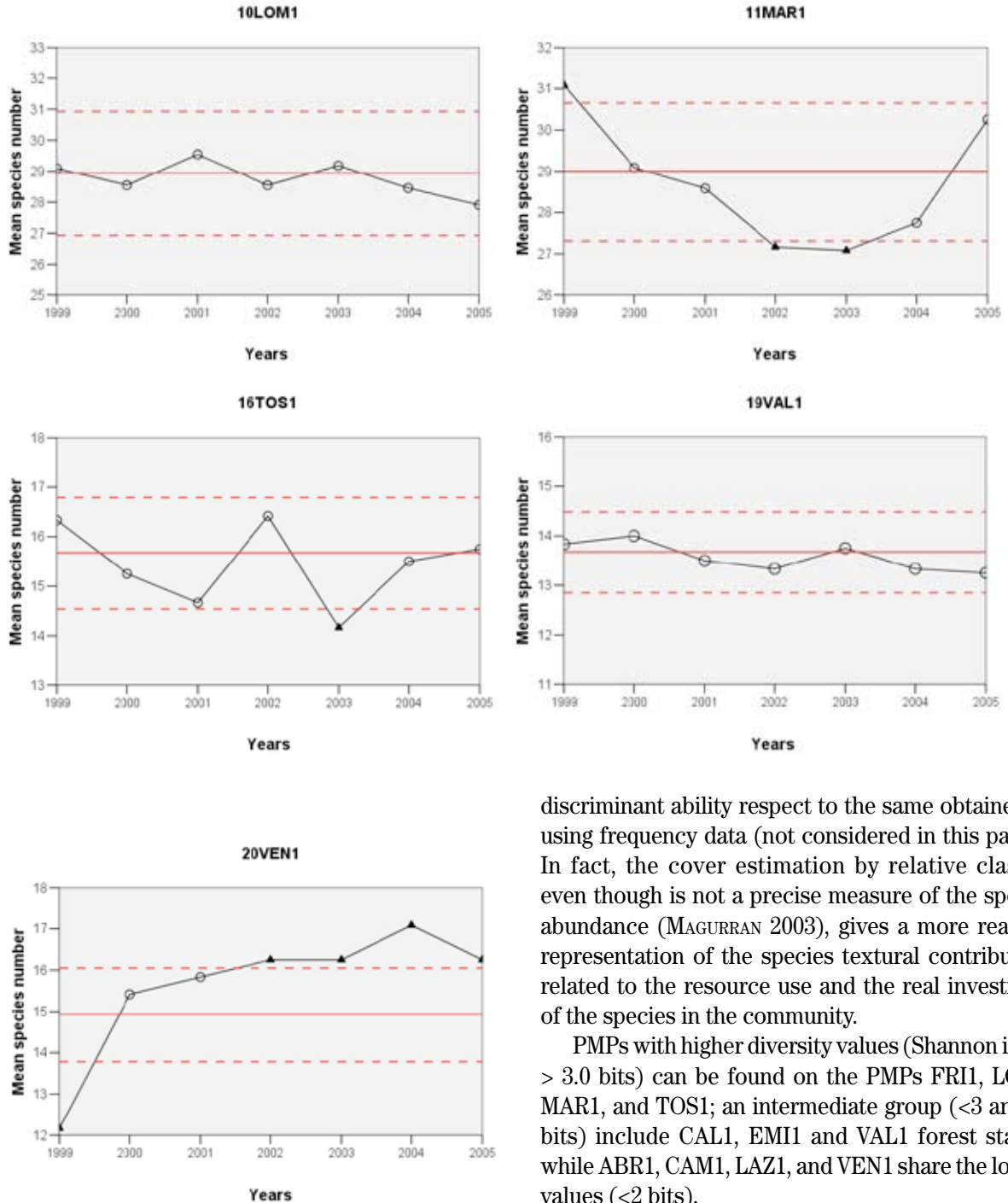
Figure 3 – Control graphs on 11 PMPs of the CONECOFOR network. Variation of species mean number $\cdot 100 \text{ m}^2$ in the considered period is compared to the reference standard (RS). The straight line represents the mean value of the first 4 years while dotted lines indicate the upper and lower values of confidence interval ($p < 0.01$). Dark triangles represent significant departure from RS. (Continue next page).

Grafici di controllo su 11 PMP della rete CONECOFOR. Le variazioni del numero medio di specie $\cdot 100 \text{ m}^2$ nel periodo considerato viene comparato con lo standard di riferimento (RS). La linea continua rappresenta il valore medio dei primi 4 anni mentre le linee tratteggiate indicano i limiti dell'intervallo di confidenza ($p < 0.01$). I triangoli neri rappresentano variazioni significative rispetto ad RS. (Continua alla pagina seguente).

In Figure 3, control graphs reported significant departures of richness values from reference standard (RS). CAL1, LOM1 and VAL1 PMPs didn't show significant variations respect to the standard reference, indicating an evident richness stability in the considered period. All of them are located in high forest

communities, with a stabilized tree structure, which have been neither affected by known disturbances nor influenced by neighbouring open communities. ABR1 presents the narrowest RS confidence interval. As it is high forest too, it depicts a similar situation to the previous areas: the variation in richness was very low

figure 3 (continued)



in the first years with a significant reduction of species number at the last term.

Shannon index

Shannon index and its relative Evenness were based on the specific mean cover contribution by SU (Table 3); in the previous report they performed a good

discriminant ability respect to the same obtained by using frequency data (not considered in this paper). In fact, the cover estimation by relative classes, even though is not a precise measure of the species abundance (MAGURRAN 2003), gives a more realistic representation of the species textural contribution, related to the resource use and the real investment of the species in the community.

PMPs with higher diversity values (Shannon index > 3.0 bits) can be found on the PMPs FRI1, LOM1, MAR1, and TOS1; an intermediate group (<3 and >2 bits) include CAL1, EMI1 and VAL1 forest stands, while ABR1, CAM1, LAZ1, and VEN1 share the lowest values (<2 bits).

The values of Evenness range from 0.10 to 0.76 (Table 3). The PMPs where such index reach the higher values are MAR1 (0.57), FRI1 (0.63), LOM1 (0.63) and TOS1 (0.76), which are forests submitted to anthropic disturbance and with a good proportion of woody species and internal heterogeneity.

The communities where the Evenness resulted

Table 3 – Shannon index and the relative Evenness values for vascular species at the community level in the PMPs of the CONEFOR network. The indices values vs. time linear regression were accomplished. Significant directional changes occurred in 07FRI1, LOM1 and VEN1 PMPs. Bold figure indicate significant values ($p < 0.05$).

Risultati dell'indice di Shannon e del relativo Evenness per le specie vascolari a livello di comunità nei PMP della rete CONEFOR. Sono riportati anche i valori della regressione lineare degli indici rispetto al tempo. Variazioni direzionali significative si registrano nei PMP FRI1, LOM1 e VEN1. I valori in grassetto indicano cambiamenti significativi ($p < 0.05$).

| PMPs | 1999 | 2000 | 2001 | years | | | | linear regression vs. time | | |
|---------------|-------|-------|-------|-------|-------|-------|-------|----------------------------|--------|--------------|
| | | | | 2002 | 2003 | 2004 | 2005 | R ² | b | p |
| 01ABR1 | | | | | | | | | | |
| H' | 0.810 | 0.574 | 0.805 | 0.805 | 0.717 | 0.677 | 0.369 | 0.331 | -0.043 | 0.177 |
| E | 0.179 | 0.125 | 0.181 | 0.181 | 0.169 | 0.154 | 0.084 | 0.508 | -0.009 | 0.245 |
| 03CAL1 | | | | | | | | | | |
| H' | 2.362 | 1.570 | 2.018 | 1.792 | 2.029 | 2.005 | 2.385 | 0.064 | 0.034 | 0.586 |
| E | 0.464 | 0.316 | 0.393 | 0.352 | 0.409 | 0.401 | 0.380 | 0.114 | -0.002 | 0.808 |
| 04CAM1 | | | | | | | | | | |
| H' | 1.500 | 1.262 | 1.322 | 1.176 | 1.438 | 1.723 | 1.574 | 0.513 | 0.045 | 0.239 |
| E | 0.302 | 0.268 | 0.275 | 0.229 | 0.285 | 0.326 | 0.324 | 0.428 | 0.007 | 0.338 |
| 05EMI1 | | | | | | | | | | |
| H' | 2.443 | 2.405 | 2.588 | 2.469 | 2.243 | 2.404 | 2.490 | 0.152 | -0.071 | 0.746 |
| E | 0.508 | 0.461 | 0.483 | 0.467 | 0.471 | 0.485 | 0.523 | 0.267 | 0.003 | 0.562 |
| 07FRI1 | | | | | | | | | | |
| H' | 3.263 | 3.276 | 3.329 | 3.510 | 3.544 | 3.719 | 3.633 | 0.944 | 0.079 | 0.001 |
| E | 0.569 | 0.571 | 0.575 | 0.612 | 0.607 | 0.627 | 0.607 | 0.842 | 0.009 | 0.018 |
| 09LAZ1 | | | | | | | | | | |
| H' | 1.453 | 1.599 | 1.462 | 3.295 | 2.038 | 1.727 | 2.114 | 0.336 | 0.100 | 0.461 |
| E | 0.251 | 0.276 | 0.250 | 0.578 | 0.361 | 0.307 | 0.367 | 0.347 | 0.018 | 0.446 |
| 10LOM1 | | | | | | | | | | |
| H' | 3.502 | 3.551 | 3.580 | 3.618 | 3.675 | 3.645 | 3.673 | 0.941 | 0.028 | 0.002 |
| E | 0.611 | 0.611 | 0.619 | 0.617 | 0.617 | 0.627 | 0.629 | 0.932 | 0.003 | 0.002 |
| 11MAR1 | | | | | | | | | | |
| H' | 3.328 | 3.143 | 3.081 | 3.335 | 3.022 | 3.359 | 3.046 | 0.248 | -0.171 | 0.592 |
| E | 0.555 | 0.524 | 0.520 | 0.565 | 0.512 | 0.568 | 0.511 | 0.156 | -0.021 | 0.793 |
| 16TOS1 | | | | | | | | | | |
| H' | 3.209 | 3.120 | 2.848 | 3.155 | 3.834 | 3.301 | 3.178 | 0.323 | 0.045 | 0.480 |
| E | 0.616 | 0.613 | 0.565 | 0.615 | 0.760 | 0.643 | 0.614 | 0.314 | 0.009 | 0.492 |
| 19VAL1 | | | | | | | | | | |
| H' | 2.550 | 2.011 | 2.120 | 2.199 | 1.984 | 2.047 | 2.395 | 0.193 | -0.019 | 0.678 |
| E | 0.501 | 0.392 | 0.407 | 0.432 | 0.396 | 0.402 | 0.474 | 0.120 | -0.002 | 0.798 |
| 20VEN1 | | | | | | | | | | |
| H' | 0.695 | 0.912 | 0.960 | 1.194 | 1.342 | 1.520 | 1.513 | 0.983 | 0.145 | 0.000 |
| E | 0.147 | 0.180 | 0.190 | 0.234 | 0.259 | 0.289 | 0.295 | 0.989 | 0.026 | 0.000 |

very low are high forests dominated by beech (0.10 - 0.20), where the abundance models characterizing the forest ecosystem is very uneven for vascular species. Both the indices result sometimes independent to the number of species collected in the whole sample (Table 2): the linear regressions between the Shannon index vs. total number of species shows very low R² values (often <10%).

The annual variations of the indices over the course of the 1999-2005 surveys were of different size. The directional changes for the cover Shannon index and relative Evenness (Table 3) were highly significant in only three cases (FRI1, LOM1, VEN1). These changes point out an increase in diversity, guided almost exclusively by richness improvements.

Species turn-over

Indices related to species turnover are reported in

Table 4. This can add relevant information about the mechanisms related to the complex vegetation dynamics processes. In most of the PMPs the β -diversity level has resulted rather low and levelled, as demonstrated by the mean values of Sorensen dissimilarity. In fact, such index ranges from 0.000 (ABR1, 2002) to 0.299 (CAM1, 2005) and in CAL1, FRI1, LOM1 and TOS1 it is always < 0.200, thus all the sets are relatively similar. By the species turn-over index (T) we can appreciate the number of species involved in the compositional variation (*i.e.* new entry species + disappeared species). Such index show (Table 5) a larger variation among the PMPs (0-12.25; ABR1, 2002 and MAR1, 2003 respectively). As expected, such index can be unrelated to Sørensen index, where the latter is a sort of standardization by the amount of species involved.

The annual changes of the indices over the course of the 1999-2005 surveys were of different magnitude.

with a significant peak (5%) in mean cover in 2003. The PMP LAZ1 reaches the significative maximum cover of both the species groups at 2002, but their number remain stable, except for a lower value of the N-species in 2003. The stand in LOM1 experienced a rise in nitrophilous species frequency in 2003 and 2005 with significant departure respect to RS. Moreover, VAL1 revealed a significant minimum in A-species cover in 2003, while in VEN1 the frequency of N-species continuously varies in the observed period (however, in both cases, within the RS confidence interval).

In some cases a linear tendency is revealed by Between-subjects contrast test. Namely, an upward tendency of N-species frequency appeared in CAM1, EMI1, FRI1 and VEN1 while the cover increases in ABR1 and FRI1 PMPs. Only in CAM1 and LAZ1 A-species are rising up, while in most of the other PMPs they show a slight but significant reduction.

Population level

Species richness

The annual changes in mean number of species *2500 cm⁻² over the period 1999-2005 (2003 and 2004 data are missing) is reported in the Table 6. As ex-

pected, the total number of species collected by the sample was always lower respect to the recorded sample at 100 m² scale (community level). Such difference ranges from 50% in ABR1 to 17% in LOM1. ABR1, CAM1 and EMI1 resulted the PMPs with lower richness (< 2 * m⁻²), while FRI1 and LOM presented the higher values.

The annual changes in mean number of species *2500 cm⁻² over the period 1999-2003, 2005 can be observed in the Table 6. The Variation Coefficient in each PMP resulted almost stable (lower than 20%) within the observation period, indicating a good stationarity and (assuming 15% of tolerable error) the number of SUs (100) was always adequate. In the considered period, the non-parametric Friedman's test revealed significant changes in species richness in all the PMPs except in LAZ1 and VAL1, in which also significant departures from RS didn't occur (as well as ABR1 and EMI1). Annual mean species variations are frequent but of relative importance. Significant increases occurred in CAM1, FRI1, MAR1 and VEN1 and, on the opposite, reduction in richness are located in LOM1 and TOS1 PMPs.

Table 6 - Total number of vascular species listed in the sampled area (100 SU) and mean number of species*2500 cm⁻² (with relative confidence interval) in each PMP of the CONECOFOR network (data sets range 1999-2003, 2005). Significant differences among the diachronic observations based on non-parametric Friedman's test are reported in bold (p<0.05). Underlined values state significant departures from Standard Reference (mean values of the first four years of observation, delimited by its confidence interval at 99%).
*Numero totale di specie vascolari raccolte nell'area campionata (100 SU) e numero medio di specie*2500 cm⁻² (con relativo intervallo di confidenza) in ogni PMP della rete CONECOFOR (dataset 1999-2003, 2005). La comparazione tra le osservazioni diacroniche è stata effettuata tramite il test non parametrico di Friedman e i risultati significativi (p<0.05) sono riportati in neretto. I valori sottolineati indicano invece differenze significative rispetto al Reference Standard (valori medi dei primi 4 anni di osservazione delimitati dai rispettivi intervalli di confidenza al 99%).*

| PMPs | descriptor | 1999 | 2000 | year 2001 | 2002 | 2005 | Friedman Asympt. p | RS | ± c.i. |
|--------|-----------------------------------|------------------|------------------|--------------|------------------|------------------|-----------------------|-------------|-----------|
| 01ABR1 | total n of species | 13 | 11 | 12 | 13 | 11 | 0.000 | 1.04 | 1.22_0.86 |
| | n sp * 0.25 m ² ± c.i. | 1.05 0.31 | 0.87 0.28 | 1.04 0.30 | 1.21 0.34 | 0.82 0.29 | | | |
| 03CAL1 | total n of species | 28 | 26 | 25 | 26 | 24 | 0.048 | 5.08 | 5.31_4.86 |
| | n sp * 0.25 m ² ± c.i. | 5.24 0.49 | <u>4.84</u> 0.40 | 5.16 0.49 | 5.09 0.46 | 5.27 0.49 | | | |
| 04CAM1 | total n of species | 21 | 16 | 22 | 22 | 21 | 0.000 | 1.54 | 1.76_1.32 |
| | n sp * 0.25 m ² ± c.i. | 1.71 0.30 | 1.35 0.27 | 1.65 0.33 | 1.45 0.28 | <u>1.99</u> 0.31 | | | |
| 05EMI1 | total n of species | 11 | 16 | 18 | 15 | 18 | 0.005 | 1.77 | 1.92_1.61 |
| | n sp * 0.25 m ² ± c.i. | 1.73 0.31 | 1.62 0.33 | 1.81 0.33 | 1.90 0.32 | 1.64 0.34 | | | |
| 07FRI1 | total n of species | 32 | 34 | 35 | 37 | 42 | 0.000 | 5.51 | 5.65_5.37 |
| | n sp * 0.25 m ² ± c.i. | 5.46 0.52 | 5.46 0.58 | 5.45 0.60 | <u>5.67</u> 0.55 | <u>6.55</u> 0.56 | | | |
| 09LAZ1 | total n of species | 43 | 42 | 39 | 35 | 38 | 0.653 | 4.84 | 4.93_4.75 |
| | n sp * 0.25 m ² ± c.i. | 4.93 0.47 | 4.83 0.48 | 4.83 0.46 | 4.77 0.51 | 4.79 0.53 | | | |
| 10LOM1 | total n of species | 44 | 43 | 42 | 46 | 40 | 0.000 | 5.54 | 6.08_5.00 |
| | n sp * 0.25 m ² ± c.i. | 5.65 0.75 | 5.61 0.76 | 5.95 0.79 | 4.95 0.70 | <u>4.98</u> 0.70 | | | |
| 11MAR1 | total n of species | 40 | 43 | 37 | 37 | 40 | 0.000 | 2.69 | 3.07_2.31 |
| | n sp * 0.25 m ² ± c.i. | 2.98 0.41 | 2.45 0.39 | 2.42 0.42 | 2.90 0.41 | <u>3.20</u> 0.48 | | | |
| 16TOS1 | total n of species | 22 | 25 | 24 | 23 | 18 | 0.000 | 4.11 | 4.48_3.90 |
| | n sp * 0.25 m ² ± c.i. | 4.00 0.36 | 3.94 0.34 | 4.26 0.37 | 4.22 0.37 | <u>3.57</u> 0.33 | | | |
| 19VAL1 | total n of species | 25 | 21 | 23 | 23 | 23 | 0.458 | 3.32 | 3.43_3.21 |
| | n sp * 0.25 m ² ± c.i. | 3.34 0.53 | 3.24 0.49 | 3.37 0.47 | 3.33 0.44 | 3.22 0.48 | | | |
| 20VEN1 | total n of species | 15 | 22 | 20 | 22 | 25 | 0.000 | 2.90 | 3.32_2.48 |
| | n sp * 0.25 m ² ± c.i. | <u>2.42</u> 0.27 | 3.16 0.36 | 3.02 0.30 | 2.99 0.28 | <u>3.90</u> 0.31 | | | |

Table 7 – Fisher's α diversity index over the period 1999-2005. Total number of functional individuals and total number of species collected in the complete sampling (100SU) are also reported. The α values vs. time linear regression was accomplished. $p < 0.05$, bold indicates significant values.

Indice di diversità Fisher α nel periodo 1999-2005. Numero complessivo di individui funzionali e numero totale di specie raccolte nell'intero campione (100SU). Sono riportati i risultati della regressione lineare dei valori di α rispetto al tempo ($p < 0.05$) con in grassetto i valori significativi.

| PMPs | Indicators | 1999 | 2000 | year | | | α vs time linear regr. | | |
|--------|-----------------------|-------------|-------------|-------------|-------------|-------------|-------------------------------|--------|--------------|
| | | | | 2001 | 2002 | 2005 | R ² | b | p |
| 01ABR1 | total n of species | 13 | 11 | 12 | 13 | 11 | 0.859 | -0.228 | 0.024 |
| | n funct. individuals | 170 | 114 | 425 | 503 | 692 | | | |
| | Fisher α index | 3.28 | 3.00 | 2.30 | 2.44 | 1.86 | | | |
| 03CAL1 | total n of species | 27 | 24 | 24 | 25 | 23 | 0.668 | -0.092 | 0.091 |
| | n funct. individuals | 3854 | 2943 | 3597 | 3221 | 3992 | | | |
| | Fisher α index | 3.92 | 3.57 | 3.45 | 3.69 | 3.23 | | | |
| 04CAM1 | total n of species | 19 | 14 | 19 | 19 | 16 | 0.200 | -0.087 | 0.450 |
| | n funct. individuals | 1248 | 1201 | 1675 | 1611 | 2389 | | | |
| | Fisher α index | 3.18 | 2.22 | 3.00 | 3.02 | 2.30 | | | |
| 05EMI1 | total n of species | 11 | 12 | 15 | 13 | 15 | 0.701 | 0.164 | 0.077 |
| | n funct. individuals | 389 | 356 | 461 | 465 | 337 | | | |
| | Fisher α index | 2.11 | 2.40 | 2.97 | 2.48 | 3.22 | | | |
| 07FRI1 | total n of species | 30 | 30 | 32 | 33 | 38 | 0.976 | 0.250 | 0.002 |
| | n funct. individuals | 1667 | 1381 | 1401 | 1667 | 1910 | | | |
| | Fisher α index | 5.20 | 5.41 | 5.83 | 5.83 | 6.72 | | | |
| 09LAZ1 | total n of species | 41 | 39 | 37 | 33 | 36 | 0.163 | -0.111 | 0.500 |
| | n funct. individuals | 1822 | 2079 | 2160 | 1808 | 1428 | | | |
| | Fisher α index | 7.45 | 6.81 | 6.34 | 5.73 | 6.71 | | | |
| 10LOM1 | total n of species | 42 | 43 | 40 | 45 | 37 | 0.471 | -0.221 | 0.201 |
| | n funct. individuals | 1532 | 1539 | 1566 | 1665 | 1761 | | | |
| | Fisher α index | 7.98 | 8.21 | 7.48 | 8.52 | 6.62 | | | |
| 11MAR1 | total n of species | 38 | 38 | 33 | 32 | 36 | 0.258 | -0.169 | 0.383 |
| | n funct. individuals | 615 | 495 | 387 | 528 | 600 | | | |
| | Fisher α index | 8.95 | 9.59 | 8.63 | 7.50 | 8.41 | | | |
| 16TOS1 | total n of species | 20 | 24 | 22 | 21 | 14 | 0.599 | -0.364 | 0.124 |
| | n funct. individuals | 306 | 294 | 341 | 322 | 252 | | | |
| | Fisher α index | 4.79 | 6.18 | 5.25 | 5.03 | 3.20 | | | |
| 19VAL1 | total n of species | 23 | 20 | 22 | 22 | 21 | 0.079 | 0.024 | 0.647 |
| | n funct. individuals | 7607 | 5655 | 5331 | 3358 | 4014 | | | |
| | Fisher α index | 2.92 | 2.60 | 2.93 | 3.16 | 2.90 | | | |
| 20VEN1 | total n of species | 14 | 21 | 17 | 18 | 17 | 0.151 | -0.091 | 0.518 |
| | n funct. individuals | 960 | 1289 | 1218 | 1354 | 4659 | | | |
| | Fisher α index | 2.32 | 3.56 | 2.80 | 2.93 | 2.22 | | | |

Diversity index

The herb layer vegetation diversity at population level was estimated using Fisher's α (CAMPETELLA and CANULLO 2000), as reported in Table 7, where also the factors included in the index (*i.e.* total number of individuals - here intended as functional individuals - and total number of rooting species) are shown.

The extreme variability of the individuals number (particularly in ABR1, CAL1, LAZ1, VAL1 and VEN1 PMPs) can be explained by the different incidence of the woody species renewal, the count of functional units that reflects the morphological-evolutive characteristics of the herbaceous species (CANULLO and FALINSKA 2003) and by the effect of local disturbance. On the contrary, some PMPs show a good stability of individuals density (EMI1, FRI1, LOM1, MAR1, TOS1). Variability and stability of individuals may influence the index in different way: VAL1 show a very high variability in individuals (even 2000 in only one year) but an almost stable index, and in MAR1 a

certain stability in individuals number is translated in a high variation of index. This is due to the effect of the species number, that in such index have a stronger influence than individuals.

The higher mean values of *alpha* index are located in MAR1 (8.62) and LOM1 (7.76); intermediate values (< 7 and > 4) can be found in FRI1, LAZ1 and TOS1, while the lower mean values (< 4) characterize ABR1, CAL1, CAM1, EMI1, VAL1 and VEN1.

Discussion

The ground vegetation features and the patterns of changes detected by various diversity indices, were discussed at different resolutions (community and population level).

Community level

As to the previous report (CANULLO *et al.* 2006), ABR1 (due to the species reduction recorded in

2005) resulted new among the ones showing significant variations. In CAM1 (high forest stand aged 100 yrs, large-sized stems with low-density) the beech tree population didn't show important structural changes. Consequently, the significant variations in richness can be due to both the ephemeral species penetration from the neighboring ecosystems (as *Myosotis arvensis*, *Geranium lucidum*, *Galium parisiense*) and the influence of seasonal shifting of some geophytes (*Anemone apennina*, *Allium ursinum*, *Ornithogalum umbellatum* and *Symphytum tuberosum*; BIERZYCHUDEK 1982). Irregular significant changes of richness occurred in the period; in 2005 a drastic reduction occurred, mostly due to the absence of geophytes species (Table 2, Figure 2).

In 2002-2003 the forest stand in EMI1 experienced a heavy mortality rate in the tree layer (6.4% to 10.8%) mainly hitting *Quercus petraea* dominant individuals, probably connected to the 2003 water stress condition (AMORIELLO and COSTANTINI this volume; FABBIO *et al.* this volume): a significant reduction in richness of the understory vegetation could be linked to above mentioned factors. A slow recovery process seems to be started again, producing a positive balance in the years 2004-2005.

In the Turkey-oak stand of LAZ1, after three years of slight fluctuations in richness, the significant species depletion occurred in the 2002 is directly linked to the complete defoliation of the tree species due to *Lymantria dispar*, which partially continued in 2003. As a resilience signal after this particular event, the two last years produced a positive balance in this area with consequent cover recovery.

The PMP TOS1 undergoes a significant decrement of species in 2003, possibly due to the heat wave (AMORIELLO and COSTANTINI this volume); VEN1 showed a drastic increase in 2000, explainable by its recovery from a tremendous hailstorm in 1998 (with recorded frequency of mechanical damages at the population level up to 100%). After this episode the richness increased slightly, with a tendency to be more stable: probably the ecosystem reached the complete recovery after 6 years.

FRI1 and MAR1 PMPs are located in two aged coppices where the traditional management ceased. In MAR1, the downward significant tendency up to 2003 has been diverted on his course: an increasing in richness can be inspected, especially in 2005. FRI1 maintain directional and significant changes with upward

tendency for all the considered period, confirming the previous trend (CANULLO *et al.* 2006). However, in both cases, the time lag in which is possible to appreciate important changes is larger than two years. According to AMORINI and FABBIO (1989) and CAMPETELLA *et al.* (2004), our results can be interpreted as the outcome of the natural non-linear regeneration processes, influenced by the alternation of trees (shoots) mortality and growing phases. We assume that such changes in structure may affect the total richness by imposing the same indirect model of temporal variation. Probably we are observing two different phases of the same general resilience-type process, so that in FRI1 the species decrement recorded in 2005 can introduce a new future downward tendency. Consequently, the present trends do not enable us to make a linear forecast.

At all the other PMPs where a significant linear trend can be detected (CAM1, LAZ1 and VEN1, Table 2; CANULLO *et al.* 2006), we invite the readers to be careful when considering this interpretation: i) the linear disposition of data seems dependent on stochastic disturbances; ii) as we still consider a short time window, what seems to be a tendency could be recognized as a little step of a more complex dynamics in a larger time range.

The variations were also tested against a Reference Standard represented by a range of values as determined by the first four surveys. As literature-based information on long time series for comparable descriptors and ecosystems are missing, the RS limits cannot represent the normal or expected variation. The arbitrary interval used was assumed for all PMPs just as a range to be used for the present dataset as a "starting point" derived from the real surveys. For some sites it can further result inappropriate, especially for systems whose dynamics lasts longer than the investigated period, showing different time series with different properties. Therefore the time series achievement is a strategic objective, also enabling to apply some analyses which can reveal adequate time intervals (PERCIVAL *et al.* 2004);

Among beech high forests, CAM1 and VEN1 show significant changes respect to RS, the former with irregular variations (2000, 2003, 2004), the latter with a strong increase in richness, stabilized after the recovering from the hailstorm. EMI1 shows significant changes (decrease alternate to increase in richness) probably due to tree mortality events (FABBIO *et al.* this volume). FRI1, LAZ1, MAR1 and TOS1 represent

communities under regeneration, originated by previous disturbances (coppice management). All of them show significant changes respect to RS, which assume a directional increase in FRI1 and non-linear changes for the others (*i.e.* due to natural disturbances as gypsy moth attack or 2003 heat wave).

Higher values of Shannon index (> 3.0 bits) can be found on PMPs characterized also by the higher species equidistribution and the larger species number (FRI1, LOM1, MAR1: Table 3); only TOS1 shows the highest woody species ratio with a large occurrence of shrubs, leading to the absolute maximum Evenness scores. All these communities present a high level of structural heterogeneity caused by recent anthropic or natural disturbances. According to several contributions (LEVIN and PAINE 1974; BEATTY 1984; PETERSON and PICKETT 1990; TILMAN and PACALA 1993), our results can be interpreted by the light of the strict interactions between disturbance (natural events and previous management) and patchiness (*i.e.* heterogeneity, niche differentiation, as suggested by the presence of several woody species in all layers), corroborating the theory in which species diversity is often greatest at intermediate levels of disturbance intensity or frequency in forest communities (CONNELL 1978; PETRAITIS *et al.* 1989; STONE and WOLFE 1996).

Intermediate values appear on forest stands with a lower number of species but an intermediate level of Evenness (CAL1, EMI1 and VAL1) and a good proportion of woody species (EMI1: number of woody species/total number of species > 0.5).

Beech dominated communities (ABR1, CAM1 and VEN1) with simple high forest tree structure (only the tree layer is well developed) belong to the last group (< 2 bits) in which the total species number and the proportion of woody species are poor. LAZ1 is included in this group, but the 2002 event must be underlined: the *Lymantria dispar* attack reduced the woody species cover and the related total number of species but, at the same time, improved so much the Evenness in cover to raise up the Shannon index at 3.295 (1.3 up to the mean value of the period).

The directional changes in FRI1, LOM1, VEN1 (cover Shannon index and relative Evenness: Table 3) point out an increase in diversity, guided almost exclusively by richness improvements. Notwithstanding the tendency reported in the previous report is confirmed (CANULLO *et al.* 2006), it is difficult to consider these results as a "real trend" in plant spe-

cies diversity; in fact, the time considered is still too short if related to the type of processes which occur in forest ecosystems.

Considering species turnover data, VAL1 represents the area of higher taxonomic stability ($T < 3.2$); the higher level of species exchanges (9.5-12.25) is related to forest stands under intense dynamic processes (*i.e.* the regeneration of old coppice forests: MAR1), affected by disturbance (*i.e.* the *Lymantria attack*: LAZ1) or in connection with other different plant communities (LOM1 and CAM1).

Concerning the annual changes, it is interesting to note that the indices remain stable in the communities characterized by intense dynamical processes (*i.e.* MAR1, FRI1). In these cases, the in-out process is always balanced over time so that the local species pool is virtually stable (thus S can be considered constant). This recall the so-called "carousel model" which can play a role in maintaining the community diversity at a given time-rate (VAN DER MAAREL and SYKES 1993). The above mentioned sites cannot be considered stable by all the diversity indicators at the observed period, but the shape of variations (Figure 3) suggests a sort of fluctuation possibly synchronized with the time-rotation of coppice management.

Sporadic significative changes (respect to RS limits) on both nitrophilous and acidophilous abundance indicators appear at all PMPs; minimum values can be related to the 2003 drought season (AMORIELLO and COSTANTINI this volume). The prevailing role of A-species in LOM1 and VAL1 is linked to the lowest pH values in organic and superficial soil layers (ALIANELLO *et al.* 2002; MATTEUCCI com. pers.), and not influenced by the atmospheric deposition (MOSELLO *et al.* 2005).

An increase in the number or frequency of nitrophilous species in deciduous and mixed woodlands in western, north-western and central Europe has been pointed out by different authors (WILMANN *et al.* 1986; TYLER 1987; THIMONIER *et al.* 1994; BRUNET *et al.* 1997). Data reported by FERRETTI *et al.* (2006) show that for some beech forest sites of the Italian network, the soil N content was higher in PMPs located in southern Italy and, on the other side, the exceedance of N critical level raised up in PMPs located in northern Italy, with the lowest N content in the soil. The increase in cover and/or frequency of nitrophilous species in some northern PMPs (EMI1, VEN1) and their relative reduction in two southern beech communities

(CAL1 and CAM1) might be influenced by the above mentioned N pattern.

A-species tendencies are always of neglectable amount both as frequency and cover values, in most cases with a significant reduction. Decline and extinction of acidophilous species were also observed in deciduous, coniferous and mixed woods growing on less fertile soils (FANGMEIER *et al.* 1994; WALTHER; 1997; VAN TOL *et al.* 1998).

Population level

The richness values at the population level show annual changes that seem to reflect only in some cases the variation occurred at the community level (CAM1, LAZ1, LOM1, MAR1, VEN1); this can be due to ecological mechanisms acting in the whole system (species penetration from other communities or reaction to disturbances).

The RS percentage ratio related to the mean number of specie in the SUs at both the scales (RS population/RS community) can be interpreted as a sort of heterogeneity index of plant species distribution, to define an additional structural state of the PMPs. It always shows very low values, always below 30% which indicate an intense patchy distribution of plants in the understory vegetation, one of the well-known features of forest ecosystems (WATT 1964; LIU and HYTEBORN 1991; GLENN-LEWIN and VAN DER MAAREL 1992; CAMPETELLA *et al.* 2004; KOTLIAR and WIENS 1991; BOBIEC 1998). A minor level of patchiness can be inferred in CAL1, TOS1 and VAL1 (respectively 29.63%, 26.19%, 24.28%), while the highest level of aggregation occurred in MAR1 (9%). In the latter, a spatial pattern analysis of herb layer vegetation confirmed a high level of patchiness and species aggregation also at a finer scale (CAMPETELLA *et al.* 1999).

Aspects related to scale and structure of vegetation must be taken into account in the monitoring activity, because they can heavily influence the results and the relative deductions (PODANI 2006). In fact, the scale dependence of vegetation pattern and processes is generally accepted, just as the mosaic nature of plant communities is well recognized at different hierarchical levels (PODANI *et al.* 1993; CANULLO and CAMPETELLA 2006a).

In most cases, significant departures from RS where located in a single observation. Probably, the sampling system at the population level can capture only the composition and dynamics of the singles

patches, microcommunities (which seems more stables over time), but cannot reveal the result of interaction among patches, aspect that focus much better the main features of the ecosystem, its dynamic and relative reaction to disturbance.

Although some differences, the results of Fisher's α index reflect the same picture described at larger scale. In fact, the medium-high values of diversity are located in communities affected by recent anthropic or natural disturbances.

Related structural studies carried on in MAR1 suggest that although individuals (ramets) of herb layer species are aggregated, their patches show a high level of species compositional diversity and are spatially independent from each other (CAMPETELLA *et al.* 1999). The older stands, represented by stabilized tree layer structure (mature high forest, in most cases dominated by beech, as CAM1 and CAL1) probably reflect an inner habitat homogenization; especially in the herb layer (*i.e.* litter composition, shadow distribution, *etc.*). These aspects can reduce the level of niche differentiation, with the consequent reduced variability in species composition among patches, as reflected by low diversity values. The disturbance occurred in VEN1 (hailstorm) directly influenced the herb layer and didn't modify the tree structure, maintaining unaltered the inner environmental conditions. In this case, the dramatic increase of functional individuals reflects the rate of recovery from mechanical damages in the first years.

Directional changes of Fisher's α index were significant in only two PMPs: ABR1 with a downward tendency opposite to FRI1. The abundance repartition in terms of ramets per species indicates a higher equitability in the latter PMP.

Conclusions

The forest vegetation data collected in a subset of PMPs (CONECOFOR Italian network) over the period 1999-2005, were analyzed to produce a present-day status and evaluation of changes, inferred by statistical tests or departures from *a priori* reference standard (RS).

All the descriptors contributed to generate a main picture of the forest sites (PMPs) in terms of structure (considering the supply of different layers), vascular species composition, effects of disturbance and dynamical mechanisms. The analysis of selected descrip-

tors raised up relevant changes in vegetation.

At the community level, significant variations in richness are more frequent in sites with high structural heterogeneity caused by recent anthropic or natural disturbances. In few PMPs directional changes can be appreciated (CAM1, FRI1, LAZ1 and VEN1) but in most cases the variations assumed a typical fluctuation pattern (more or less regular), with different cycle length. The use of a reference standard (RS) supported the interpretation of changes, even if the *a priori* time lag selection may generate a term of comparison from extremely heterogeneous data (*i.e.* recovering processes include a heavy variability year by year or last longer than our surveillance period).

At population level annual mean species variations are frequent but of minor importance. Probably, the finer scale sampling system is not able to detect structural complexity derived by the interaction among patches, which can reveal the ecosystem features, its dynamics and the relative reaction to disturbances.

Considering the monitoring activity, the results at the community level seem more sensitive to describe important changes at the level of forest stand: variations in richness, diversity, species turnover and species composition are strictly linked both to the nature of forests community and the observed disturbances. The population level results lead to the assessment of fine scale variability and to investigate the role of species assemblages in diversity maintenance (HERBEN *et al.* 1993; VAN DER MAAREL and SYKES 1993; CZÁRÁN 1998). Moreover, other accurate data collected at that scale (*i.e.* number of individuals or ramets, their cover, damages entity) could be used to obtain appropriate descriptors, as abundance and variation of functional groups, woody species renewal, population dynamics of key species, *etc.*

In most of the PMPs the Sorensen's dissimilarity index has resulted rather low and leveled, while the species turn-over index has shown a larger variation among the forests. Higher values occurred in communities under intense dynamical processes, affected by disturbance or influenced by neighboring plant communities with a different species composition (CAM1, LAZ1, LOM1, MAR1).

The abundance of *nitrophilous* species was particularly consistent in beech forests; the increase in the PMP VEN1 and the relative reduction in two southern beech communities (CAL1 and CAM1), corroborates the relation patterns with N soil content previously

described (FERRETTI *et al.* 2006). The contribution of *acidophilous* species at the extreme values of the indicator's range, didn't show particular evidences.

The relationship between plant diversity and the forest dynamical state seems relevant: at both the sampling scales, the higher values of diversity indices occurred in communities with a high level of structural heterogeneity caused by recent anthropic or natural disturbances. Our results pointed out the interaction between disturbance and patchiness, corroborating the theory of maximum species diversity at intermediate levels of disturbance intensity or frequency in forest communities.

All the studied stands are characterized by significant changes in richness which can be influenced by the 2003 drought season: in both the EMI1 sessile oak and TOS1 holm oak stands a particular co-occurrence with the minimum values in coverage and species richness seems evident.

As a general remark, the inherent non-linear dynamics of forest regeneration processes emphasizes the needs of long-term datasets for detecting the plant diversity responses to environmental changes.

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