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A N N A L I
C.R.A. - ISTITUTO SPERIMENTALE PER LA SELVICOLTURA

Special Issue on

ASPECTS OF BIODIVERSITY IN SELECTED FOREST ECOSYSTEMS IN ITALY

Status and changes over the period 1996 - 2003

Report 3 of the Task Force on Integrated and Combined (I&C) Evaluation of the CONECOFOR programme

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CONECOFOR (*CONtrollo ECOsistemi FORestali*) is the intensive monitoring programme of forest ecosystems in Italy. The programme is framed within the Pan-European Level II Monitoring of Forest Ecosystems. It is co-sponsored by the European Union (EU) under the Regulation no. 2152/2003 " Forest Focus" and co-operate with the UN/ECE ICP-Forests and the UN/ECE ICP-Integrated Monitoring of Ecosystems. CONECOFOR is managed by Corpo Forestale dello Stato, Divisione 6ª, CONECOFOR Board, acting also as National Focal Center (NFC) of Italy within the EU and UN/ECE programmes.

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Biodiversity - its assessment and importance in the Italian programme for the intensive monitoring of forest ecosystems CONECOFOR

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Abstract – Biodiversity is a central issue in forest ecosystem management and its maintenance is a serious concern both at national and global level. This paper summarizes the investigations related to biodiversity currently carried out at the intensive monitoring plots of the CONECOFOR programme. Forest structure, species diversity (vascular plants, epiphytic lichens, invertebrates), deadwood, naturalness and landscape indices are currently being investigated in (part of) the plots. The core of the available dataset is represented by the data about forest structure (available since 1996) and vascular plant diversity (available in a standardized comparable format since 1999). The paper will present the whole report structure

Key words: *forest ecosystem, integrated evaluation, intensive monitoring, Italy, biodiversity.*

Riassunto – Biodiversità - la sua valutazione ed importanza nel programma italiano di monitoraggio intensivo degli ecosistemi forestali CONECOFOR. La biodiversità rappresenta un argomento centrale nella gestione forestale ed il suo mantenimento è una preoccupazione a livello nazionale e globale. Questo articolo riassume le attività attualmente condotte nei siti di monitoraggio intensivo del programma CONECOFOR. Struttura del bosco, diversità specifica (piante vascolari, licheni epifiti, invertebrati), necromassa, naturalità, ed indici relazionati al paesaggio vengono misurati e valutati in tutti o parte dei plot. La parte più cospicua dei dati attualmente disponibili è rappresentata dai dati sulla struttura forestale (disponibili a partire dal 1996) e sulla diversità di specie vascolari (disponibili in forma standard e comparabile a partire dal 1999). L'articolo intende presentare la struttura del rapporto nel suo insieme.

Parole chiave: *biodiversità, ecosistemi forestali, Italia, monitoraggio intensivo, valutazione integrata.*

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"..it appears that scientists can offer a very large number of possible "diversity measures", but that these measures cannot be aggregated into a unique measure of the diversity of the system" (Norton 1994, in Gaston 1996a)

"Biologists must find a way to communicate biodiversity's complexity lucidly to the public" (Takacs 1996, in Weber *et al.* 2004)

"Species richness does indeed capture something of the essence of biodiversity" (Gaston 1996c).

Introduction

Biological diversity – or *biodiversity*, in its condensed and popularized term - is a top issue in the environmental political agenda and for natural resource managers and its importance is stressed in several international conventions (Rodrigues *et al.* 2004; Weber *et al.* 2004). Gaston (1996a) provided a thoughtful introduction about the term biodiversity and how it is viewed. He identified three main viewpoints about biodiversity: biodiversity as (i) a concept, (ii) a measurable entity and (iii) as a social/political construct. The three viewpoints are closely connected

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because the concept adopted has consequences on the measurement approach, and measurements are requested because biodiversity is acknowledged as a political/societal value to be protected, thus to be quantified and monitored. Although there is a number of published definitions (see Gaston 1996a, p. 2; Kännel 1997; Dobbertin-Kännel 1998), the term biodiversity is mainly used to mean the basic concept of "variety of life" and – as such – it implies a multidisciplinary approach. While the concept is fascinating, it is very difficult to be placed into an operational perspective, *e.g.* how biodiversity can be measured. This has been recognized since some time as an elusive task, as an all-embracing measure of biodiversity does not exist. This is true also for forest biodiversity (Innes and Koch 1998) and the inherent complexity of biodiversity assessment has resulted in a number of schemes to serve as a convenient framework for operational perspectives. These schemes involve: (i) conventional hierarchical divisions, (*e.g.* genetic diversity, species or taxonomic or organismal diversity and ecosystem or ecological diversity) which encompass also ecological structures, functions and processes (Gaston 1996b); (ii) spatial scales (*e.g.* local, landscape, regional), which are in turn connected to time scale (*e.g.* Innes 1998); and (iii) convenient, realistic measurement endpoints *(indicators)* that can capture key facets of biodiversity (*e.g.* Lindenmayer *et al.* 2000; Gaston 1996c). As it is obvious, biodiversity as a general term incorporates different types of diversity. In the reminder of this paper, the term biodiversity will be used to refer to the general concept, while individual facets of biological diversity (*e.g.* species diversity, structural diversity) will be referred to as appropriate. Despite the above limitations, assessment of monitoring of (facets of) diversity has become central in conservation strategies (*e.g.* Huston 1994; Spellerberg and Sawyer 1999), restoration ecology (Bartha *et al.* 2004), sustainable forest management (Hall 2001, Hunter 1990) and to forest ecosystem health assessment (*e.g.* Innes and Karnosky 2001; Ferretti 2004). For example, the maintenance and conservation of biological diversity of forest ecosystems is one of the six criteria for sustainable forest management (SFM) identified by the Ministerial Conference on the Protection of Forest in Europe (MCPFE). In a forest community, the link between taxonomic, structural, and functional diversity is particularly obvious (*e.g.* Neumann and Starlinger 2001): tree canopy *(e.g.* conifers and/or broadleaves), age, stem density, tree size, forest management, internal dynamics, competition and disturbances exert a major role in regulating the environmental condition (light, temperature) of the understorey and the nutrient flux, thus impacting species composition and competition (*e.g.* Thimonier *et al.* 1992, 1994; du Bus de Warnaffe and Lebrun 2004) (Figure 1). Recent experimental results suggest that relationships between species richness and fertility, with resulting increased biomass and reducing light passing through the canopy under more fertile condition, may have been more complex that believed (Chiarucci *et al.* 2004; see also Berendse, 2005 and references therein).

A number of different indices of biodiversity have been developed (*e.g.* Neumann and Starlinger 2001). Species richness, the total number of species in a community, is considered as an important measure of biodiversity in view of its ease in measurement (at least for vascular plant species), comparability across communities and facility to be communicated to resource managers and the public (Chiarucci 2001; Hellmann and Fowler 1999), despite some important misunderstandings in its interpretation. Assessment and monitoring of biodiversity can be carried out at a variety of scale (Weber *et al.* 2004) (Table 1) and, at each scale, a variety of key factors has been identified (Table 2). At European level, a first assessment based on vegetation assessment performed at Level II plots was carried out by EC-UN/ECE (2003), on the basis of the data collected over the years 1994-2000. Within the Italian intensive forest ecosystem monitoring programme (Italian acronym: CONECOFOR, see below),

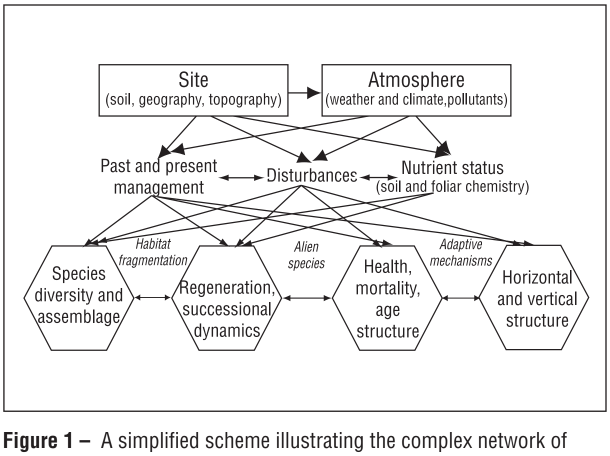

Figure 1 – A simplified scheme illustrating the complex network of relationships linking factors, processes and diversity at the plot scale.
Schema semplificato della rete di relazioni che collegano fattori e processi alla diversità alla scala di plot.

Table 1 – Characteristics of biodiversity assessment at various spatial scales.
Caratteristiche della biodiversità a scale diverse.

Spatial Scale	Characteristics		
	Definition	Area (m^2)	Human impact involved
Local	Within-habitat diversity	10^1	Land-use, site management, deposition loads, colonization
Landscape	Within-habitat-mosaic diversity	10^6	Size and distribution of different habitat (land-use) types
Macro-scale	Within-region-diversity	10^{10}	Species extinction, influences on colonization

diversity assessment has been carried out at the scale of the 0.25 ha plot since 1996, mostly with a taxonomic approach. The present report will provide descriptive information on key diversity indicators, *e.g.* forest structure, vascular plant diversity, epiphytic lichens, invertebrates and dead wood. Some of the results presented in the report were achieved in the frame of the multi-national pilot project “ForestBIOTA”, co-sponsored by the EU under the National Programme “Forest Focus – IT 2003-2004”. In this paper we will: (i) summarize the political framework, (ii) the structure of the CONECOFOR programme, (iii) the biodiversity facets considered by the programme and (iv) outline the report structure.

The political framework and the pan-European initiatives

The global scale of the concern about the potential biodiversity loss demands concerted international action. At the global level, the Convention on Biological Diversity (CBD), adopted at the 1992 Earth Summit in Rio de Janeiro, ratified by Italy in 1994, provides a new integrated approach for these concerted actions. At the Pan-European level, the PEBLDS EBMI-F (Pan-European Biological and Landscape Biodiversity Strategy, European Bio-diversity Monitoring and Indicators Framework) was developed by the initiatives of the Council of Europe and UNEP (UN Environment Programme) to support the implementation of the CBD at this level. In this framework, the biodiversity resolution taken by the 5th Conference of the European Ministers of Environment “Environment for Europe” (Kiev, 2003) includes the keystone decision to develop by 2006 a core set of biodiversity indicators and to establish by 2008 a Pan-European network on biodiversity monitoring and reporting, with a framework of collaboration with MCPFE (Ministerial Conference on the Protection of Forests in Europe). A pan-European Co-ordination Team, formed by European Environment Agency, UNEP, European Centre for Nature Conservation and the Expert Groups leaders is operative since 2004 and has started his work collecting the available information and drafting a work plan (to be approved by EC and Council of Europe) for developing a pan-European programme on biodiversity monitoring and reporting. This work plan provides the logical framework for the activities that need to be carried out in order to ensure European coordination of the development and implementation of biodiversity indicators for assessing, reporting on and communicating achievement of the 2010 target to halt biodiversity loss. This activity is called *Streamlining European 2010 Bio-diversity Indicators (SEBI2010)*, with the main objectives to: (1) consolidate, test, refine, document and help produce workable sets of policy-relevant biodiversity indicators meaningful in the context of the 2010 target, “Halt of biodiversity loss 2010”; (2) help ensure adequate funding for monitoring, indicators and assessments to support implementation and achievement of the policy decisions and targets; (3) improve coordination, exchange of information and collaboration on biodiversity-related indicators and monitoring activities building on current activities and good practice; (4) consider the wider use of the indicators, and their applicability within other relevant indicator frameworks and assessment processes. The Expert Groups have just started their activities: demonstration activities to be carried out in test countries were expected by 2005; the definition and publishing of the final revision of the indicators set is expected by 2006; the establishment of a co-operative monitoring network at pan-European level is expected by 2008.

The activity of the ICP Forests Working Group on Biodiversity

An attempt to harmonise and test indicators of forest biodiversity at pan-European level has been made by the ICP Forests Working Group on biodiversity since 2003 and a test-phase was launched in 2004, anticipating the new tasks required by Regulation (EC) n. 2152/2003 *“Forest Focus”*. First results of the 2004 biodiversity test-phase in Italy (Petriccione 2004)

Table 2 – A list of key factors of European forest biodiversity as preliminary identified by the BEAR project (Anonymous). Functional key factors are relevant to all scales.
Una lista di fattori-chiave della biodiversità forestale europea identificata in via preliminare del progetto BEAR (Anonimo). I fattori-chiave a livello funzionale sono relativi a tutte le scale.

Scale	Structural key factors	Compositional key factors	Functional key factors	
National/ regional (Macro)	Total area of forest with respect to: *legal status/utilisation or protection* *forest ownership* *tree species and age* *old growth forests/forests left for free development* *afforestation*	Native species Non-native or not "site original" tree species	Natural disturbance: fire, wind, snow, biological disturbance	Human influence: forestry, agriculture, grazing, other land use, pollution
Landscape	Number and type of habitats (incl. water courses) continuity and connectivity of important habitats Fragmentation History of lanscape use	Species with specific landscape-scale requirements Non-native or not "site original" tree species		
Stand (Local)	Tree species Stand size stand edge/shape forest history habitat types tree stand structural complexity deadwood Litter	Species with specific stand-type and scale requirements Biological soil condition		

show that: (1) in a short time and with relatively low costs it is possible to obtain important indications on biodiversity status of forest communities; (2) the ICP Forests harmonized methods (vegetation, lichens, stand structure and deadwood) can provide a basis for the assessment, although some progress is still necessary in different respects (Ferretti and Chiarucci 2003); (3) the new tested parameters (naturalness, landscape diversity) provided data that deserve a closer look; (4) the surveyed forest communities have shown very high values for nature conservation (for example, Community interest or priority habitats and species occur on 8 of 12 plots, according to the Habitat Directive (EEC) n. 92/43); (5) finally, qualitative results are very important to increase the basic scientific knowledge (in a few months of survey on lichens and insects, 3 new species for science and 20 new or very rare for Italy have been discovered). This experience has been the basis to start the Pan-European pilot project *ForestBIOTA (Forest BIOdiversity Test Phase Assessment)*, a joint project by 14 European Countries, co-funded by EC, based on 120 EU/ICP Forests permanent plots, collecting data on four main biodiversity indicators in standardised way (Petriccione and Stofer 2004).

The ALTER-Net initiative

Starting in 2004, ALTER-Net *(A Long-Term Biodiversity, Ecosystem and Awareness Research Network)* is a partnership of 24 organisations (National Forest Service is the Italian partner) from 17 European countries which will develop durable integration of biodiversity research capacity at a European level. The Network of Excellence is contributed by EC with 10M € over the years 2004-2008. Main objectives of ALTER-Net are (1) to create a network for European long-term terrestrial and fresh-water biodiversity and ecosystem research, based on existing facilities; (2) to develop approaches to assess and forecast changes in biodiversity, structure, functions and dynamics of ecosystems and their services; (3) to consider the socio-economic implications and public attitudes to biodiversity loss.

The CONECOFOR programme

The Italian programme for the monitoring of forests ecosystems (CONECOFOR) started in 1995 within the framework of the intensive forest monitoring programme launched by the European Commission (Regulation EC n. 1091/94) and carried out under the Convention on Long Range Transboundary Air Pollution of United Nations - Economic Commission for Europe (CLRTAP UN/ECE) (Petriccione and Pompei 2002). In 1995, 20 permanent monitoring plots (PMPs) were either incorporated from existing projects or selected *ex novo* by the National Focal Centre (the Italian National Forest Service) (Figure 2). More recently, new PMPs have been incorporated and now CONECOFOR includes 31 PMPs (Table 3) (Figure 2). In all cases the location of the PMPs was selected on a preferential basis. Therefore, while the PMPs of the programme are installed within important Italian forest ecosystem types, they should be considered as a series of case studies and not a statistically representative sample of the Italian forests. This implies that the results obtained through the programme do not allow for formal statistical inferences, *e.g.* findings cannot be extrapolated to sites other than those being monitored.

However, it is reasonable to suggest that consistency of results from different sites spread throughout Italy can provide circumstantial evidence of trends that may occur also in other sites. While the results are difficult to extrapolate to other sites, the major benefit of the intensive monitoring programme is to concentrate on the same site a number of different investigations that provide the basis for the integrated assessment. The investigations carried out at the PMPs include crown condition assessment, chemical content of soil and foliage, deposition chemistry, gaseous air pollutants (mostly O_3), tree growth, meteorological measurements, ground vegetation and remote sensing (Table 4). Soil solution, streamflow chemistry, Leaf Area Index and litterfall are also investigated in several PMPs. Additional investigations related to biodiversity were initiated in 2003 and include epiphytic lichens, deadwood, invertebrates, naturalness and landscape indices. Details relating to set up of the different investigations and data collection are in Petriccione and Pompei (2002); an overview of the first results obtained is reported by Ferretti (2000), Mosello *et al.* (2002) and Ferretti *et al.* (2003). The data collected from all the CONECOFOR PMPs are submitted to the European Commission (under the Regulation EC no. 2152/2003 *Forest Focus*) and to the UN/ECE International Cooperative Programme on Assessment and Monitoring Air Pollution Effects on Forests (ICP-Forests). Since 1997, 11 of the CONECOFOR plots have been also included among the sites of the International Co-operative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP-IM) (Table 4).

Figure 2 - The location of the Permanent Monitoring Plots of the CONECOFOR programme. Circles: PMPs operational within the programme since 1995; squares: PMPs that have joined the programmed in the period 1999-2000; triangles: PMPs incorporated in 2002-2003.
Localizzazione delle aree permanenti di monitoraggio del programma CONECOFOR. I cerchi indicano le aree permanenti operative all'interno del programma sin dal 1995; i quadrati indicano le aree permanenti che sono state incorporate nel 1999-2000; i triangoli quelle inserite nel 2002-2003.

The diversity measurements within the CONECOFOR programme and related problems

According to Fady-Welterlen (2005), the Mediterranean basin has approximately 30,000 plant species (ca. 10% of all known higher plant species on Earth) and 80% of all endemic plants in Europe are Mediterranean species. Thus, measurements of diversity are important in a monitoring programme installed in a Mediterranean country. Diversity can be measured with a variety of methods and indices (Magurran 1988). Virtually, all the investigations carried out at the CONECOFOR plots are linked to biodiversity assessment, although at different levels. A distinction can be made between the investigations that have a direct link to biodiversity (those ones that provide actual data on *e.g.* species or structural diversity) and the investigations that are useful to explain status and changes of a given diversity indicator.

Table 3 – Permanent Monitoring Plots (PMPs) of the CONECOFOR programme over the period 1995-2004. Asterisks indicate those PMP incorporated in the ICP-IM. In brackets: cases of PMPs installed outside the CONECOFOR programme and subsequently incorporated in the programme. The report will concentrate mainly on the first 20 PMPs, e.g. those operational since 1995. FTBA (Forest Type for Biodiversity Assessment) classification is reported for those plots for which it is available.
Aree permanenti del programma CONECOFOR nel periodo 1995-2002. Gli asterischi indicano le aree permanenti incorporate in ICP-IM. Tra parentesi: i casi di aree installate indipendentemente da CONECOFOR e successivamente incorporate nel programma. Il rapporto si concentrerà principalmente sulle prime 20 aree, cioè quella attive dal 1995. La classificazione FTBA (Forest Type for Biodiversity Assessment) viene riportata per quei plot per i quali è disponibile.

Code	Lat	Long	Alt (m)	Main tree species	FTBA	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
ABR1*	415061	133523	1500	*Fagus sylvatica*	7N.3b	+	+	+	+	+	+	+	+	+	+
BAS1	403638	155225	1125	*Quercus cerris*		+	+	+	+	+	+	+	+	+	+
CAL1*	382538	161047	1100	*Fagus sylvatica*	7N.3b	+	+	+	+	+	+	+	+	+	+
CAM1	402558	152610	1175	*Fagus sylvatica*		+	+	+	+	+	+	+	+	+	+
EMI1*	444306	101213	200	*Quercus petraea*		+	+	+	+	+	+	+	+	+	+
EMI2*	440631	110700	975	*Fagus sylvatica*		+	+	+	+	+	+	+	+	+	+
FRI1	454734	130715	6	*Q.robur/Carpinus betulus*		+	+	+	+	+	+	+	+	+	+
FRI2	462928	133536	820	*Picea abies*	3N.1	+	+	+	+	+	+	+	+	+	+
LAZ1*	424950	130010	690	*Quercus cerris*		+	+	+	+	+	+	+	+	+	+
LOM1*	461416	93316	1190	*Picea abies*	3N.1	+	+	+	+	+	+	+	+	+	+
MAR1*	431738	130424	775	*Quercus cerris*		+	+	+	+	+	+	+	+	+	+
PIE1	454055	80402	1150	*Fagus sylvatica*		+	+	+	+	+	+	+	+	+	+
PUG1	414910	155900	800	*Fagus sylvatica*		+	+	+	+	+	+	+	+	+	+
SAR1	392056	83408	700	*Quercus ilex*	2N	+	+	+	+	+	+	+	+	+	+
SIC1	375432	132415	940	*Quercus cerris*	1N.7	+	+	+	+	+	+	+	+	+	+
TOS1*	433034	102619	150	*Quercus ilex*	2N	+	+	+	+	+	+	+	+	+	+
TRE1*	462137	112942	1775	*Picea abies*	3N.1	+	+	+	+	+	+	+	+	+	+
UMB1	432757	122757	725	*Quercus cerris*		+	+	+	+	+	+	+	+	+	+
VAL1*	454326	65555	1740	*Picea abies*		+	+	+	+	+	+	+	+	+	+
VEN1	460326	120156	1100	*Fagus sylvatica*		+	+	+	+	+	+	+	+	+	+
ABR2	415409	142100	980	*Q. cerris/C. betulus/Abies alba*	1N.7								+	+	+
LAZ2	415061	133523	190	*Quercus ilex*	2N								+	+	+
LOM2	455726	100753	1150	*Picea abies*			(+)	(+)	(+)	+	+	+	+	+	+
LOM3	455441	93017	1250	*Fagus sylvatica*						+	+	+	+	+	+
TOS2	425212	104634	30	*Quercus ilex*	2N	(+)	(+)	(+)	(+)	+	+	+	+	+	+
TOS3	434418	113422	1170	*Fagus sylvatica*		(+)	(+)	(+)	(+)	+	+	+	+	+	+
BOL1*	463516	112604	1740	*Picea abies*	3N.1	(+)	(+)	(+)	(+)	(+)	+	+	+	+	+
LIG1	442410	92730	1290	*Fagus sylvatica*								(+)	+	+	+
PIE2	453129	84234	135	*Quercus robur, Carpinus betulus*						*operational since 2005*					
PIE3	461958	81650	1860	*Larix decidua*						*operational since 2005*					
VEN2	451203	104408	60	*Quercus robur, Carpinus betulus*						*operational since 2005*					

Measurements of diversity

Direct measurements of diversity collected on the CONECOFOR plots permit to calculate indicators of structural and specific plant diversity (Neumann and Starlinger 2001). They are reported in Table 5-6. Investigations include the assessment of stand characteristics like circumference, height, spatial and vertical distribution of individual trees (Amorini and Fabbio 2000; Fabbio *et al.*, this volume), the frequency and cover of vascular species (Campetella and Canullo 2000; Canullo *et al.*, this volume), the frequency of epiphytic lichen species (Giordani *et al.*, this volume), the amount and quality of deadwood (Travaglini *et al.*, this volume), invertebrates (Mason *et al.*, this volume), the degree of naturalness of a given plot (Petriccione, this volume) and its relation to the surrounding landscape (Ingegnoli, this volume). As it is obvious from Table 5, until now only stand structure, vascular plant species diversity and, at a lesser extent, lichen species diversity, have sufficient spatial or temporal coverage.

Measurement of factors influencing the diversity

Biological, structural and functional diversity at a given site is the result of a number of factors that operate at every time all together (Figure 1). The data collected within the CONECOFOR programme are relevant for many of these factors and include (Table 4): meteorological data and stress indices (Amoriello and Costantini 2000); soil chemistry (Alianiello *et al.* 2000); foliar chemistry (Matteucci *et al.* 2000); atmospheric deposition (Mosello *et al.* 2000, 2002) and gaseous air pollutants (Buffoni and Tita 2000, 2003). Other investigations were useful for calculating diversity indicators related to the spatial distribution of trees (remote sensing) and to interpret and complement

Table 4 – Investigation categories carried out at the PMPs of the CONECOFOR programme. In brackets: cases of investigations formerly undertaken outside the CONECOFOR programme. Note: individual investigations may have covered only part of the 1996-2003 period. Details about the nature of the various investigations are provided by Petriccione and Pompei (2002), Ferretti (2000) and Ferretti et al. (2003).
Categorie di indagini portate avanti presso le aree permanenti del programma CONECOFOR. Tra parentesi: indagini iniziate prima dell'incorporazione nella rete CONECOFOR. Nota: alcune indagini possono non avere coperto l'intero periodo 1995-2003. I dettagli sulla natura delle varie indagini sono riportati da Petriccione and Pompei (2002), Ferretti (2000) e Ferretti et al. (2003).

PMP no.	Code	Site data	Tree condition	Soil chemistry	Foliage chemistry	Forest structure, tree growth	LAI	Litterfall	Ground vegetation	Deposition chemistry	Ozone meas.	Meteo meas.	Remote sensing	Lichens	Deadwood	Insects	Naturalness	Landscape
1	ABR1	+	+	+ (1)	+	+	+	+	+	+	+	+	+				+	
2	BAS1	+	+	+	+	+		+	+		+		+					
3	CAL1	+	+	+	+	+	+	+	+	+	+	+	+		+	+		
4	CAM1	+	+	+	+	+		+	+	+	+		+					
5	EMI1	+	+	+	+	+	+	+	+	+	+ (3)	+	+	+				
6	EMI2	+	+	+	+	+	+	+	+	+ (2)	+	+	+					
7	FRI1	+	+	+	+	+	+	+	+	+	+ (3)		+					
8	FRI2	+	+	+	+	+	+	+	+	+ (2)	+	+	+	+			+	
9	LAZ1	+	+	+ (1)	+	+	+	+	+	+ (2)	+	+	+					
10	LOM1	+	+	+	+	+	+	+	+	+	+	+	+	+			+	
11	MAR1	+	+	+	+	+	+	+	+	+	+		+					
12	PIE1	+	+	+	+	+	+	+	+	+ (2)	+	+	+					
13	PUG1	+	+	+	+	+	+	+	+		+ (3)		+					
14	SAR1	+	+	+	+	+	+	+	+		+ (3)		+		+	+		
15	SIC1	+	+	+	+	+	+	+	+	+	+		+		+	+		
16	TOS1	+	+	+	+	+	+	+	+	+	+ (3)	+	+	+			+	
17	TRE1	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+
18	UMB1	+	+	+	+	+	+		+		+		+					
19	VAL1	+	+	+	+	+	+	+	+		+ (3)	+	+					
20	VEN1	+	+	+	+	+	+	+	+	+	+	+	+	+				
21	ABR2	+	+						+		+				+	+	+	
22	LAZ2	+	+						+		+						+	
23	LOM2	+	+	(+)	+	+			+	+	+							
24	LOM3	+	+		+	+			+	+	+	+						
25	TOS2	+	+	(+)	+	+	+	+	+	+	+	+		+			+	
26	TOS3	+	+	(+)	+	+	+	+	+	+	+							
27	BOL1	+	+	(+)	+	(+)	(+)	(+)	+	+	+	+					+	+
28	LIG1	+	+	(+)	(+)				+	+	+	+						
29	PIE2	+							+									
30	PIE3	+							+									
31	VEN2	+							+									

(1) plus soil solution chemistry
(2) plus streamflow chemistry
(3) plus SO_2

Table 5 – Number of sites covered by each investigation directly related to biodiversity assessment carried out at the PMPs of the CONECOFOR programme.
Numero di siti per ciascuna indagine direttamente connessa alla biodiversità portata avanti presso le aree permanenti del programma CONECOFOR.

Investigation	no. of plots									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
FTBA	0	0	0	0	0	0	0	0	12	19
Forest structure	0	20	0	0	24	0	0	0	0	31(a)
Ground vegetation	0	20	0	19	19	12	12	12	11	11(b)
Epiphytic lichens	0	0	0	0	0	0	0	0	0	7
Invertebrates	0	0	0	0	0	0	0	0	0	4
Deadwood	0	0	0	0	0	0	0	0	0	4
Naturalness	0	0	0	0	0	0	0	0	0	9
Landscape	0	0	0	0	0	0	0	0	0	2

(a): scheduled for late 2004-winter 2005
(b): data validation scheduled in winter 2005

Table 6 – Indicators and indices used in the various contributions of this volume. See individual papers for details.
Indicatori e indici usati nei vari contributi di questo volume. Vedi i singoli per i dettagli.

Indicator	**Stand structure diversity** (Fabbio *et al.* this volume)	**Vascular plant diversity** (Canullo *et al.* this volume)	**Lichen diversity** (Giordani *et al.* this volume)	**Invertebrates** (Mason *et al.* this volume)	**Deadwood** (Travaglini *et al.* this volume)	**Naturalness** (Ingegnoli e Petriccione this volume; Petriccione this volume)	**Landscape** (Ingegnoli and Petriccione this volume) Petriccione this volume)
Number of species	+	+	+	+		+	
Shannon Index (Shannon 1948)	+	+					
Ellenberg's indicator values		+					
Simpson Index (Simpson 1949)	+						
Evenness (Lloyd and Ghelardi 1964)	+						
Lichen Diversity Value (Asta et al. 2002)	+		+				
Dominant and mean tree height	+						
Number of stem per area unit	+						
Basal area per unit area and mean dbh	+						
Dominant and total basal area	+						
Presence (%) of the main tree species in the dominant storey	+						
Standard deviation of the DBH	+						
Index of nonrandomness (Pielou 1959)	+						
Index of clumping (Strand 1953; Cox 1971)	+						
Species Profile index (Pretzsch 1996)	+						
Complexity index (Holdridge 1967)	+						
Stumps					+		
Lying coarse wood pieces					+		
Lying fine wood pieces					+		
Dynamic stage						+	
Biological Territorial Capacity							+

biodiversity data (litterfall and LAI, Cutini 2000).

Problems in estimating diversity at the plot scale

Given its design based on a series of preferentially selected case studies and its relatively low number of sites, CONECOFOR does not aim at providing estimates for biodiversity indicators valid for the national scale. In this respect, the use of the data obtained from the Level II plots "to calculate 'γ-diversity' indices, which therefore represented the number of species found within a country" (EC-UN/ECE 2003, p. 41) is wrong (see also p. 50-51). At the same extent, and for the same reason, it would be wrong to use these data to infer estimates of α-diversity (*e.g.* at the sub-plot scale) for the national level. Rather, CONECOFOR wish to obtain reliable estimates of diversity indicators only *at the scale of individual plots* (γ –diversity) in order to document their status and changes over time and to assess relationships (if any) between these changes and concurrent changes in environmental drivers (*e.g.*, changes in climate, deposition loads, canopy structure). Even this apparently simple objective, however, suffers many constraints (Magurran 1988) and EC-UN/ECE (2003) reports a number of sources of bias, errors and scarce comparability between data collected at the international scale. They include: the size of the sampled area, the frequency of observation, the number and shape of sub-plots, the fencing, the number of observers involved, and the degree of familiarity of observers with a given plot. In Italy, these problems are much less, as plots are almost all fenced, the size and shape of subplots is always the same, observers receive the same training and use the same Standard Operative Procedures (SOPs). Only the familiarity factor remains, which may cause "a spurious increase in species richness over time" (EC-UN/ECE 2003, p. 48). Hellmann and Fowler (1999) discuss three characteristics that species richness estimates (as many other environmental estimates) should consider: bias, accuracy and precision. Bias is the difference between the expected value of the estimator (the mean of the estimates of all possible samples that can be taken from the population) and the true, unknown population value. Accuracy is the difference between the estimate based on sample data and the true value for the population being sampled. Precision is the difference between an estimate based on sample data and the mean of all possible samples of the same size from the population being sampled (Hellmann and Fowler 1999). Precision is measured by the variance of the estimator, accuracy is measured by the mean square error of the estimator. Bias, precision and accuracy depends on different aspects of the monitoring: sampling design, data quality, inherent properties of the estimator used, and nature of the population parameter to be estimated.

Sampling design

With the exception of the trees inventory, which is based on a complete census of all the trees in the plot[6], naturalness and landscape assessment, all the other investigations carried out in the CONECOFOR plots are based on sampling. Thus, a probabilistic sampling design (which ensures that each element of the target population has a non-null probability to be selected in the sample) is essential to produce unbiased estimates of the population parameters of concern (*e.g.*, mean, frequency, totals). Besides their spatial arrangements, the design needs to consider number, shape and dimension of the sampling units. Different solutions were adopted for the different surveys in the CONECOFOR plots: for example, vascular plant diversity used an area frame systematic design with twelve 10*10m sampling (proportion of population sampled: 48%, Canullo and Campetella, this volume); on the other hand, epiphytic lichens used a stratified random sampling (four strata based on tree diameter and tree bark pH) to select twelve trees per plot (proportion of population sampled: 1.3-13%, according to the plot, Giordani *et al.*, this volume).

Data quality

Data quality is essential to ensure full compliance of data with monitoring objectives. Data quality covers survey design (which is essential for proper statistical analysis), data plausibility (which is essential to avoid artefacts), data completeness (which is essential for proper calculations) and data consistency in space and time (which is essential for proper comparability) (Chiarucci 2001; Ferretti and Erhardt 2002; Brunialti *et al.* 2004). Thus, field procedures need to be harmonized, personnel performance standardized, and adequate control activity undertaken to check and document possible source of error and bias. Within the CONECOFOR programme, tree measurements, vascular species diversity, epiphytic lichen species diversity and deadwood assessment were carried out according to standard protocols (*e.g.* Canullo *et al.* 1999; Ferretti and Nibbi 2000; Stofer *et al.* 2003; Travaglini *et al.*, this volume): in general, data completeness was documented to be high (~100%) and training and control activity implemented.

Estimators

Although species richness is considered an important indicator of biodiversity, problems exist even with this relatively simple estimation. For the time being, no estimator has been developed that may provide unbiased estimates of total number of species over an area on the basis of a sample survey (D'Alessandro and Fattorini 2002). Hellmann and Fowler (1999) discussed the behaviour of several estimators (simple species richness, first- and second order jackknife, bootstrap) on five 50*80m forest plots sampled with 5*5m quadrats (consider that CONECOFOR plots are 50*50m and the vegetation quadrats are 10*10m). They aimed to calculate the total number of species per plot (γ-diversity) from the number of species obtained from the sample quadrats (α-diversity). A common approach in these cases is to use non-parametric estimators. However, it has been recently demonstrated to be incorrect (D'Alessandro and Fattorini 2002; Chiarucci *et al.* 2003); Hellmann and Fowler (1999) themselves encountered considerable problems with each of the estimators they used. This is because of the occurrence of rare species, which creates the condition for an asymptotic behaviour of the estimators (estimators reach the true value only with a disproportionate number of sampling units) (D'Alessandro and Fattorini 2002). Recently, a new estimator has been proposed that appears to provide reliable results when the area of inference is within 3 times the area sampled (Colwell *et al.* 2004).

Species richness and species density

This distinction is controversial and here it is kept only for make it clear that the estimates of total species richness are not possible for the time being, while mean number of species per area is feasible. As reported by Gotelli and Colwell (2001), "ecologists have not always appreciated the effects of abundance and sampling effort on richness measures and comparisons". Because of the above reported problems with the estimators, species richness remains an elusive task unless a complete census of the community of interest can be carried out. This is not always possible even because the larger the area observed, the lower the precision of the field survey. In this case,

[6] All trees above 3 and 5 cm dbh, for coppice and high forests respectively.

sampling is the only way to proceed. However, sampling implies estimates, and – for the time being - no unbiased estimates of the total number of species can be achieved (D'Alessandro and Fattorini 2002). Rather, unbiased estimates of the species density (*e.g.* mean number of species per area unit) can be obtained if a probabilistic sampling design is adopted. The problem is that – in some cases - there can be no correlation between the mean number of species per quadrat and the total number of species per plot (Hellmann and Fowler 1999).

The I&C evaluation system and the biodiversity assessment

The I&C evaluation system [7]

The importance of a clear concept for integrating data collected on Level II plots has been recently emphasised by Seidling (2005a, b). In Italy, in 1998 the National Focal Center (NFC) (the National Forest Service) decided to develop a formal evaluation system for the data generated by the Italian forest ecosystem monitoring programme (CONECOFOR) (Gruppo di Esperti CONECOFOR-I&C 1998). The first step was to establish a Task Force (TF) set up by the team leaders of the various investigations (see Table 4). The TF agreed upon a general concept for the evaluation system. The evaluation system was termed Integrated and Combined (I&C) because it is an attempt (i) to integrate data on different indicators, collected according to different sampling regimes and to different metrics; and (ii) to combine different evaluation perspectives in a cohesive and consistent evaluation system. Detailed information on the I&C evaluation system and first results have been published elsewhere (*e.g.* Ferretti *et al.* 2000; 2003; Ferretti 2000; 2002).

The I&C TF recognized three major issues of concern for the evaluation system: (i) the need to evaluate and identify the actual and potential risk status of the various PMPs in relation to air pollution, atmospheric deposition and meteorological stress; (ii) the need to evaluate, identify and quantify changes in biological, chemical, and physical ecosystem status and (iii) the need to evaluate and identify the determinants of changes. All together, the above issues constitute the framework within which the I&C evaluation system was established. Operatively, three categories of analysis were identified, each dealing with one of the issues mentioned above: Risk Analysis (RA), Status and Changes analysis (S&C) and Nature of Change analysis (NoC) (see Ferretti 2000, for details). Within the 2001-2005 strategy plan, biodiversity was considered an important issue to be covered by the I&C evaluation (Task Force I&C 2001; Ferretti *et al.*, 2004).

I&C and biodiversity

Biodiversity is a complex subject and it fits in the aims and tasks of the I&C system. The I&C Task Force agreed to cover the biodiversity issue in two phases. Firstly, a descriptive approach will be adopted; it aims at providing basic information about indicators and indices of diversity (*e.g.* vascular plant species diversity) at the various plots. This phase will results into site-based statistics about the various diversity indicators and – if possible – their trend over time. Secondly, an analytical approach will be adopted; it aims at exploring statistical relationships between indicators of specific diversity and structural and environmental factors in space and time.

"Aspects of biodiversity in selected forest ecosystems in Italy": the third I&C report

The importance of plant diversity in the Mediterranean Basin has been emphasised from different perspectives (*e.g.* Fady-Welterlen 2005; Petit *et al.* 2005). The present report aims at providing a first overview about activity and main results obtained in the field of biodiversity within the CONECOFOR programme in Italy, a target area for the potential impact of predicted global changes. As it is obvious from Table 5, presented results are most relevant to forest structure and plant species diversity and to the original twenty plots that were selected in 1995, although some more recent data from the other plots will be used as well. A number of structural and compositional indicators have been used by different contributors (Table 6). Fabbio *et al.* (this volume) report about the structural diversity (dimensional diversity, horizontal and vertical arrangement of the tree layers) of the plots. Canullo *et al.* (this volume) use the data collected over the 1999-2003 period to evaluate the diversity of vascular species in terms of number of species and various indices (*e.g.* Shannon) and their changes through time. These papers are supplemented by other ones dealing

[7] After Ferretti *et al.* 2003

with lichens (Giordani *et al.* this volume), invertebrates (Mason *et al.*, this volume), deadwood (Travaglini *et al.*, this volume), naturalness (Petriccione, this volume) and landscape (Ingegnoli, this volume). Ferretti *et al.* (this volume) investigate the statistical relationships between plant species diversity and site and environmental variables. Finally, Ferretti *et al.* (this volume) provide a synthesis of major achievements, problem and perspectives.

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Aspects of biological diversity in the CONECOFOR plots. I. Structural and species diversity of the tree community

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Abstract – Relationships between mensurational parameters as well as indices of structural and specific diversity, were calculated for the original set of 20 permanent plots established since 1995 in Italy within the Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems. The main goal of this paper was to test: i) the performance of different indices over a wide range of structural and ecological conditions as occurring in the network; ii) the relationship between stand structure and species diversity. The plots included Norway spruce and beech high forests, deciduous and evergreen oak-dominated, beech and mixed broadleaved coppice forests; common features and variability according to the main tree species and management system were highlighted. The age in the dominant storey, the stand origin (coppice or high forest) and the applied silviculture showed to be the major determinants of stand structure, while site elevation was the main factor driving specific richness. Besides the observed decrease of species diversity and stand complexity with elevation, only limited correlations were found between specific diversity and stand structure. The more recently disturbed type, *i.e.* the ageing coppice forest, exhibited cases of dynamical specific and structural rearrangement and the highest values of tree richness.

Key words: *forest monitoring, tree community, mensurational parameters, structural diversity, specific diversity.*

Riassunto – Aspetti della diversità biologica sulle aree CONECOFOR. I. Diversità strutturale e specifica della componente arborea. Si presentano nel lavoro le relazioni tra i parametri dendrometrici e gli indici descrittivi della diversità strutturale e specifica per la rete di 20 aree monitorate in Italia fino dal 1995 nell'ambito del Programma pan-europeo di monitoraggio intensivo e continuo degli ecosistemi forestali. Obiettivi principali dello studio sono: i) confrontare indici diversi in un ampio campo di variazione delle strutture e delle condizioni ecologiche, così come rappresentate nella rete di monitoraggio; ii) analizzare la relazione tra diversità strutturale e diversità specifica. La rete di monitoraggio comprende fustaie di abete rosso e di faggio, cedui in invecchiamento a prevalenza di querce caducifoglie (cerro, rovere), sempreverdi (leccio), di faggio e misti. L'ordinamento delle aree secondo la composizione specifica e la forma di governo, evidenzia gli aspetti comuni, la variabilità interna di ciascun tipo e i fattori che controllano la dinamica. Età dominante del bosco, forma di governo e selvicoltura applicata sono i maggiori determinanti della struttura arborea, mentre la quota della stazione appare il fattore principale che spiega la ricchezza specifica. Oltre la diminuzione del numero di specie e della complessità strutturale con l'aumentare della quota, soltanto relazioni limitate sono state trovate tra diversità specifica e struttura del popolamento. Il ceduo, ossia Il tipo più intensivamente gestito fino al passato recente, mostra casi di ricchezza specifica elevata e una dinamica accelerata di ricomposizione spaziale e strutturale.

Parole chiave: *monitoraggio delle foreste, popolazione arborea, parametri dendrometrici, diversità strutturale, diversità specifica.*

F.D.C. 524.634: 228.0: 187

Introduction

Biological diversity (Helms 1998) is a major matter of concern in forest management due to its functional role and to the processes to be implemented for its maintenance and development (Marell *et al.* 2003), or even to limit its erosion. A review of terms and concepts of biodiversity relevant to forest management is addressed by Roberts and Gilliam (1995).Biodiversity includes the ecological structures, functions, and processes (Society of American Foresters 1991) and different hierarchical levels (Probst and Crow 1991). A compositional, structural and functional diversity is also identified (Crow *et al.* 1994). Assessment and monitoring of ecosystem diversity is nowadays considered a key issue for conservation (Huston 1994), productivity (Burkhart and Tham 1992), nutrient cycling (Loreau 1995; Tilman *et al.* 1996), pest damage dynamics (Bengtsson *et al.* 1997), and a prerequisite of sustainable forest management (Hunter 1990; Bengtsson *et al.* 2000; Hall 2001). In this connection, an increasing demand arises on *alpha*-diversity (Whittaker 1977) and especially on the spatial distribution of trees and their attributes (species, sizes, or age classes) as

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factors driving habitat and specific diversity (Mason and Quine 1995; Zenner and Hibbs 2000; Ferris and Humphrey 1999 in Pommerening 2002). In general, increasing heterogeneity of horizontal and vertical stand structure is concomitant with higher number of species and higher ecological stability (Altenkirch 1982 and Ammer *et al.* 1995 in Pretzsch 1999).

The dominant stand age plays a major role within the driving forces modelling the observed forest physiognomies; it manages tree spatial distribution with the progress of individual size and relationships among neighbouring trees. Tree density, canopy arrangement and stand structure, also depend on a set of natural and man-induced factors. Natural determinants are: (i) the auto-ecology of tree species, *e.g.* the strategy of taking up the available growing space since the crop establishment and the adaptive ability in the following stages; (ii) the higher or lower compliance with site conditions; (iii) the occurrence and frequency/scale of disturbances. Common anthropogenic factors are *vice versa*: (i) the management system, *i.e.* the predetermined rotation in even-aged forests and the periodical harvesting of grown up trees in uneven-aged systems which to some extent reduce their functional lifespan; (ii) the intermediate and final silviculture (thinnings and regeneration cuttings); (iii) the multiple use of forest and forest floor. Each factor affects either positively or negatively standing trees throughout their lifespan. Canopy arrangement, tree density and stand structure control also inner microclimate and thus drive the establishment, development and evolutive pattern of the associated forest floor communities.

Biodiversity is also matter of concern within the "Pan-European programme for Intensive Monitoring of Forest Ecosystems" (ICP-Forests), consisting of several hundred level II plots installed all over Europe and representing the most important forest species and widespread growing conditions. In this connection, Neumann and Starlinger (2001) suggested to use the network as a basis for diversity assessments and described the Austrian Level II plots by comparing a wide set of structural and specific diversity indices. Besides the manifold reasons relevant to the ICP Forests programme and the underlying research questions, the same authors point out the shortage of literature dealing with: (i) the comparison of different indices over a wide range of ecological conditions (as occurring at national networks); (ii) the relationship between stand structure and species diversity.

The aim of this paper is the description of tree populations surveyed at each plot by the assessment of some indices of structural and specific diversity. Focus is made on the mensurational parameters, on the spatial arrangement of trees, on the species composition and allocation. Further aims are to give a contribution to the following questions: (i) to what extent can the basic stand parameters feature stand structure? (ii) which indices, among those computable within the ICP-Forests survey protocol, show a better interpretative ability? (iii) which is the level of correlation between the computed indices? (iv) what about the correlation between stand structure and species diversity?

Material and Methods

The plots' network

The paper is based on the twenty Level II Permanent Monitoring Plots (hereafter referred to as PMPs) surveyed in winter 1996/97 (1st tree inventory and growth survey). The plots, (50x50m = 2500 m^2) have been established since 1995 into the public domain throughout the Italian peninsula and major islands by the National Forest Service (Allavena *et al.* 1999). All the PMPs were installed into mass vegetation areas and inside homogeneous forest covers (10 to 100 ha): site conditions were therefore assumed to be consistent with tree species ecology in a natural range of site-classes. Each plot is a "patch" *i.e.* a relatively small uniformly disturbed area under the same dynamics (Petraitis *et al.* 1989) where a tree population and associated vegetation is growing under similar site conditions (Oliver and Larson 1990) or, biometrically, a "collection of measurements" (Prodan 1968). Different tree species and mixtures, management systems, age classes and stand structures (*i.e.* the most diffused forest types) were represented in the network in accordance with UN-ECE guidelines (1998). The origin, high forest or coppice forest, was the main discriminant inside the network. No thinnings, removals or other practices have been implemented inside the plots and the neighbouring area since their establishment. Due to the network design (preferential sampling, no explicit model adopted), each PMP was considered as a case-study.

The main site factors (abiotic diversity) are reported in Table 1. The geographical (latitude, longitude) and topographical (elevation) distribution of plots had a noteworthy importance on climate parameters (annual rainfall and mean temperature), influencing both

Table 1 - Site characteristics of the CONECOFOR PMPs.
Caratteristiche stazionali delle aree CONECOFOR.

n°	Plot code	Lat.	Long.	Rainfall mm yr^{-1}	Mean temp. °C	Elevation a.s.l.m	Topographical position	Aspect	Slope gradient
01	ABR1	415051	133523	1300	10	1500	UM	SW	30%
02	BAS1	403638	155225	750	13	1125	UM	SW	25%
03	CAL1	382538	161047	1500	10	1100	UM	NE	20%
04	CAM1	402558	152610	1250	10	1175	UM	W	30%
05	EMI1	444306	101213	1200	12	200	P	flat	5%
06	EMI2	440631	110700	1800	10	975	IM	W	30%
07	FRI1	454734	130715	500	14	6	P	flat	0%
08	FRI2	462928	133536	1500	6	820	IM	N	25%
09	LAZ1	424950	130010	1000	12	690	H	W	10%
10	LOM1	461416	93316	1300	8	1190	LM	SW	30%
11	MAR1	431738	130424	1250	10	775	IM	SE	60%
12	PIE1	454055	80402	1500	8	1150	IM	NW	55%
13	PUG1	414910	155900	800	12	800	UM	SE	25%
14	SAR1	392056	83408	900	14	700	IM	E	15%
15	SIC1	375432	132415	800	13	940	UM	NE	25%
16	TOS1	433034	102619	900	15	150	H	NE	30%
17	TRE1	462137	112942	800	5	1775	IM	N	15%
18	UMB1	432757	122757	1250	11	725	LM	N	25%
19	VAL1	454326	65555	1000	5	1740	IM	NW	55%
20	VEN1	460326	120156	1900	5	1100	IM	NW	10%

UM = upper mountainside; IM = intermediate mountainside; LM = lower mountainside; H = hillside; P = plain.

tree growth and length of the vegetation period (7 to 4 months from the Mediterranean sites to the alpine region). The locally variable topography (position, aspect, slope gradient) and soil quality either enhanced or reduced the expected difference between sites.

As for tree species composition, broadleaves were largely prevailing. High forest (9 PMPs) included 4 Norway spruce [*Picea abies L.*] plots aged 80-200 along an east-west transect on southern alpine slopes) and 5 beech [*Fagus sylvatica L.*] plots aged 75-130 located on the Apennines (4) and Alps (1). Broadleaved forest counted also 11 PMPs aged 35-75, already managed under the coppice system *i.e.* harvested by clearcutting on short rotations (15-25 yrs according to the species) and originating clumped tree (shoot) populations from stool resprouting. Two different stand structures were recognizable: (i) forests naturally evolving since the suspension of harvesting and named "aged" or "stored" because of tree biomass stocking with ageing; (ii) "transitory crops" *i.e.* aged coppices undergoing periodical thinnings which drastically reduced tree density and progressively shaped the stand structure into the physiognomy of a high forest aged likewise. The prevailing tree species composition is made by deciduous oaks (Turkey oak [*Quercus cerris L.*], sessile oak [*Quercus petraea Matts.*], 6 PMPs), evergreen oak (holm oak [*Quercus ilex L.*], 2 PMPs), beech (2 PMPs), other broadleaves (hornbeam [*Carpinus betulus L.*] and peduncolate oak [*Quercus robur L.*], 1 PMP).

Parameters and indices

The basic growth variables were measured (ICP Forests Manual 1998) as follows: dbh of all trees alive (threshold 3 to 5 cm in coppice and high forests respectively), tree height and height to base of crown. Tree mapping was available in 18 out of 20 plots. Tree species were determined and individual social rank estimated according to Kraft (Assmann 1970). This made it possible to stratify each tree population within homogeneous growth environments. At the purpose of reducing the subjectivity inherent to the former attribution, trees were then pooled into three well-discernible dominant, intermediate and dominated (even-aged forests) or upper, intermediate and lower (uneven-aged forests) layers (Amorini and Fabbio 1997, 2000). This arrangement has been used for the calculation of a few indices of specific diversity and stand structure. Basal area (b.a.), mean/dominant dbh were calculated and mean/top height estimated by the allometric functions (Fabbio and Amorini 2000, 2002). The assessment of Leaf Area Index (17 plots), litter and leaf litter production (19 plots), provided further synthetical indices of standing crop productivity and functioning (Cutini 2000 and 2002). The management plans and forest managers provided further information on the dominant age or age classes and stand history.

The main tree species, applied management system, structural type, stand age and mensurational parameters are reported in Table 2. The following

PMP	Main Tree species (MTS)	Management system	Structural type	Stand age	Tree density	Tree species in the PMP	Tree species dominant/ upper layer	MTS dominant/ upper layer	Mean dbh	Basal area (total)	Basal area (dominant/ upper layer)	Mean height	Top height	Standing volume	DIFN	Canopy depth (main crop layer)	LAI	LAD	Leaf litter	Total litter
code				yrs	n ha^{-1}	n°	n°	%	cm	m^2	m^2	m	m	m^3 ha^{-1}	%	m	m^2/m^2	m^2/m^3	Mg ha^{-1}	Mg ha^{-1}
FRI2	Picea a.	high forest	one-storied	90-110	532	2	1	100	35,2	52,90	28,13	29,1	32,6	*739*	4,75	18,2	3,98	0,22	4,587	5,116
LOM1	Picea a.	high forest	stratified	80	1043	9	8	65	22,2	40,23	35,68	18,3	26,1	*368*	2,80	17	4,29	0,25	2,556	3,195
TRE1	Picea a.	high forest	one-storied	180-200	393	2	1	100	41,8	53,89	35,59	28,2	30,5	*699*	11,40	22,5	2,94	0,13	2,171	3,518
VAL1	Picea a.	high forest	irregular	140	745	2	2	70	29,3	50,18	46,75	20	24,7	*482*	8,60	14,3	3,26	0,23	2,911	3,442
ABR1	Fagus s.	high forest	one-storied	110	899	1	1	100	23,7	40,09	32,64	19,5	24,6	430	1,77	9,3	4,67	0,5	2,969	3,884
CAL1	Fagus s.	high forest	one-storied	100-120	333	2	1	100	39,1	39,90	22,39	24,1	28,6	529	3,00	14,1	4,36	0,31	4,644	6,577
CAM1	Fagus s.	high forest	one-storied	100	228	2	1	100	51,5	47,57	32,68	26,8	28	714	n.a.	14,1	n.a.	n.a.	2,295	5,493
PUG1	Fagus s.	high forest	one-storied	75	940	7	2	97	23,5	43,77	22,87	22,6	27,5	574	1,00	14,2	5,43	0,38	4,172	5,886
VEN1	Fagus s.	high forest	one-storied	115-130	345	1	1	100	35,8	34,64	15,34	23,9	25,2	455	1,20	7,4	5,25	0,71	2,318	2,906
EMI2	Fagus s.	stored coppice	two-storied	45	4540	2	2	99	10	35,77	20,36	12,4	13,6	266	3,00	9,3	4,61	0,5	2,370	3,006
PIE1	Fagus s.	trans. crop	one-storied	55-70	1213	4	2	93	17,4	28,93	16,18	15,2	20	251	3,10	11,1	4,24	0,38	2,964	4,894
BAS1	Q. cerris	trans. crop	two-storied	60	917	3	2	95	23,8	40,85	23,96	16,9	20,2	318	n.a.	7	n.a.	n.a.	3,973	4,938
SIC1	Q. cerris	trans. crop	one-storied	50	855	3	2	98	19,3	25,01	14,58	14,6	16,9	197	13,20	6,8	2,44	0,36	4,997	7,847
UMB1	Q. cerris	trans. crop	one-storied	75	739	8	2	99	24,2	33,92	21,38	24,4	28,5	430	3,95	10,9	4,11	0,38	n.a.	n.a.
LAZ1	Q. cerris	stored coppice	one-storied	35	1629	2	1	100	13,7	23,94	14,99	13,3	16,8	166	7,20	5,1	3,38	0,66	3,510	4,082
MAR1	Q. cerris	stored coppice	one-storied	35	4233	11	3	94	10,4	35,84	23,40	12,1	17,9	212	3,15	5,7	4,43	0,78	3,866	5,253
EMI1	Q. spp.	stored coppice	one-storied	45	2057	6	2	57	12,6	25,68	20,21	12,9	19,1	152	7,00	12,6	3,35	0,27	4,271	6,539
FRI1	Mix.broadl.	trans. crop	one-storied	45	1126	6	5	29	16,5	24,05	15,11	15,9	22,4	199	2,25	9,7	4,44	0,46	4,538	6,143
SAR1	Q. ilex	stored coppice	one-storied	50	1710	5	1	100	17,3	40,54	24,95	13,5	16,7	246	n.a.	8,6	n.a.	n.a.	3,506	5,806
TOS1	Q. ilex	stored coppice	two-storied	50	2404	13	7	71	12,5	30,14	12,00	11,6	15,4	157	3,50	6,2	5,22	0,84	4,548	7,510

Table 2 – Main tree species, management system, stand structure, age, tree richness and mensurational parameters at the level II PMPs network (survey 1996-97). Plots are arranged according to the main tree species. Stand age: average value in the dominant storey. DIFN: Diffuse Non Interceptance. Canopy depth: referred to the main canopy layer. LAI: leaf area index. LAD: leaf area density (LAI/canopy depth ratio). Standing volume: stemwood in Italics; stemwood + branchwood in Roman. Minimum dbh surveyed = 3 cm in coppice forests; = 5 cm in high forests and transitory crops. n.a.= not available.
Specie prevalente, forma di governo, struttura, età, ricchezza specifica e parametri dendrometrici delle aree comprese nella rete di II livello. Stand age = età media nel piano dominante. DIFN: vuoti nella copertura. Soglie diametriche minime misurate: 3 cm nei cedui; 5 cm nei cedui in avviamento e nelle fustaie. Volume: volume cormometrico in corsivo; volume dendrometrico in tondo. n.a. = non disponibile.

statistics and indices were used to describe canopy properties, tree size distribution, tree spatial pattern and layering, species diversity and stand complexity.

- Leaf area index (LAI) and leaf area density (LAD), litter and leaf litter production, percentage of gaps (DIFN). Canopy affects tree growth and allows the penetration of light and precipitation. Upper canopy drives therefore the structure, composition and development of subordinate tree layers, understorey vegetation and forest floor communities; *i.e.* their diversity and biodiversity in general (LATHAM *et al.* 1998). Top height provides the age-related site index, while its difference to mean height determines the upper canopy roughness and crown depth in the main crop layer. Tree density, total and dominant basal area (b.a.), mean dbh, percentage presence (b.a.) of the main tree species (MTS) into the dominant storey, were also considered at the purpose of describing this facet of "mensurational" diversity.
- Dbh distribution is a key element of stand structure and thus a determinant of biological diversity. Since the relationship between dbh and tree height is well defined and there is a strong positive correlation between canopy height and foliage height, tree size diversity should serve as a good proxy for foliage height diversity (BUONGIORNO *et al.* 1994). Tree size diversity was examined by dbh standard deviation (S_{DBH}), coefficient of variation (CV_{DBH}) (DE VRIES *et al.* 1999; ZENNER and HIBBS 2000) and by the SHANNON index applied to the proportion of trees in each size (dbh) class (SH_{SIZE}) (WHITTAKER 1975; BUONGIORNO *et al.* 1994).
- The PIELOU index (*PI*) of non-randomness or neighbourhood pattern (1959) and the COX index (*CI*) of clumping (STRAND 1953; COX 1971) were used

to describe horizontal micro and macrostructure, respectively. Pielou was computed according to a systematic 5x5 m grid (100 sampling points in each PMP); Cox was calculated on 25 10x10 m subplots. For both indices, values <=>1 indicate regular to random to clustered distributions, respectively.

- The Vertical Evenness (*VE*) (Neumann and Starlinger 2001 modified) served as descriptor of tree layering. Given the crown projection area as in the original calculation was available only for a few plots in our dataset, the index was computed by proportion of number of trees (VE_N) and basal area (VE_G) into each layer (= social rank).
- The Species Profile index (*A*) (Pretzsch 1999; Fischer and Pommerening 2003), a combination of Shannon index after stratification into prefixed height bands (100-80%; 80-50%; <50% of maximum stand height), provided the assessment of relative specific abundance in the stand profile. According to Pretzsch, the index performs quite well one-storied to multi-layered stand structures, peaks being reached in mixed stands with heterogeneous structures.
- The Shannon index per layer (= social rank) (SH_L), served as a further descriptor of richness-abundance throughout the vertical profile. A notation about the use of Shannon index per layer was found in Zenner and Hibbs (2000). The summation of SH_L was also computed.
- The Shannon (*SH*) (1948), Simpson (*SI*) (1949) and Evenness (*E*) indices reported on tree species richness, relative abundance and equitability (Margalef 1958; Lloyd and Gherardi 1964; Magurran 1988; Pielou 1966; Magnussen and Boyle 1995).
- The Holdridge index (*HC*) (1967), based on top height, basal area, tree density, number of species, *i.e.* the parameters available in our survey, described stand complexity.

The computed values, formulae and correlation coefficients are reported in Tables 3, 4 and 5. The correlation analysis (Spearman's *rho*) was performed with Statistica, Statsoft® Inc.

Results

Structural diversity

Canopy cover was generally high (DIFN < 5%) in 11 out of 17 plots; gaps exceeded 10% only in TRE1 and SIC1. LAI ranged from 2.4 to 5.4, but was higher than 4.0 on two thirds of plots in accordance with the full stocking. As for litter production, the prevalence of leaf *vs.* total litter (spruce 78%, beech 76%, deciduous 74% and evergreen 60% oaks-dominated stands) (Cutini 2002) provided evidence that the grown-up phase has not been reached yet in the observed standing crops. LAD varied from 0.13 (TRE1) to 0.84 (TOS1).

The difference between mean and top height resulted higher in uneven-aged, mixed or irregular structures (LOM1 and VAL1), in the most dense beech forests (ABR1, CAL1, PUG1, EMI2) and in the mixed, fully stocked coppice forests (EMI1, FRI1, TOS1). The relationship mean/top height *vs.* crown depth is shown in Figure 1. Similar basal areas (the age-related index of site carrying capacity under a complete canopy cover) matched with quite different mean dbhs, depending on the widely variable tree density. The arrangement of dominant *vs.* total basal area (Figure 2) showed that the major share was located in the upper layer into uneven-aged or irregular forests (LOM1 and VAL1); the same ratio was better balanced into even-aged stands, where both tree density and species auto-ecology drive the basal area partition. As expected, the main tree species was largely prevailing in the dominant storey, whilst a shared presence was limited to mixed forests. As for dbh, a wider range was associated with high stockings, the intense level of inter-tree competition enhancing size differences. Among the computed statistics, CV_{DBH} proved (Figure 3) to fit better than S_{DBH} the between-plot variability because it links both dbh variation and mean. CV_{DBH} exhibited also significant positive correlations with a number of indices (*CI*, *PI*, VE_N, *A*, *SH*, *SI*, *E*, *HC*). S_{DBH} showed *vice versa* significant correlations only with

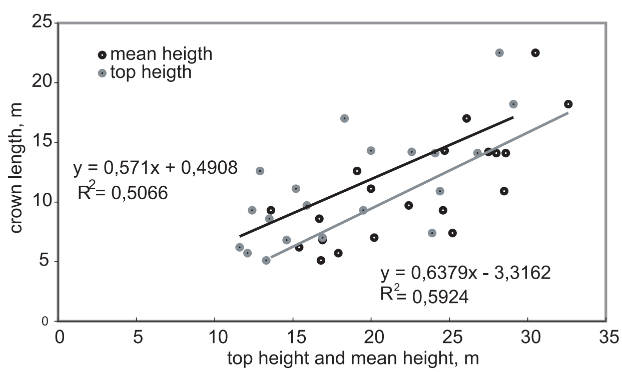

Figure 1 - Crown length vs. top and mean heigth.
Profondità della chioma in relazione alle altezze dominante e media.

Table 3 - Within-plot (alpha) diversity: the indices. SH/U = Shannon dominant/upper layer SH/I = Shannon intermediate layer SH/L = Shannon dominated/lower layer n.a. = not available
Indici di diversità entro le aree.

PMP	Management system	Structural type	Tree species richness	Tree size diversity (dbh)			Tree horiz. distrib. pattern		Tree diversity in the stand profile							Tree species diversity			Compexity
code			n	SH	St. dev.	CV	Cox	Pielou	VE_N	VE_G	A	SH/U	SH/I	SH/L	ΣSH_L	SH	E	SI	HC
FRI2	high forest	one-storied	2	2,75	9,5	27,6	0,4	0,7	0,96	0,84	0,61	0	0	0,64	0,64	0,21	0,21	0,06	18,34
LOM1	high forest	stratified	9	3,03	13,6	77,8	1,9	1,3	0,98	0,37	2,33	1,9	2,19	1,7	5,79	2,01	0,63	0,66	98,56
TRE1	high forest	one-storied	2	3,32	14,5	36,9	0,4	0,6	0,94	0,65	0,78	0	0,23	0	0,23	0,08	0,08	0,02	12,91
VAL1	high forest	irregular	2	3,19	11,8	44,1	0,9	1,0	0,77	0,3	1,46	0,85	0	0	0,85	0,7	0,7	0,31	18,46
ABR1	high forest	one-storied	1	2,96	12,2	59,9	2,3	1,3	0,92	0,55	1,08	0	0	0	0	0	0	0	8,87
CAL1	high forest	one-storied	2	3,65	19,3	56,8	1,0	1,2	0,99	0,75	1,06	0	0	0,37	0,37	0,17	0,17	0,05	7,59
CAM1	high forest	one-storied	2	3,12	13,2	26,5	0,5	1,1	0,69	0,57	0,18	0	0	0	0	0,13	0,13	0,04	6,08
PUG1	high forest	one-storied	7	3,22	12,2	57,6	3,4	1,5	0,96	0,9	1,53	0,25	0,51	1,54	2,3	1,08	0,39	0,35	79,21
VEN1	high forest	one-storied	1	2,89	9,1	25,3	0,9	1,0	0,72	0,67	0	0	0	0	0	0	0	0	3,01
EMI2	stored coppice	two-storied	2	2,48	4,9	56,2	5,6	4,0	0,96	0,86	1,02	0,07	0,03	0	0,1	0,03	0,03	0,01	50,99
PIE1	trans. crop	one-storied	4	2,43	7,3	46,2	2,1	1,3	0,82	0,77	0,97	0,39	0,28	1,64	2,31	0,5	0,25	0,15	28,08
BAS1	trans. crop	two-storied	3	3,07	11,9	57,5	n.a.	n.a.	0,99	0,81	1,19	0,28	0,18	0,38	0,84	0,3	0,19	0,09	22,7
SIC1	trans. crop	one-storied	3	1,79	3,9	20,4	1,1	0,6	0,8	0,68	0,73	0,19	0,23	0,23	0,65	0,22	0,14	0,06	39,75
UMB1	trans. crop	one-storied	8	2,5	9	40,1	1,1	0,9	0,97	0,72	1,22	0,1	0,4	2,07	2,57	0,94	0,31	0,27	21,43
LAZ1	stored coppice	one-storied	2	2,43	4	30,5	0,8	0,7	0,89	0,8	0,71	0	0,04	0	0,04	0,03	0,03	0,01	13,11
MAR1	stored coppice	one-storied	11	2,76	5,7	66,2	1,8	1,7	0,98	0,79	2,03	0,31	1,94	2,3	4,55	2,23	0,64	0,71	217,26
EMI1	stored coppice	one-storied	6	3,04	7,8	78,3	2,7	2,4	0,97	0,58	1,48	0,95	1,69	0,24	2,88	1,51	0,59	0,58	60,55
FRI1	trans. crop	one-storied	6	3,04	7,6	52	1,5	1,3	0,99	0,82	2,07	1,91	0,77	1,71	4,39	1,73	0,67	0,57	36,41
SAR1	stored coppice	one-storied	5	3,44	9,4	64,1	n.a.	n.a.	0,98	0,81	1,68	0	0,63	1,76	2,39	1,13	0,49	0,37	57,88
TOS1	stored coppice	two-storied	13	3,17	7,3	71,3	2,6	1,0	0,77	0,99	2,21	1,62	2,19	1,96	5,77	2,15	0,58	0,7	124,88

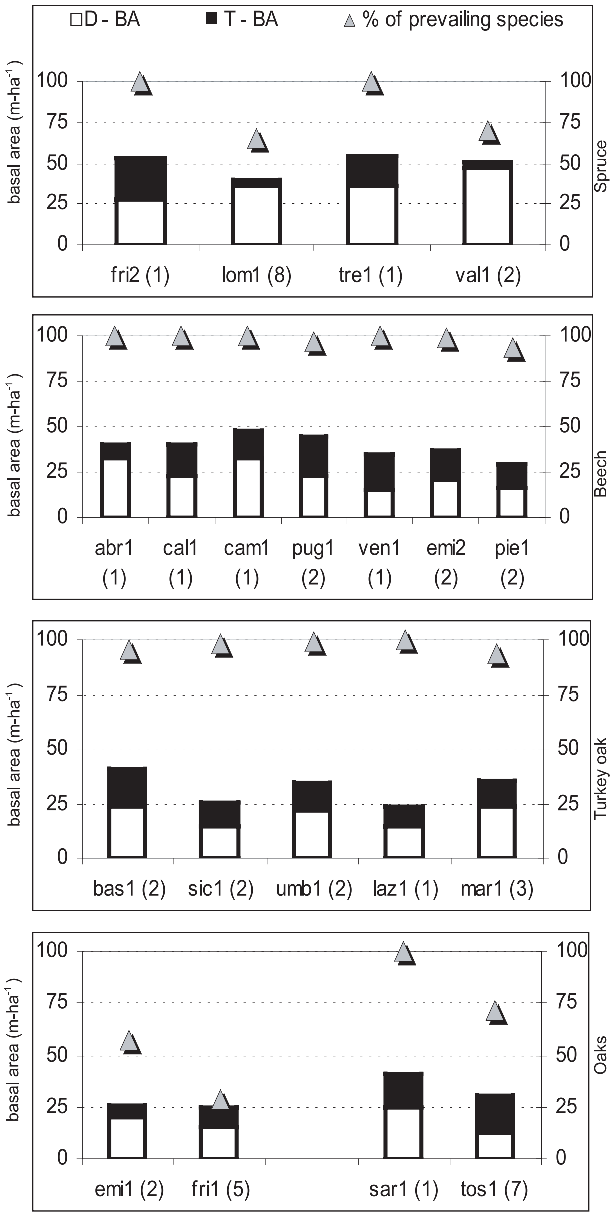

Figure 2 - Total basal area (T-BA), basal area in the dominant/upper storey (D-BA) and percentage of the main tree species in the dominant/upper storey per forest typology. ( ) is the number of species in the dominant/upper storey.
Area basimetrica totale (T-BA), area basimetrica del piano dominante/superiore (D-BA) e percentuale della specie principale nel piano dominante/superiore per ciascun tipo forestale. ( ) è il numero di specie nel piano dominante/superiore.

site elevation and SH_{SIZE}. SH_{SIZE} (Figure 4) exhibited a limited between-plot variation in spite of the different distribution of trees highlighted by the relative position of mean dbh in the size range.

Pielou (*PI*) is plotted *vs.* Cox (*CI*) in Figure 5. Both the indices showed consistent results (regular to random to clustered). The major share of managed

Table 4 - Computed indices and formulae.
Indici calcolati e relative formule.

RI	Tree species richness	N	N is the number of species.
SH_{DBH}	Shannon applied to dbh classes (Buongiorno et al. 1994)	Σ(-log2pi)pi	p_i is the relative abundance of trees in the i_{th} size class.
Cox	Index of clumping (Strand 1953, Cox 1971)	s^2_x/x_m	s^2_x is the variance and x_m is the mean stem number on sub-plots.
Pielou	Index of non-randomness (Pielou 1959)	$\pi(n/A\ 1/K)\Sigma r_i^2$	n is the stem number per plot, A is the plot area, K is the number of sample points and r_i is the minimum distance from sample point to the nearest tree.
VE_N	Vertical Evenness	$\Sigma((-\log_2 p_i)\ p_i/\log_2 3)$	p_i is the relative abundance of trees in each layer.
VE_G	Vertical Evenness	$\Sigma((-\log_2 p_i)\ p_i/\log_2 3)$	p_i is the relative basal area in each layer.
A	Species Profile index (Pretzsch 1996)	$-\Sigma s \Sigma h(p_i \ln p_i)$	s is the number of tree species, h is the number of height layers and pi is the relative abundance of the i_{th} species in each layer.
SH_L	Shannon per layer (Shannon 1948)	$\Sigma(-\log_2 p_i)p_i$	p_i is the relative abundance of the ith species in each layer.
ΣSH_L	Summation of SH_L (Shannon 1948)	$\Sigma L \Sigma(-\log_2 p_i)p_i$	L is the number of layers and p_i is the relative abundance of the i_{th} species in each layer.
SH	Shannon index of diversity (Shannon 1948)	$\Sigma(-\log_2 p_i)p_i$	p_i is the relative abundance of the i_{th} species.
E	Evenness (Lloyd and Ghelardi 1964, Magurran 1988)	$SH/\log_2 N$	N is the number of species.
SI	Simpson index of diversity (Simpson 1949)	$\Sigma(1-p_i)p_i$	p_i is the relative abundance of the i_{th} species.
HC	Complexity index (Holdridge 1967)	H BA n N	H is the top height, BA is the basal area, n is the stem number and N is the number of species.

Table 5 - Correlation coefficients (Spearman's rho) among statistics and indices tested. In bold type the values significant at $p < 0.05$.
Coefficienti di correlazione tra le statistiche e gli indici calcolati. In grassetto i valori significativi per p<0.05.

	Elevation	SH_{SIZE}	S_{DBH}	CV_{DBH}	Cox	Pielou	VE_N	VE_G	A	SH	E	SI	HC
Elevation	1												
SH_{SIZE}	0,13	1											
S_{DBH}	**0,59**	**0,71**	1										
CV_{DBH}	-0,23	0,36	0,11	1									
Cox	-0,27	0,10	-0,18	**0,71**	1								
Pielou	-0,16	0,28	0,04	**0,66**	**0,79**	1							
VE_N	-0,33	0,22	0,14	**0,51**	0,37	**0,53**	1						
VE_G	**-0,63**	-0,03	-0,39	0,12	0,37	0,26	0,28	1					
A	-0,35	0,35	0,01	**0,83**	**0,57**	**0,47**	**0,51**	0,17	1				
SH	**-0,47**	0,21	-0,14	**0,63**	0,39	0,31	0,42	0,21	**0,86**	1			
E	-0,33	0,27	-0,05	**0,52**	0,23	0,28	0,38	0,07	**0,80**	**0,92**	1		
SI	**-0,45**	0,23	-0,12	**0,65**	0,38	0,33	0,40	0,20	**0,85**	**1,00**	**0,94**	1	
HC	**-0,47**	-0,04	-0,39	**0,68**	**0,64**	0,40	0,33	0,39	**0,77**	**0,83**	**0,67**	**0,82**	1

high forests (FRI2, TRE1, CAM1, VEN1, VAL1, CAL1) was included within the "regular" area, while most of coppice forests and transitory crops originated the expected clumped distributions. The correlation between *PI* and *CI* was high; *CI* was also related significantly to *A* and *HC*; *PI* with VE_N and *A*.

VERTICAL EVENNESS by proportion of number (VE_N) and basal area (VE_G) is reported in Figure 6. VE_N showed high values (0.7 to 0.9 or more) close to its theoretical maximum (=1) in 13 out of 20 plots. VE_G weighed up each tree subset and exhibited intermediate to high values (0.55 to 0.99) in 18 out of 20 plots. The generally high stockings determined a stratification driving the index towards its maximum, in spite

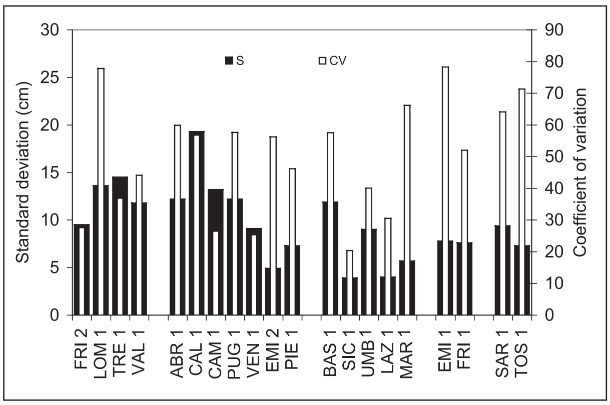

Figure 3 - Tree size diversity: dbh standard deviation and coefficient of variation.
Diversità degli alberi: deviazione standard e coefficiente di variazione del diametro.

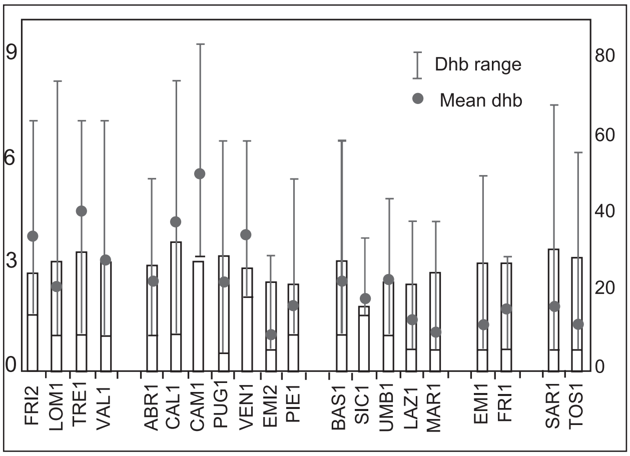

Figure 4 - Tree size diversity: the Shannon index (left axis) applied to dbh classes(right axis).
Diversità dimensionale degli alberi: indice di Shannon applicato alle classi di diametro.

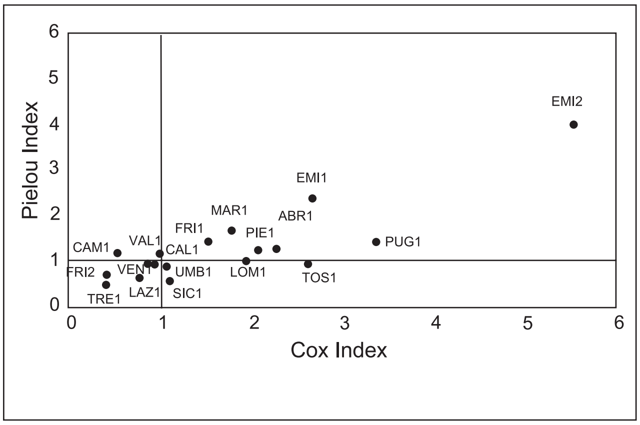

Figure 5 - Spatial tree distribution (horizontal structure): Cox index (macrostructure) *vs.* Pielou index (microstructure).
Distribuzione spaziale degli alberi (struttura orizzontale): indice di Cox (macrostruttura) in relazione all'indice di Pielou (microstruttura).

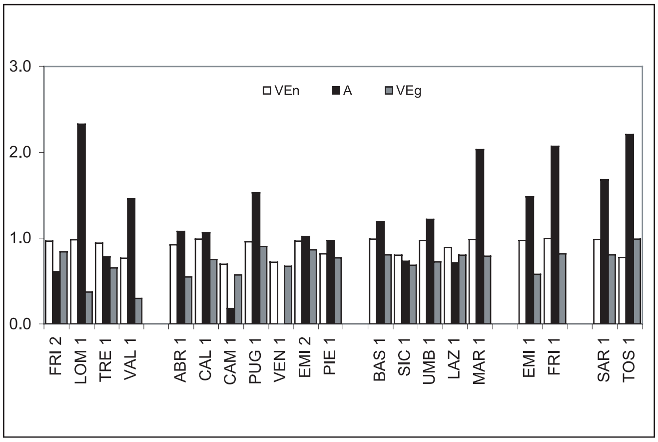

Figure 6 - Spatial tree distribution (vertical structure): Vertical Evenness (VE_N and VE_G) and Stand Profile Index (A).
Distribuzione spaziale degli alberi (struttura verticale): Vertical Evenness (VE_N and VE_G) e Stand Profile Index (A).

of the even-aged structures and of the definition of "one-storied" stands. Lower values (0.30 and 0.37) characterize the irregular or uneven-aged structures, the major share of basal area being here incorporated into the upper layer. Significant correlations were found between VE_N, PI, A and CV_{DBH}. VE_G was correlated negatively with site elevation.

Tree species diversity

The Species Profile index (A) takes into account tree species composition, *i.e.* a site attribute that is relatively independent from the applied management system. The Species Profile index (Figure 6) reached the highest values ($A > 2$) in LOM1 (9 sp.), MAR1 (11 sp.), FRI1 (6 sp.), TOS1 (13 sp.) whilst it was > 1 in 9 out of the remaining 16 plots *i.e.* a spruce forest (VAL1), three beech high forests (ABR1, CAL1, PUG1), a stored beech coppice (EMI2), a number of oak-dominated coppice forests (BAS1, UMB1, EMI1, SAR1). As expected, A was correlated significantly with the indices of specific diversity (SH, E, SI), as well as with most indices of structural diversity (CV_{DBH}, CI, PI, VE_N) and complexity (HC).

Shannon per layer (SH_L) (Figure 7) highlighted a similar (LOM1, TOS1) or a quite different specific diversity throughout the vertical profile (VAL1, PUG1, PIE1, MAR1, EMI1, FRI1, SAR1). The summation of SH_L is also reported, which emphasizes the diversity expressed by species layering.

Shannon (SH), Evenness (E) and Simpson (SI) indices (Figure 8) showed a different sensitivity to the relative species abundance and distribution. Shannon fits better the between-plot variation where three or more species occur, its algorithm weighing also less abundant (rare) species. The index exhibited a 0 to 2.23 range as a function of tree richness (also reported in the figure). Among high forests, once more LOM1 and PUG1 showed the peak values. It is of interest the case of PUG1, where due both to canopy gaps and site conditions, different tree species regenerate under the main crop layer. High values were reported also for the oak dominated coppice forests (UMB1, MAR1, EMI1, FRI1, SAR1, TOS1), where a number of shade-tolerant species were recorded under the dense main cover. With the exception of PUG1, beech forests are *vice versa* naturally poor in terms of species. Correlations between the indices were high; they exhibited also significant positive correlations with CV_{DBH} and HC

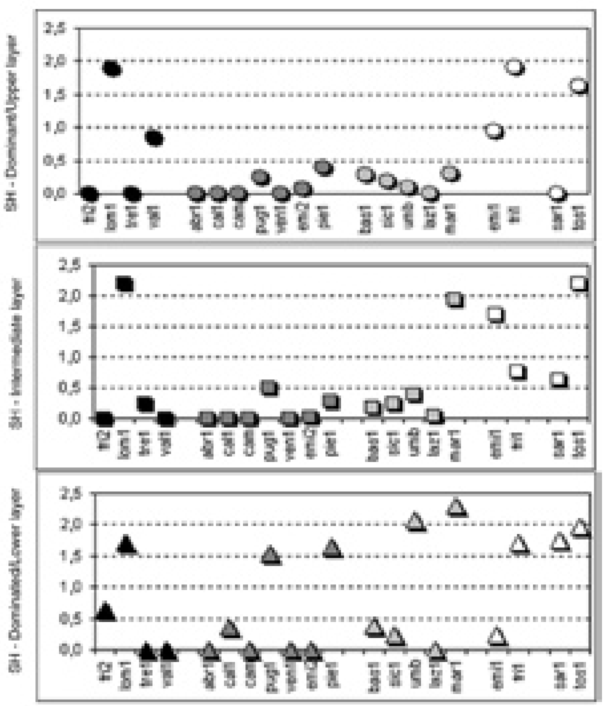

Figure 7 - Tree specific diversity per layer: the Shannon index (SH_L) .
Diversità specifica degli alberi per piano: indice di Shannon (SH_L).

and a negative correlation with site elevation.

Stand complexity

The Holdridge index (*HC*) was computed (Figure 9). Given the multiplicative nature of the index (*top height*basal area*stem number*number of species*), the resulting value was mostly determined by the occurrence of a high number of species and elevated stockings as reported for LOM1, PUG1, MAR1 and TOS1. No information is provided about stand structure. *HC* was positively correlated with indices of dimensional (CV_{DBH}), structural (*CI*), specific (*A SH*, *E*, *SI*) diversity and negatively with site elevation.

Discussion

Relationships among mensurational parameters reflect the between-plot difference in terms of dominant age, stand origin, tree density, applied silviculture, tree species composition and site quality. They provide also a preliminary tool to address further issues of diversity.

As for tree size, the coefficient of variation of dbh showed the wide variation throughout the network. Its significant correlation with structural, species diversity and complexity indices is remarkable.

Cox and Pielou performed a consistent description of horizontal diversity. Deviations were reduced both in number and size. Most of managed high forests were arranged as “regular”, while coppice forests and transitory crops prevailed within the “irregular” area. Both indices are correlated with the Species Profile index which links structural and species diversity.

In relation to the vertical distribution, the Vertical Evenness (in terms of proportion of number of trees and basal area) exhibited a controversial response. VE_N maintained high values at most of the plots, even under even-aged condition where – in general – there is a tendency to establish one-storied structures; VE_G exhibited values opposite than expected (low to high from multi-storied to one-storied stands), as a function of basal area partition into layers. The generally high tree density favoured the stratification of crowns highlighted by the balanced attribution of trees to the different layers; VE_N showed therefore to be very sensitive to the occurrence of fully stocked conditions and VE_G to the related basal area allocation. VE_N was reported to correlate significantly with the dbh coefficient of variation and Pielou, while VE_G was correlated with site elevation. The performance of *VE* in terms of relative crown area per layer, as in the original calculation of Neumann and Starlinger, should be much more consistent but it was not computable within our dataset.

The Species Profile index by Pretzsch fits well the specific diversity in the different layers. Its interpretative ability and the number of significant correlations established suggest the profitable use of this index either in this or similar assessment contexts.

Shannon per layer provided information about tree species allocation and allowed an ecological understanding of specific diversity. The time of establishment and the persistence of trees living in the canopy layer or in the understorey may be actually quite different. In general, under the main cover the establishment of new trees is usually connected with openings in the canopy that allow more light to penetrate inside, whereas their persistence is often linked to the recovery of pre-existent ecological conditions. There is evidence that specific diversity may have a quite different time perspective and functional meaning between high forests and aged coppice forests. In the latter case, the natural evolution following a long time of harvesting on short rotations, originated a process of recovery from these disturbances (com-

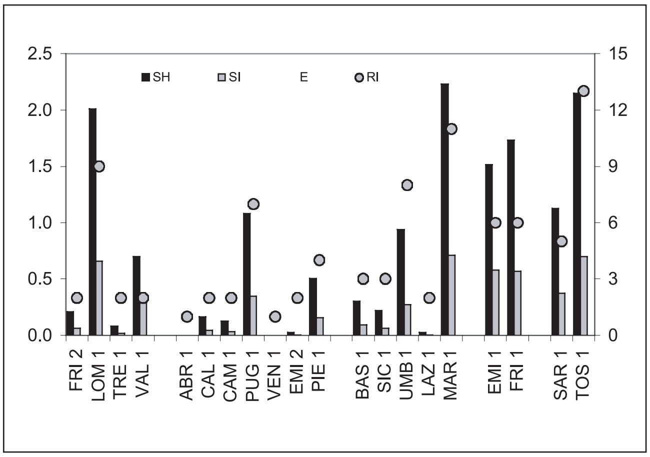

Figure 8 - Tree species diversity: the Shannon (SH), Simpson (SI), Evenness (E) indices (left axis) and tree species richness (RI) (right axis).
Diversità specifica degli alberi: indici di Shannon (SH), Simpson (SI), Evenness (E) (asse di sinistra) e ricchezza specifica (RI) (asse di destra).

mon feature) that can be influenced by site factors (individually different from plot to plot). That is why most of specific diversity was observed into coppice forests, *i.e.* the originally more intensively managed stands that are now experiencing substantial changes. The arrangement of tree species in the vertical profile and their auto-ecology, may suggest a sort of "transitional" diversity related to the dynamic processes currently underway.

As for the specific diversity indices (plot level), Shannon exhibited the highest sensitivity to the between-plot variation. The joint calculation of the same algorithm per layer (SH_L) ensured a more in-depth reading of the same phenomenon.

There is evidence of a significant decrease of species diversity and complexity computed by Shannon, Simpson and Holdridge indices with site elevation. As far as the relationship between stand structure and species diversity are concerned, a significant correlation was found only with the dbh coefficient of variation; no correlation was obvious with the indices describing the horizontal or vertical distribution pattern. As already discussed by Neumann and Starlinger , the reduced number of plots does not allow the stratification needed to address the specific diversity to a targeted influencing factor. The Species Profile index, a combined descriptor of structure and species diversity, showed *vice versa* a significant correlation with almost all the indices tested.

The use of Holdridge index is recommendable due to the easily available dataset needed, but the different "weight" of each factor should be always taken into account.

Conclusions

Datasets within the action "tree growth" of the ICP-Forests monitoring programme can provide a consistent basis to compute a number of indices of structural and specific diversity, if a few optional assessments as tree mapping and social rank are also available. It is also recommendable to measure crown projection areas. A basic definition of structural characteristics and diversity of tree populations throughout the Italian Level II network has been achieved; the same analysis could be usefully repeated in subsequent occasions, at least for the more dynamic cases and facets of diversity. High rates of regular mortality and changes in the tree species composition over the following monitoring period can drive and focus the attention on the more interesting case-studies.

A different interpretative ability and number of correlations among the statistics and indices tested have been highlighted. Both common features and differences inside each type and between types are explained by the underlying driving factors: the age in the main crop layer, the site index and location, the applied management system as well as the irregular practice of silviculture which are the major determinants of plots' diversity. Ageing coppice forests showed the more dynamical perspective in terms of stand structure and tree richness. In this connection, the analysis on ground vegetation (Canullo *et al.*, this volume) will usefully supplement these findings.

Besides the observed decrease of tree species diversity and stand complexity with site elevation, no significant correlations were found between tree diversity and their spatial distributive pattern, the only exception being the measure of relative tree size distribution. A close relationship was established only by the Species Profile index that combines both specific and structural diversity attributes.

Our findings highlighted how the more recently disturbed cases (the coppice forests) originate the more complex, structured and rich tree communities. There is evidence that (i) this is a result of the dynamical rearrangement following the suspension of repeated short rotation harvestings and that (ii) a transitory status may be naturally inherent to the accelerated

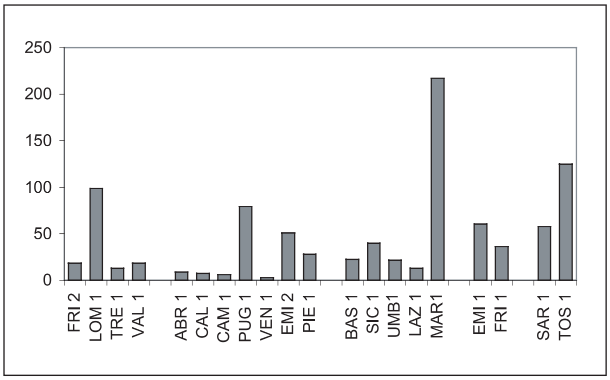

Figure 9 - The Complexity Index (Holdridge).
L'indice di complessità di Holdridge.

phase of development monitored in these systems.

Caution is therefore needed in the interpretation of the observed specific and structural diversity attributes in terms of steady qualities of forest ecosystems.

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Aspects of biological diversity in the CONECOFOR plots. II. Species richness and vascular plant diversity over the period 1999 - 2003

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Abstract – A better understanding of the effects of air pollution and other stress factors on forests requires long-term investigations focusing on ecosystem complexity and diversity. The EU regulation "Forest Focus" implemented ground vegetation assessment leading to the estimation of plant diversity. In this paper, data from the permanent monitoring plots (PMPs) of the CONECOFOR network (1999-2003) were used to quantify the species richness and vascular plant diversity. The Shannon indices of diversity (based on mean cover and frequency of the species), mean number of species*100 m^{-2} and their changes in the examined time frame were used to summarize several ecological-structural characteristics of the investigated forest ecosystems. The data presented were based on species composition of vascular plants assessed inside each permanent plot, and can be used as a reference model (baseline) to assess further changes in plant diversity components.

Key words: *forest ecosystems, permanent plots, Shannon diversity index, evenness, temporal changes.*

Riassunto – Aspetti di diversità biologica nelle aree della Rete CONECOFOR. II. Ricchezza specifica e diversità delle piante vascolari nel periodo 1999-2003. Le ricerche a lungo termine focalizzate sullo studio della complessità e diversità degli ecosistemi, possono condurre ad una migliore comprensione degli effetti degli inquinanti e di altri fattori di stress sulle foreste. Il regolamento EU "Forest Focus" ha proposto un'implementazione verso la valutazione della diversità di specie vegetali. In questo contributo, i dati provenienti dalle aree permanenti di monitoraggio della rete CONECOFOR sono stati utilizzati per quantificare la ricchezza specifica e la diversità delle piante vascolari. Gli indici di diversità di Shannon (basati sulla copertura e sulla frequenza delle specie), il numero medio di specie*100 m^{-2} ed i loro cambiamenti nel periodo di tempo considerato, sono stati utilizzati per sintetizzare diversi caratteri ecologico-strutturali dei sistemi forestali indagati. I dati presentati sono basati sulla composizione specifica delle piante vascolari, rilevate nel sistema di campionamento interno alle aree permanenti e possono essere utilizzati come riferimento (baseline) per la stima delle variazioni di alcuni componenti della diversità vegetale.

Parole chiave: *ecosistemi forestali, aree permanenti, indice di diversità di Shannon, evenness, variazioni temporali.*

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Introduction

The term diversity, in its strictly descriptive meaning, indicates the differentiation level of the elements composing an ecosystem. From this point of view, both the number of different elements and their quantitative relationships are important descriptors of compositional diversity (Helms 1998). Considering its application to natural ecosystems, the term diversity is widely used, although a comprehensive definition is still lacking (Magurran 1988; Kaennel 1998). Usually, it indicates the variety and variability among organisms, defined by number and frequency of different components organised at different levels, in a wide hierarchical range from genes across species to ecosystems. Species diversity is better known, but functional and structural diversity are also important facets (Van der Maarel 1988; Barkman 1979; Turner 1995).

In forest ecosystems, most of the European plant species have evolved and adapted to past natural disturbance regimes (Bengtsson *et al.* 2000). However, forest areas are also determined by more recent natural and anthropogenic disturbances (including management practices). Consequently, understanding former disturbance dynamics is essential in preserving and managing biodiversity as well as ecosystem functions in the human-dominated European forests (Nilsson and Ericson 1997).

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Over the last decades, studies and theoretical scientific discussions on biological diversity have emerged as one of the most important subjects. Species diversity may have positive effects on important ecosystem processes such as productivity and nutrient cycling (TILMAN *et al.* 1996). A high specific (or, at least, functional) diversity may also entail ecosystem stability, resistance to perturbations, resilience after disturbances, and stability of ecosystem functions over time (TILMAN and DOWNING 1994; PETERSON *et al.* 1998; NAEEM 1998; GRIME *et al.* 2000). Possible effects of air pollution on species diversity have to be considered (BOBBINK *et al.* 1998). BOBBINK and WILLEMS (1987) (confirmed by SCHULZE and GERSTBERGER 1993; HOGG *et al.* 1994; DE VRIES *et al.* 1995) found that a surplus of atmospheric depositions of sulphur (S) and nitrogen (N) can change the status of nutrients and thus alter interspecific relationships towards competitive exclusion of ecosystem components and consequent reduction of biological diversity. Moreover, it is generally recognised that eutrophication is one of the major causes of changes in biodiversity in developed temperate countries (TAMIS *et al.* 2005). However, some other research in forest ecosystems has underlined opposite trends (THIMONIER *et al.* 1992; FALKENGREN-GRERUP 1986), and LIU and BRAKENHIELM (1996) found that the species diversity of the understorey vegetation in some Swedish permanent monitoring sites was not significantly influenced by atmospheric deposition, explaining the observed changes as natural processes.

In order to reach a better understanding of the effects of air pollution and other stress factors on forests and to improve knowledge about forest condition and evolution, the EU regulation termed *Forest Focus* implemented ground vegetation assessment leading to the estimation of plant diversity (NEUMANN and STARLINGER 2001). Accordingly, over the period 1999-2003, ground vegetation assessment was performed on 19 Level II Permanent Monitoring Plots (PMPs) of the Italian CONECOFOR network (Table 1). Vascular plants as well as terricolous bryophytes and lichens included in the 0.25 ha fenced plots were considered. The databank containing all the records from two approaches (population level on the understory, community level on whole plot, *sensu* CANULLO and CAMPETELLA 2000), and from both the fenced plots and an unfenced neighbouring site, provides the information for describing the plant diversity of the studied PMPs.

In the present paper, the evaluation of species diversity focused on vascular plants and considers the datasets originating from the surveys carried out from 1999 to 2003. Data considering total richness including bryophites and lichens will be briefly reported as well. By focusing on the compositional elements of plant diversity, the purpose of the paper is to contribute to the overall definition of the status of individual PMPs (see FERRETTI *et al.* 2000), also by means of "ecological spectra" (which consider the indicator value of the occurring species). The main objective is to establish the baseline condition of the

Table 1 - General information on the CONECOFOR plots used for vegetation monitoring in Italy. The last column includes the total number of species recorded in all surveys (incl. bryophytes and lichens), at both the community and population level.
Informazioni generali sui plot CONECOFOR considerati per il monitoraggio della vegetazione in Italia. L'ultima colonna include il numero totale di specie rilevate in tutti gli anni (incluse briofite e licheni) a livello di comunità e di popolazione.

N	Site name	Latitude	Longitude	Altitude m a.s.l.	Forest type	surveys	cumulative species number
01	ABR1 - Selvapiana	+415051	+133523	1500	beech	1999-2003	50
02	BAS1 - Monte Grosso	+403638	+155225	1125	turkey oak	1999	99
03	CAL1 - Piano Limina	+382538	+161047	1100	beech	1999-2003	76
04	CAM1 - Serra Nuda	+402558	+152610	1175	beech	1999-2003	91
05	EMI1 - Carrega	+444306	+101213	200	sessile oak	1999-2003	81
06	EMI2 - Brasimone	+440631	+110700	975	beech	1999	56
07	FRI1 - Bosco Boscat	+454958	+131004	6	hornbeam-oak	1999-2003	85
08	FRI2 - Tarvisio	+462928	+133536	820	spruce (and fir)	1999	93
09	LAZ1 - Monte Rufeno	+424950	+115410	690	turkey oak	1999-2003	145
10	LOM1 - Val Masino	+461416	+093316	1190	spruce (and fir)	1999-2003	111
11	MAR1 - Roti	+431738	+130424	775	turkey oak	1999-2003	92
12	PIE1 - Val Sessera	+454055	+080402	1150	beech	1999	35
13	PUG1 - Foresta Umbra	+414910	+155900	800	beech	1999	45
14	SAR1 - Marganai	+392056	+083408	700	holm oak	1999, 2002	36
15	SIC1 - Ficuzza	+375432	+132415	940	turkey oak	-	-
16	TOS1 - Colognole	+433034	+102119	150	holm oak	1999-2003	59
17	TRE1 - Passo Lavazè	+462137	+112942	1800	spruce	1999	48
18	UMB1 - Pietralunga	+432757	+122757	725	turkey oak	1999	81
19	VAL1 - La Thuile	+454326	+065555	1740	spruce	1999-2003	140
20	VEN1 - Pian di Cansiglio	+460326	+120156	1100	beech	1999-2003	70

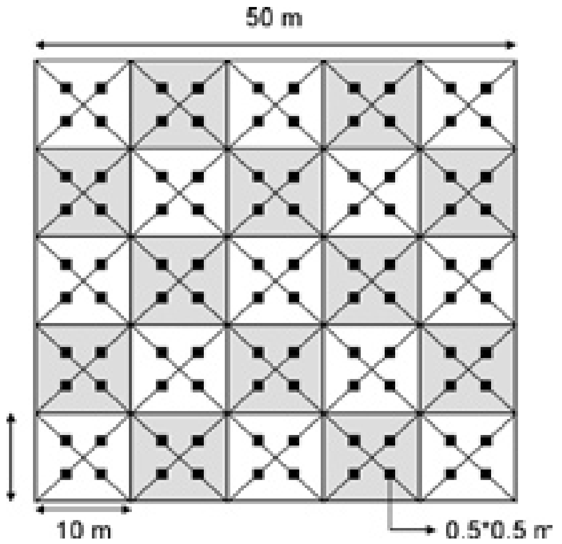

Figure 1 – Sampling design adopted for vegetation monitoring within the CONECOFOR plots (based on Canullo *et al.* 1999a). The main plot is divided into twenty-five 10*10m sampling units, twelve of which (shaded) were selected for monitoring at the community level. One hundred quadrats 50*50 cm were installed for the monitoring at the population level (black squares along diagonals).
Disegno di campionamento per il monitoraggio della vegetazione nei plot CONECOFOR (disegnato da Canullo et al.*, 1999a). Il plot principale è diviso in 25 unità campionarie di 10*10 m; di queste, 12 sono state selezionate per il monitoraggio a livello di comunità (in grigio). Inoltre 100 quadrati 50*50 cm sono stati impiantati per il monitoraggio a livello di popolazione (quadrati neri sulle diagonali).*

vegetation diversity in the CONECOFOR plots at the beginning of the monitoring programme and to identify short-term temporal changes by means of the diversity indices considered.

Methods

Data collection

Data were collected according to the Manual compiled by the Expert Group on Ground Vegetation Assessment (Dupouey 1998; Canullo *et al.* 2002; Aamlid *et al.* 2002). The sampling design is reported in Figure 1. At the community level, twelve 10x10 m sampling units (SU) out of the 25 possible within each 50*50 m fenced PMP were selected. SUs were arranged systematically in a chessboard pattern in order to minimize spatial correlation. The unfenced surrounding area was sampled using the same method (further details: Canullo *et al.* 1999, 2001; 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 (Braun-Blanquet 1932, 1951), assigning each species to correspondent classes (r = rare; + = < 1%; 1= 1-5%; 2 = 5-25%; 3 = 25-50%; 4 = 50-75%; 5 = 75-100%). At the population level, a systematic grid of one-hundred 50*50 cm quadrats were selected within the fenced PMP. Species-specific cover estimates, density of functional individuals, and frequency of mechanical and parasitic damage were recorded in the understory (up to a height of 1.3 m).

The full list of species occurring inside each PMPs (obtained from the 1999-2003 database) was used for general considerations (cumulative species number, Table 1). In this paper, only data on vascular plants obtained from the summer survey of the 10*10m SUs are used to estimate species richness and diversity indices. With the exception of SIC1, all the 20 PMPs selected in 1994-1995 were visited during 1999 in order to have the initial description of plant diversity at the various plots. On the other hand, data covering the 1999-2003 period were available only for 11 PMPs and this was used to explore the temporal trend of species richness and diversity (Table 1).

Quality Assurance (QA)

In order to have coherent and comparable environmental data sets, a proper Quality Control (QC) data programme must be created, with clearly defined quality objectives. A Quality Assurance programme was implemented by the "Ground Vegetation Assessment" group, led by the Department of Botany and Ecology of Camerino University:

1. Field manual use (Canullo *et al.* 1999) to assure harmonisation.
2. Definition of Measurement Quality Objectives (MQOs) and Data Qualities Limits (DQLs) for each parameter (see Table 2).
3. Annual team-training course, comprising a series of lectures followed by guided field-

Table 2 – Measurements of Quality Objectives (MQOs) expressed as Data Quality Levels (DQLs). @=agreement.
Obiettivi di qualità di misurazione (MQOs) espresso come limiti di qualità dei dati (DQLs). @=accordo.

Parameter	Unit of measure	DQLs
Total vegetation cover (scale 10x10m)	%	90% @ ±10%
Specific cover (scale 10x10m)	7 classes	90% @ ±1 class
Specific herb and woody cover (50x50cm)	%	90% @ ±10%

work practice. The objective here is to assure conformity with the field manual and intercalibration among all the teams composed of two experienced members; a control team has also been involved since the manual was revised. Repeated observations on the same plot allow the assessment of relative scores.

4. The teams perform the actual surveys in the network of permanent plots. At the same time, the control team carries out field controls on randomly chosen plots and a related fraction of sampling units; this control is used to observe the difference between values recorded by the control team and those of the survey teams.
5. The data acquisition is successive to validation executed by data-base procedures, in order to ascertain the consistency and plausibility of the data. The first part of the data import procedure is the validation of all scientific names of species, according to PIGNATTI's Italian flora (1982), using a dedicated archive. The database performs some checks for each attribute, verifying its correspondence with the upper and lower limits previously set by the system Administrator. In addition, about twelve different crosschecks provide further verification of data integrity for observations on both community and population levels. The last tool is the automatic association between the Italian flora archive and the coded archive of *Flora Europaea* (derived from the PANDORA taxonomic database system of the Royal Botanic Garden, Edinburgh).

Data analysis

Vascular plant species richness was expressed as the total number of species identified in the sample quadrats and as the mean number of species*100 m^{-2} (± confidence interval at p=0.05). As we repeated the data collection on the same 12 SUs at more than two time-points, these measurements are inherently autocorrelated. In order to appreciate possible significant differences in species richness over time (1999-2003), the Repeated Measures ANOVA (RMA) test has been applied in each PMP considering the variation of mean species number recorded on the 12 SUs (Within-Subjects Effects test). This statistical application allows also to test a significant linear trend over time (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 pairwises of temporal data.

Richness-abundance relations were assessed using the Shannon index, one of the most used in the literature (MAGURRAN 1988; NEUMANN and STARLINGER 2001). 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:

$$H' = -\Sigma p_i \log_2 (p_i)$$

where p_i is the relative abundance of the species i.

The two abundance parameters considered were mean cover and frequency of species. In the first case, p_i is estimated using c_i/C in which c_i is the average relative cover of the species i in all layers of the 12 SU, and C is the summation of the average relative cover of all species. The use of relative cover values permits assessment of the total cover distribution among all species. In the second case, p_i is the relative frequency f_i/F, where f_i is the frequency of the species i within the 12 SU and F is the summation of all species frequencies.

To analyse the distribution level of the frequency and cover among species, the Shannon Evenness was also calculated as follows:

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

where H'_{max} represents the maximum of the Shannon-Wiener index at the given species richness ($H'_{max}=\log_2 S$, where S is the total number of species) and H' is the field value of the Shannon index. The linear regression for Shannon indices values vs. time were also calculated, by estimating the angular coefficient and its significant level by ANOVA.

All the vascular species from summer surveys (1999-2003) recorded within the sampling system, were assigned to widely accepted "ecological" groups (SAGE *et al.* 2005; FISCHER *et al.* 2002). Plants were distinguished by their prevalent participation to wide vegetation community categories (forests, borders and hedges, open herbaceous, nitrophile, ruderal and segetal systems). This was to made a first hemeroby evaluation, as a measure for man's cultivation influence on ecosystems, based on the extent of effects

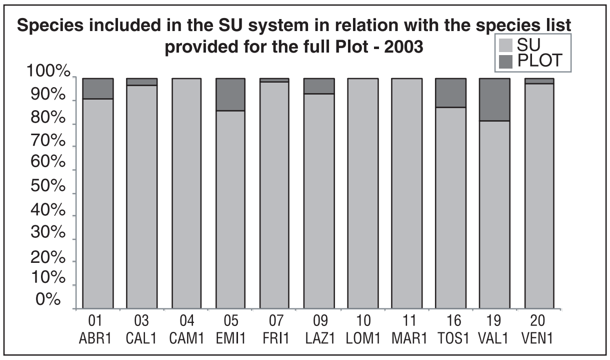

Figure 2 – Percent of species "captured" by the sampling system at the community level (12 quadrates 100 m^2 each), compared to the expected (*i.e.* the complete list of species recorded in the whole plot).
Percentuale di specie catturata dal sistema campionario a livello di comunità (12 quadrati di 100 m^2 ciascuno) in relazione a quanto rilevato sull'intero plot.

of those anthropogenic influences which affect the system's development towards a final state (Kowarik 1988; Neumann and Starlinger 2001). Ellenberg's indicator values for the Italian flora (Pignatti 2005) were modified to summarize few indicators of different environmental conditions (light, soil moisture, soil pH and nutrient contents). Nomenclature of species follows *Flora Europaea* (Tutin *et al.* 1964-1980).

Results and Discussion

Mean status 1999-2003

Species richness

The total number of species resulting from all the records obtained over the period 1999-2003 is reported in Table 1 for any given PMP. Considering all vascular species and terricolous bryophytes and lichens included on each *florula*, some simple summary observations can be made:

(i) all the plots belonging to beech (*Fagus sylvatica*) communities, mostly one-storeyed in the tree layer, show a contingent with a maximum of 91 taxa (CAM1), though these plots most frequently numbered less than 80 entities, and sometimes had only a few dozen (*e.g.* PIE1);

(ii) the number of species encountered in *Quercus ilex* (holm oak) formations is mostly formed of several woody species and a little pool of taxa of the understorey herbs;

(iii) a low number of species was also found in one subalpine forest stand dominated by *Picea abies* (TRE1) with a few dwarf shrubs, herbs and bryophytes, while the other coniferous systems have higher values (93 to 140 species);

(iv) on mesophilous and submontane mixed oak-deciduous forests the *florula* exceeds 80 taxa.

The richest lists (more than 100 species) were compiled for those plots influenced by disturbances, edge effects, and local heterogeneity, and areas with a high participation of lichens and bryophytes (*e.g.* LAZ1, LOM1, and VAL1 respectively).

At the community level, the species richness on the 12 quadrats of each PMP represents more than 80% of the total number of species recorded in the full PMP (Figure 2); the expected full *florula* (in terms of number of species) was recorded in the sampled area for more homogeneous PMPs at the survey scale of 0.25 ha (CAM1, LOM1, and MAR1). The mean density of vascular species per SU (n*100 m^{-2}) can be considered a good *proxy* of the specific richness of each PMP. On the basis of this assumption, Table 4 reports the mean number of species*100 m^{-2} for each plot and year. In 1999, the highest values have been found in mixed stand and/or disturbed sites: BAS1 was dominated by *Quercus cerris* with penetration of species probably linked to the impact of cattle grazing in the neighbourhood; FRI1 is a lowland hornbeam-oak forest with a number of woody species; LAZ1 is dominated by *Quercus petraea* and *Q. cerris* and reflects previous and present disturbances (penetration of anthropogenic species and defoliation by *Lymantria dispar* in 2002/2003); LOM1 is a mixed spruce forest with some penetration of species from the beech communities and the neighbouring grasslands; MAR1 is a Turkey oak (*Quercus cerris*) forest with a number of deciduous tree species, recovering after past coppice management, as is UMB1.

Indicator value

An ecological interpretation of the CONECOFOR PMPs can be performed inspecting the scores showed in the Table 3. Here the species percentage distribution in different ecological groups (Pignatti 2005) is presented by each PMP.

Vegetation - In almost cases of beech plots (ABR1, CAL1, CAM1, EMI2, PIE1, PUG1, VEN1) the percentage of *forest* species resulted very close or more than 90%; in EMI2 a certain penetration of species characterizing *herbaceous* and *border* communities (9,09 and 6,06 respectively) is probably due to the intensive previous disturbance (coppicing). The PMPs located in oak-mixed deciduous woodlands show a *forest* species percentage around 80%, while the more consistent penetration of species from external ecosystems can

Table 3 – Species percentage distribution in different ecological groups by each PMP. The ecological species groups were based on their prevalent participation to wide vegetation categories (vegetation) and on their occurrence in different environmental conditions, summarized by few indicators (light, soil moisture, soil pH and nutrient contents).
Percentuale di specie in differenti gruppi ecologici per ciascuna PMP. I gruppi sono basati sulla loro prevalente partecipazione ad ampie categorie di vegetazione (vegetation) e sulla loro occorrenza in diverse condizioni ambientali sintetizzate da alcuni indicatori (luce, umidità del suolo, pH del suolo e contenuto in nutrienti).

forest type	ABR1 beech	BAS1 turkey oak	CAL1 beech	CAM1 beech	EMI1 sessile oak	EMI2 beech	FRI1 hornbeam -oak	FRI2 spruce (and fir)	LAZ1 turkey oak	LOM1 spruce (and fir)	MAR1 turkey oak	PIE1 beech	PUG1 beech	SAR1 holm oak	TOS1 holm oak	TRE1 spruce	UMB1 turkey oak	VAL1 spruce	VEN1 beech
Vegetation																			
forest	90,0	72,6	88,1	90,0	80,4	78,8	84,8	94,4	79,7	78,7	84,0	93,8	100,0	100,0	82,1	93,8	83,9	82,2	95,0
border/hedges	3,3	4,1	0,0	0,0	5,9	6,1	7,6	1,9	4,3	4,0	6,7	0,0	0,0	0,0	10,3	0,0	7,1	4,4	2,5
herbaceous open	3,3	13,7	2,4	10,0	9,8	9,1	4,5	1,9	11,6	13,3	8,0	0,0	0,0	0,0	5,1	6,3	7,1	13,3	0,0
nitrophile	0,0	4,1	9,5	0,0	0,0	3,0	0,0	0,0	2,9	2,7	1,3	0,0	0,0	0,0	0,0	0,0	1,8	0,0	2,5
segetal/ruderal	3,3	5,5	0,0	0,0	3,9	3,0	3,0	1,9	1,4	1,3	0,0	6,3	0,0	0,0	2,6	0,0	0,0	0,0	0,0
Light																			
unvaluable	0,0	0,0	0,0	2,5	0,0	0,0	0,0	0,0	4,3	0,0	0,0	0,0	0,0	0,0	2,6	0,0	0,0	0,0	0,0
full shadow	23,3	8,2	33,3	30,0	3,9	18,2	13,6	24,1	5,8	25,3	10,7	31,3	33,3	12,5	7,7	31,3	7,1	17,8	35,0
halfshadow	76,7	89,0	64,3	65,0	94,1	78,8	84,8	74,1	87,0	73,3	88,0	68,8	63,0	83,3	84,6	68,8	92,9	80,0	62,5
light	0,0	2,7	2,4	2,5	0,0	0,0	0,0	0,0	1,4	0,0	0,0	0,0	3,7	4,2	5,1	0,0	0,0	0,0	0,0
broad spectrum	0,0	0,0	0,0	0,0	2,0	3,0	1,5	1,9	1,4	1,3	1,3	0,0	0,0	0,0	0,0	0,0	0,0	2,2	2,5
Moisture																			
unvaluable	0,0	0,0	0,0	2,5	2,0	0,0	0,0	1,9	4,3	1,3	0,0	0,0	0,0	0,0	2,6	6,3	0,0	2,2	0,0
dry soil	3,3	11,0	4,8	2,5	13,7	3,0	4,5	1,9	11,6	6,7	12,0	12,5	3,7	45,8	30,8	0,0	8,9	2,2	5,0
moist soil	86,7	83,6	95,2	95,0	72,5	90,9	87,9	85,2	73,9	81,3	84,0	56,3	88,9	54,2	59,0	62,5	87,5	86,7	95,0
floaded soil	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
broad spectrum	10,0	5,5	0,0	0,0	11,8	6,1	7,6	11,1	10,1	10,7	4,0	31,3	7,4	0,0	7,7	31,3	3,6	8,9	0,0
Ph																			
unvaluable	0,0	0,0	0,0	2,5	2,0	0,0	1,5	5,6	5,8	6,7	0,0	6,3	0,0	0,0	2,6	6,3	0,0	8,9	5,0
acidic soil	13,3	6,8	4,8	7,5	11,8	6,1	0,0	20,4	14,5	16,0	5,3	31,3	0,0	0,0	5,1	56,3	1,8	26,7	5,0
neutral soil	56,7	68,5	64,3	60,0	51,0	66,7	66,7	37,0	53,6	44,0	60,0	37,5	63,0	75,0	56,4	25,0	55,4	33,3	65,0
basic soil	6,7	8,2	9,5	15,0	9,8	15,2	15,2	18,5	14,5	2,7	22,7	0,0	11,1	8,3	20,5	0,0	25,0	6,7	2,5
broad spectrum	23,3	16,4	21,4	15,0	25,5	12,1	16,7	18,5	11,6	30,7	12,0	25,0	25,9	16,7	15,4	12,5	17,9	24,4	22,5
Nutrients																			
unvaluable	3,3	1,4	2,4	2,5	2,0	0,0	1,5	3,7	4,3	4,0	1,3	0,0	3,7	0,0	2,6	12,5	0,0	4,4	5,0
poor soils	13,3	20,5	14,3	15,0	23,5	21,2	9,1	29,6	26,1	22,7	24,0	37,5	7,4	25,0	28,2	62,5	16,1	35,6	2,5
mesotrophic soil	43,3	49,3	57,1	47,5	37,3	57,6	51,5	40,7	47,8	44,0	48,0	37,5	51,9	58,3	46,2	12,5	53,6	33,3	47,5
fertilized soil	30,0	16,4	19,0	22,5	13,7	18,2	19,7	14,8	5,8	21,3	12,0	12,5	25,9	8,3	5,1	6,3	16,1	20,0	40,0
broad spectrum	10,0	12,3	7,1	12,5	23,5	3,0	18,2	11,1	15,9	8,0	14,7	12,5	11,1	8,3	17,9	6,3	14,3	6,7	5,0

be underlined in BAS1 and LAZ1. The holm oak forest ecosystems (SAR1 and TOS1) present none or just few penetration whereas among the spruce forests only LOM1 exhibits 13,33% of species from *herbaceous* open vegetation.

Light - Almost all ecosystems studied are well provided of *halfshadow* plants (62-94%), while the *light* plants are really scarce. The *full shadow* plants play an important role in the beech and spruce forests (mean values 29 and 24 % respectively), but of few importance in the other systems (8%). The soil "moisture" indication shows that in most of the monitored communities the extent of *moist soil* species is larger than 70%; in the holm oak PMPs (SAR1 and TOS1) this percentage became noticeably reduced (58 and 54% respectively), as in PIE1 (56%) and TRE1(62%), where a high percentage of species with broad spectrum can be underlined. As expected, the *dry soil* plants contingent reaches the maximum value on SAR1 (46%).

Soil pH - In most of the cases, the percentage of species indicating *neutral* soil lies around 60%; particular situations are represented by PIE1 and TRE1 (37 and 25 % respectively), where in the latter the highest percentage of *acidic soil* species occurs (56%).

Soil nutrients - The nutrients content (mostly N and P) renders a high heterogeneity among the main types of forest. The beech woodlands display a pool of *mesotrophic soil* species ranging between 40 and 50%; in PIE1 this value shows a reduction (37,5%), underlined also by the equal presence of *poor soil* species (37,5%). In such forests, the contingent of *fertilised soil* species seems to be of a certain importance (mean value 24%), with a maximum value in VEN1 (40%). In the oak-mixed deciduous and holm oak woodlands, the *mesotrophic* plants values are similar to that of beech communities. On the other hand, the contingent of *poor soil* species resulted of major importance (mean value 22 %), while the pool of *fertile soil* plants is around 12%. The spruce communities show a low *mesotrophic* contingent (mean value 32%), and the most important pool of *poor soil* plant (mean value 38%), that in TRE1, due to the extremely poor soil (podsol), reaches the maximum value for this category (62,5%).

Temporal variation

Number of species

The annual variations over the period 1999-2003 surveys are plotted in Figure 3. The coefficient of

Table 4 – 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 (data sets range 1999-2003). 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.
*Numero totale di specie vascolari rilevate, numero medio di specie*100^{-2} ed intervallo di confidenza) per ciascuna area permanente. Differenze significative tra le coppie di osservazioni per uno stesso plot (Within-subjects effects) e significatività della tendenza lineare (Within-subjects contrasts) sono state testate mediante ANOVA per misure ripetute e sono marcate in grassetto.*

Plot	Indicator	year					Repeated Measures Anova	
		1999	2000	2001	2002	2003	Within subjects effects (p)	Within subjects contrasts (p)
01ABR1	total number of species	23	24	22	22	19		
	n species * 100 m^{-2}	8.92	9.58	9.67	9.67	8.67	0.13	0.67
	confidence interval	1.26	1.30	1.35	1.35	1.23		
02BAS1	total number of species	75	-	-	-	-		
	n species * 100 m^{-2}	29.50	-	-	-	-		
	confidence interval	3.15	-	-	-	-		
03CAL1	total number of species	34	31	35	34	31		
	n species * 100 m^{-2}	17.41	17.66	17.25	16.16	16.75	0.18	0.96
	confidence interval	1.98	2.03	1.65	1.45	1.50		
04CAM1	total number of species	31	26	28	35	33		
	n species * 100 m^{-2}	14.83	12.50	14.33	14.75	16.75	**0.00**	**0.01**
	confidence interval	1.92	1.26	1.37	1.13	1.13		
05EMI1	total number of species	28	37	41	39	27		
	n species * 100 m^{-2}	11.41	12.58	13.83	14.75	11.41	**0.00**	0.17
	confidence interval	1.00	1.42	1.00	1.22	1.09		
06EM2	total number of species	33	-	-	-	-		
	n species * 100 m^{-2}	11.67	-	-	-	-		
	confidence interval	1.45	-	-	-	-		
07FRI1	total number of species	53	53	55	53	57		
	n species * 100 m^{-2}	24.25	25.33	26.33	27.91	28.41	**0.00**	**0.00**
	confidence interval	2.31	1.97	1.88	1.95	1.62		
08FRI2	total number of species	54	-	-	-	-		
	n species * 100 m^{-2}	22.41	-	-	-	-		
	confidence interval	3.76	-	-	-	-		
09LAZ1	total number of species	55	55	57	52	50		
	n species * 100 m-2	23.50	22.00	23.25	20.08	20.00	**0.00**	**0.00**
	confidence interval	3.14	2.53	2.47	2.30	2.43		
10LOM1	total number of species	53	56	55	58	62		
	n species * 100 m^{-2}	29.09	28.54	29.54	28.54	29.18	0.80	0.81
	confidence interval	2.94	3.36	2.77	2.91	2.20		
11MAR1	total number of species	64	64	61	60	60		
	n species * 100 m^{-2}	31.08	29.08	28.58	27.16	27.08	**0.02**	**0.01**
	confidence interval	1.98	2.62	2.75	2.52	2.01		
12PIE1	total number of species	16	-	-	-	-		
	n species * 100 m^{-2}	8.17	-	-	-	-		
	confidence interval	1.07	-	-	-	-		
13PUG1	total number of species	30	-	-	-	-		
	n species * 100 m^{-2}	15.50	-	-	-	-		
	confidence interval	1.28	-	-	-	-		
14SAR1	total number of species	19	-	-	25	-		
	n species * 100 m^{-2}	12.41	-	-	13.16	-		
	confidence interval	0.97	-	-	1.50	-		
16TOS1	total number of species	37	34	33	35	33		
	n species * 100 m^{-2}	16.33	15.25	14.66	16.41	14.16	**0.01**	0.15
	confidence interval	1.74	1.54	1.62	1.92	1.68		
17TRE1	total number of species	16	-	-	-	-		
	n species * 100 m^{-2}	11.75	-	-	-	-		
	confidence interval	0.72	-	-	-	-		
18UMB1	total number of species	57	-	-	-	-		
	n species * 100 m^{-2}	25.00	-	-	-	-		
	confidence interval	4.82	-	-	-	-		
19VAL1	total number of species	34	35	37	34	32		
	n species * 100 m^{-2}	13.83	13.91	13.50	13.33	13.75	0.75	0.60
	confidence interval	1.40	1.22	1.26	1.19	1.56		
20VEN1	total number of species	26	33	33	34	36		
	n species * 100 m^{-2}	12.16	15.41	15.83	16.08	15.58	**0.00**	**0.00**
	confidence interval	1.01	1.03	1.94	1.80	1.70		

variation on each PMP is almost stable (lower than 25%) within the five-year observation period, indicating a good stationarity, and (assuming 15% of accepted error) the number of SUs was always adequate. In seven PMPs, the Within-Subjects Effects test (RMA) raised out that richness varied significantly over the five time-points. The Bonferroni post-hoc test appreciates all pairwise comparisons in the richness data, detecting in which surveys significant variation appears (Figure 3). Annual changes are frequent and can be due to natural cycles and/or recovery from previous disturbances. In CAM1 the tree population (high forest stand aged 100, made up of large-sized stems with a low density) seemed to be stable in the considered period, so that the significant variations in richness can be explained as a result of ephemeral species penetration from the external ecosystems: a significant reduction of richness occurred in 2000, while significant increase occurred in 2001 and 2003 (Table 4, Figure 3). In the 2002-2003 the forest stand in EMI1 experienced strong mortality in the tree layer, probably influencing the understory vegetation with a significant reduction in richness. However, the possibility that the extreme drought bore a direct influence in this kind of ecosystem should be examined. In LAZ1, after three years of richness stability, the significant species depletion for the year 2002 appear probably related to the complete defoliation by *Lymantria dispar* and subsequent high litterfall, which continued partially in 2003. TOS1 reported a significant decrement of species in 2003, while VEN1 showed a drastic increase in the summer of 2000, explainable by its recovery from a tremendous hailstorm in 1998 (with recorded frequency of mechanical damage at the population level up to 100%). Only two sites (FRI1, and MAR1) show directional and significant changes with upward and downward tendency, respectively. In both cases, the time lag in which is possible to appreciate important changes is larger than two years. It is important to note that in both of these forests the coppice management practiced in the past has ceased. The natural processes developing in such cases are not-linear (Amorini and Fabbio 1987), and so in this instance we probably are observing two different phases of the same general resilience-type process. Consequently, the present trends do not enable us to make a linear forecast. In fact, also for all the other PMPs (CAM1, LAZ1, VEN1) in which is possible to underline a significant linear trend (Table 4: Within-

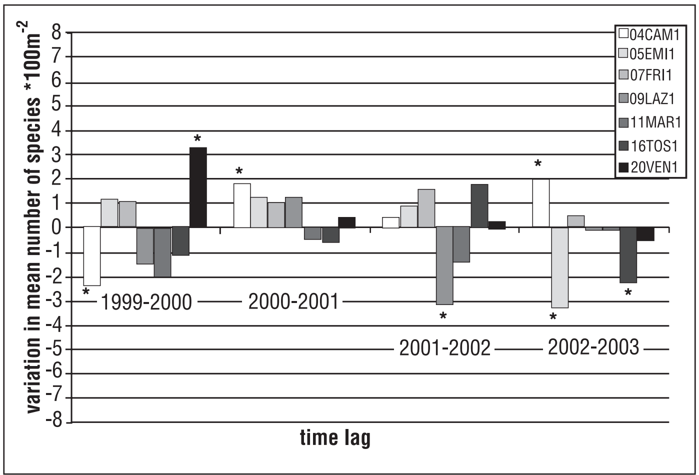

Figure 3 – Changes in mean number of species*100m^{-2} occurred in each couple of consecutive years. Here are considered only the PMPs that reported a significant variation (Between-subjects effect test) in the considered period (1999-2003). When appropriate the results of Bonferroni test have been reported ($p<0.05$, asterisk indicates significant variations).
Cambiamenti nel numero medio di specie accaduti in anni consecutivi. Sono considerati solo i plot che hanno mostrato variazioni significative nel periodo considerato (1999-2003). Variazioni significative (ANOVA per misure ripetute con correzioni di Bonferroni) sono indicate dall'asterisco.

Subjects Contrast test) we invite the readers to be careful when considering this interpretation: as we consider a short temporal window, what seems to be a tendency could be recognized as a little step of a more complex dynamics in a larger time range.

Shannon index

The Shannon index enhances the influence of small samples on frequency data, leading to the underestimation of the common vascular species and the overestimation of the rare ones because it amplifies the specific equidistribution of abundance and tends to maximize the index in each PMP (Pielou 1966). Table 5 shows that the Evenness values based on frequency are - in most of the cases - extremely high (0.8 - 0.9). On the other hand, the Shannon index calculated using the frequency of species originates from more precise data than cover estimates. This characteristic, joined with the fact that the information comes from the data subset for a consistent sampling design, leads to the comparability of the measurements over time (Figure 4). The Shannon index by frequency expresses the changes in species number in the PMPs: in most cases, a positive linear correlation with the number of species ($r > 0.9$) can be observed (Table 5). Because the diversity assessments over time are influenced by constantly high Evenness values, the index shows weak discriminant ability among the PMPs. Two main groups of PMPs are evident from Figure 4. The first one, where the index range is 4.1 - 4.8, is composed of forests mostly dominated by one or two tree species, with a total species number from 20 to 40 (ABR1, CAL1, CAM1, EMI1, TOS1, VAL1 and VEN1); the second main group, where the index range is 5.2-5.7, includes forests with higher inner heterogeneity, co-dominated by a number of tree species, and with a total species number from 40 to 60 (FRI1, LAZ1, LOM1, MAR1), (Table 5).

A "weighted" Shannon index was based on the specific mean cover contribution by SU; it performs a better discriminant ability. The index values were generally lower, but a higher variability among the investigated ecosystems can be pointed out. The

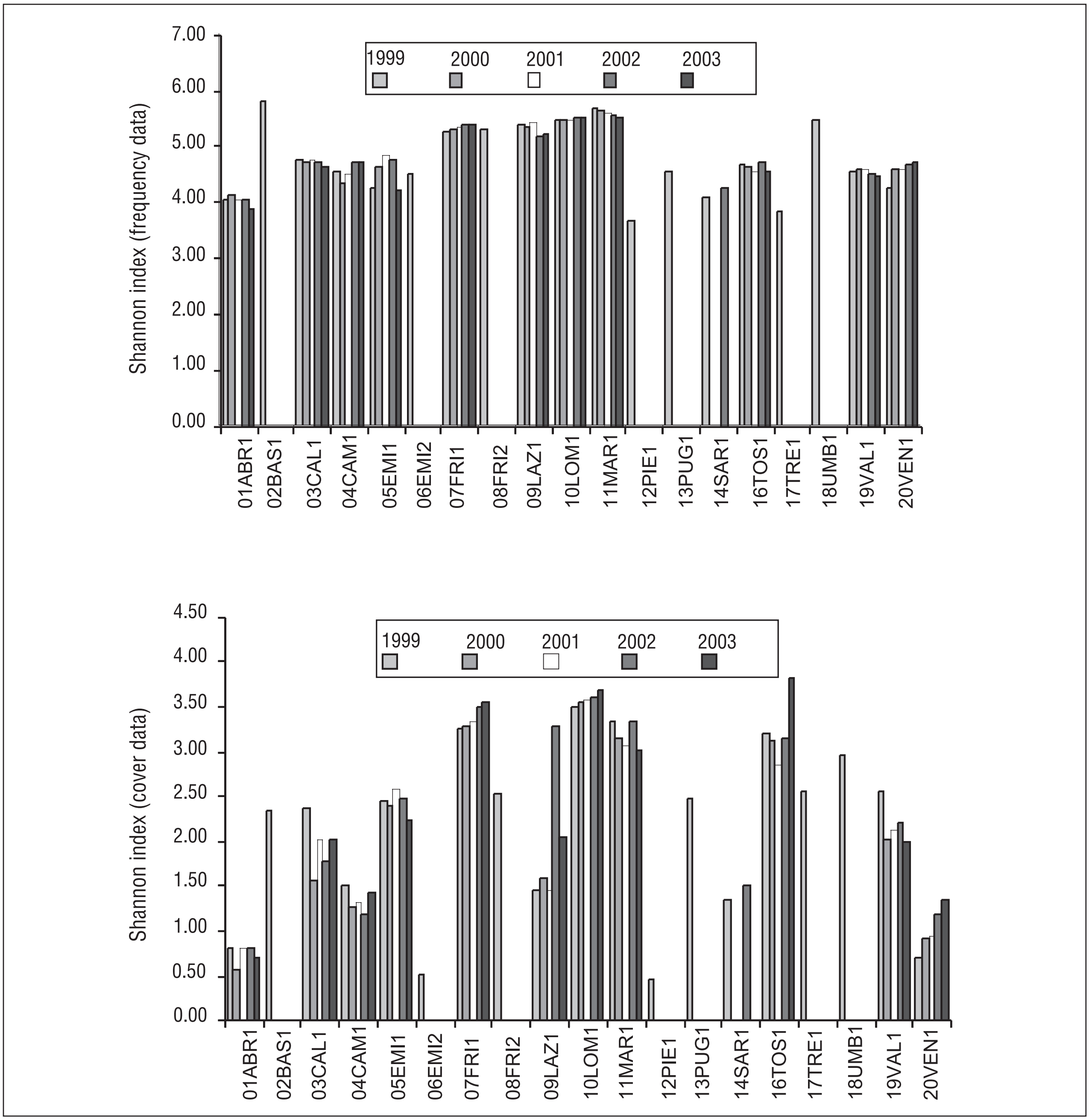

Figure 4 – Temporal variation of the Shannon index score. Top: results based on frequency species data; bottom: results based on relative mean cover species data.
Variazione temporale dell'indice di Shannon. In alto: risultati in base alla frequenza di specie; in basso: risultati in base alla copertura.

Table 5 – Shannon indices and their relative Evenness values. Significant directional changes are in bold (p<0.05)..
Indice di Shannon e relative valore di Evenness. Tendenze significative sono riportate in grassetto.

	years					H' vs. time linear regression		
PMPs	1999	2000	2001	2002	2003	R^2	slope	p
01ABR1								
H' freq.	4.041	4.131	4.071	4.072	3.869	0.44	-0.04	0.21
E freq.	0.891	0.902	0.912	0.914	0.913			
H' cov.	0.810	0.574	0.805	0.805	0.717	0.005	0.004	0.912
E cov.	0.179	0.125	0.181	0.181	0.169			
02BAS1								
H' freq.	5.802							
E freq.	3.150							
H' cov.	2.347							
E cov.	0.377							
03CAL1								
H' freq.	4.764	4.718	4.749	4.685	4.651	0.787	-0.026	**0.045**
E freq.	0.936	0.952	0.925	0.921	0.938			
H' cov.	2.362	1.570	2.018	1.792	2.029	0.056	-0.044	0.701
E cov.	0.464	0.316	0.393	0.352	0.409			
04CAM1								
H' freq.	4.575	4.341	4.504	4.715	4.725	0.446	0.067	0.218
E freq.	0.923	0.923	0.937	0.919	0.936			
H' cov.	1.500	1.262	1.322	1.176	1.438	0.063	-0.021	0.683
E cov.	0.302	0.268	0.275	0.229	0.285			
05EMI1								
H' freq.	4.257	4.610	4.825	4.737	4.185	0.001	0.0018	0.987
E freq.	0.885	0.884	0.900	0.896	0.880			
H' cov.	2.443	2.405	2.588	2.469	2.243	0.181	-0.034	0.475
E cov.	0.508	0.461	0.483	0.467	0.471			
06EMI2								
H' freq.	4.526							
E freq.	0.897							
H' cov.	0.506							
E cov.	0.100							
07FRI1								
H' freq.	5.306	5.329	5.366	5.366	5.407	0.950	0.023	**0.005**
E freq.	0.926	0.930	0.928	0.936	0.926			
H' cov.	3.263	3.276	3.329	3.510	3.544	0.895	0.079	**0.015**
E cov.	0.569	0.571	0.575	0.612	0.607			
08FRI2								
H' freq.	5.311							
E freq.	0.923							
H' cov.	2.529							
E cov.	0.439							
09LAZ1								
H' freq.	5.381	5.335	5.410	5.196	5.241	0.523	-0.042	0.167
E freq.	0.930	0.922	0.927	0.911	0.928			
H' cov.	1.453	1.599	1.462	3.295	2.038	0.339	0.287	0.303
E cov.	0.251	0.276	0.250	0.578	0.361			
10LOM1								
H' freq.	5.437	5.480	5.489	5.516	5.531	0.954	0.022	**0.004**
E freq.	0.949	0.943	0.949	0.941	0.929			
H' cov.	3.502	3.551	3.580	3.618	3.675	0.989	0.041	**0.001**
E cov.	0.611	0.611	0.619	0.617	0.617			
11MAR1								
H' freq.	5.677	5.668	5.618	5.561	5.5347	0.960	-0.039	**0.003**
E freq.	0.946	0.945	0.947	0.942	0.937			
H' cov.	3.328	3.143	3.081	3.335	3.022	0.215	-0.042	0.431
E cov.	0.555	0.524	0.520	0.565	0.512			
12PIE1								
H' freq.	3.675							
E freq.	0.919							
H' cov.	0.457							
E cov.	0.114							
13PUG1								
H' freq.	4.106							
E freq.	0.928							
H' cov.	1.341							
E cov.	0.507							

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	years					H' vs. time linear regression		
PMPs	1999	2000	2001	2002	2003	R^2	slope	p
14SAR1								
H' freq.	4.106			4.244				
E freq.	0.966			0.914				
H' cov.	1.341			1.502				
E cov.	0.315			0.323				
16TOS1								
H' freq.	4.694	4.657	4.539	4.711	4.555	0.198	-0.022	0.452
E freq.	0.901	0.915	0.900	0.919	0.903			
H' cov.	3.209	3.120	2.848	3.155	3.834	0.312	0.128	0.328
E cov.	0.616	0.613	0.565	0.615	0.760			
17TRE1								
H' freq.	3.858							
E freq.	0.965							
H' cov.	2.554							
E cov.	0.639							
18UMB1								
H' freq.	5.466							
E freq.	0.937							
H' cov.	2.958							
E cov.	0.507							
19VAL1								
H' freq.	4.575	4.579	4.599	4.497	4.489	0.620	-0.025	0.114
E freq.	0.899	0.892	0.882	0.884	0.897			
H' cov.	2.550	2.011	2.120	2.199	1.984	0.429	-0.094	0.230
E cov.	0.501	0.392	0.407	0.432	0.396			
20VEN1								
H' freq.	4.261	4.589	4.612	4.702	4.667	0.688	0.092	0.082
E freq.	0.906	0.909	0.914	0.924	0.902			
H' cov.	0.695	0.912	0.960	1.194	1.342	0.974	0.158	**0.002**
E cov.	0.147	0.180	0.190	0.234	0.259			

cover estimation by relative classes, even though is not a precise measure of the species abundance (MAGURRAN 1988), gives a more realistic representation of the textural contribution of the species. In particular, compared to the frequency data, it expresses a certain relation with the use of *e.g.* nutrients, light and space. In this case, the values of Evenness were generally lower and more variable (from 0.1 to 0.7; Table 5). This is due to the effect of the species abundance models characterizing the forest stands, where, in most cases, the cover of vascular species is very uneven. Consequently, the index scores were less correlated (sometimes independent) to the number of species collected in the sample: the linear regressions between the Shannon index vs. total number of species showed very low R^2 values (often <0.10), and in four cases (CAM1, LAZ1, TOS1, and VAL1), the slope was negative.

The higher values of the Shannon index (more than 3.0 bits) can be found on the PMPs FRI1, LAZ1, LOM1, MAR1 and TOS1 (Figure 4). Intermediate values (<3 and >2 bits) can be allocated in PMPs CAL1, EMI1 and VAL1, while the lower values (<2 bits) are revealed in ABR1, CAM1, and VEN1. The higher diversity pool is represented by the same PMPs detected by the frequency index, as the richest in number of species, with the addition of TOS1, where we can find the highest Evenness value and also the highest woody species/total number of species ratio. All these communities present a high level of structural heterogeneity caused by recent anthropic or natural disturbances.

The intermediate group included forest stands with a lower number of species but an intermediate level of Evenness and, especially in plot EMI1, with a good proportion of woody species (number of woody species/total number of species > 0.5).

In the last group are allocated only beech dominated forests in which the structure is not complex (only the tree layer is well developed) and with low total species number and proportion of woody species (number of woody species/total number of species < 0.2).

The yearly variations of the indices over the course of the 1999-2003 are shown in Table 5. Considering the frequency Shannon index, in four sites (CAM1, FRI1, LOM1 and MAR1) the directional changes were highly significant (Table 5): the first three cases can be characterized by a positive tendency, while in MAR1 an opposite trend can be observed. The directional changes for the cover Shannon index were significant in only three cases (FRI1, VEN1, and LOM1). In some cases, changes are driven almost exclusively by richness variations, particularly evident in VEN1. In LOM1 the mean number of species seems to be stable and consequently the increasing of the index is due to an increased equidistribution of abundance among the species. As discussed for richness data, it is difficult to consider these results as "real trend" in plant species diversity; in fact, the time considered is too short if related to the type of processes which can occur in forest ecosystems, and we still didn't consider how the sampling error was implemented in the statistical analyses.

Conclusions

A first evaluation of the CONECOFOR PMPs state has been possible by the species allocation on typical ecological groups. An introductory assessment of the anthropogenic influences on the natural development of forest ecosystems (hemeroby), revealed that the most important penetrations of species from external systems (*i.e.*, borders and hedges, open herbaceous, nitrophile, and ruderal and segetal systems) occurred in PMPs affected by previous intense disturbance (coppicing or pasturages, *i.e.* EMI2, BAS1 and LAZ1) or characterized by certain inner heterogeneity (LOM1). The percentage distribution of Ellemberg indicator values can be useful for detecting particular site characteristics. Shannon indices (frequency and cover) and mean number of species*100^{-2} can be considered interesting variables, useful in summarizing several ecological characters of the investigated forest ecosystems, mainly from the structural point of view (Neumann and Starlinger 2001). In the context of this monitoring activity, their future estimations will be consistent only if compared with a reference standard. This reference, ideally, would be the status of 'natural' or 'original' forests. However, in Italy, as in most of Europe, it is almost impossible to find such forests. In this case, for each of the 11 PMPs, a 'baseline' (standard) can be established as the lowest value, or as the mean value and its range of variation in this first period of five-year surveillance. The starting point established with these criteria will allow a better inference of the spatio-temporal changes in the vegetation texture of the monitored CONECOFOR areas, when the full survey programme will be accomplished (Hellawell 1991).

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Aspects of biological diversity in the CONECOFOR plots. III. Epiphytic lichens

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Abstract – Epiphytic lichen diversity was surveyed on the trunks of randomly selected trees in 7 CONECOFOR Level II plots. The percentage contributions to the total lichen diversity of each growth form, photobiont and reproductive strategy were taken into account in order in assessing the differences among the plots. In this paper, results referred to these topics are reported to provide a first baseline for planned long-term monitoring of the CONECOFOR Level II plots. Further, an outlook of potential results expected from the lichen monitoring of CONECOFOR plots, in the framework of the European ForestBIOTA project, is provided.

Key words: *forest ecosystems, epiphytic lichens, biological indicators, Italy.*

Riassunto – Diversità dei licheni epifiti nei plot CONECOFOR. La diversità dei licheni epifiti è stata rilevata in 7 aree di studio CONECOFOR Livello II, su alberi selezionati in base ad un campionamento randomizzato stratificato. Per stimare le differenze tra i plot sono stati considerati i contributi percentuali alla diversità lichenica totale della forma di crescita, del fotobionte e della strategia riproduttiva delle specie licheniche rilevate. Nel presente lavoro vengono riportati i risultati ottenuti nel corso di questa prima campagna di rilevamento, come punto di partenza per la pianificazione di un monitoraggio a lungo termine dei plot CONECOFOR Livello II. Vengono inoltre discusse le prospettive dello studio della diversità lichenica nelle aree CONECOFOR, nell'ambito del progetto ForestBIOTA.

Parole chiave: *ecosistemi forestali, licheni epifiti, indicatori biologici, Italia.*

F.D.C. 524.634: 172.9 (450)

Introduction

Commercial large-scale forestry affects biodiversity on various spatial and temporal scales. As a result, old-growth forests are today scarce and heavily fragmented (Hilmo and Sastad 2001). Habitat loss, habitat alteration and fragmentation of previously continuous forests has reduced species diversity in forest ecosystems (Saunders *et al.* 1991). Due to forest fragmentation, several species are at high risk of local extinction. In particular, in the last 50 years, concern about the loss of lichen diversity in connection with forest management and forest fragmentation has led to many studies designed to assess patterns and monitor trends of lichen diversity in forests worldwide (Will-Wolf *et al.* 2002).

Although lichen communities only occasionally comprise a major portion of the biomass of a forest, they play many ecological roles in forest ecosystems, such as nitrogen fixation, nutrient cycling, and provision of food and nesting material for wildlife (Will-Wolf *et al.* 2002). For this reason, the assessment of their biodiversity in managed forests has become an important issue for studying ecosystems and their conservation (Hilmo and Sastad 2001). Several studies have shown that many variables may influence microhabitat characteristics important to lichens: substrate tree age; size and age of gaps; standing dead snags; size, age and quantity of downed woody debris (Will-Wolf *et al.* 2002). Some species have been proved to be good indicators of sustainable forest management, being more frequent and abundant in old-growth for-

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ests with high spatial and temporal continuity (ROSE 1976, 1992; ROSE and COPPINS 2002; HILMO 1994; HILMO and SASTAD 2001; KUUSINEN 1996a; HYVÄRINEN *et al.* 1992; HUMPHREY *et al.* 2002; GIORDANI 2003). This is the case of *Caliciales* (TIBELL 1992; SELVA 1994, 2002), alectoroides fruticose lichens (ESSEEN *et al.* 1996), cyanolichens and the species of the *Lobarion pulmonariae* community (GAUSLAA 1995; KUUSINEN 1996b; KONDRATYUK and COPPINS 1998). The ecological characteristics of lichen species emphasise marked differences among the forest types considered. In this paper the preliminary results of a lichen biomonitoring survey carried out in seven CONECOFOR plots in Italy are reported. The main aim is to provide baseline data for long-term monitoring of the CONECOFOR Level II plots and to provide an outlook of the results expected to be gained from lichen monitoring in the framework of the European 'ForestBiota' project. ForestBIOTA (Forest Biodiversity Test-phase Assessments) is a forest biodiversity monitoring project currently being developed by 10 European countries, with the aim of further development of monitoring methods for some aspects of forest biodiversity, as well as performing correlative studies between some compositional, structural and functional indices of forest biodiversity. In particular, the lichen biomonitoring surveys within the seven CONECOFOR forest plots were carried out with the following objectives:

- to monitor lichen species richness and frequency in EU/ICP Forests Level II plots;
- to explore the relationship between lichen diversity and forest stand characteristics (*e.g.* stand structure and composition, deposition). This objective is consistent with the overall aim of the test-phase to validate key factors for forest biological diversity;
- to evaluate the suitability of the monitoring approach. This objective is consistent with the overall aim of the test-phase, *i.e.* to test a methodology for biodiversity assessment and evaluation specifically for EU/ICP Forest Level II plots;
- to identify the baseline condition in order to monitor future changes at plot level. In this paper the first descriptive results of the lichen monitoring of seven CONECOFOR Level II plots are reported as a baseline for planned long-term monitoring.

Materials and methods

Selection of the Level II plots

The main characteristics of the CONECOFOR plots are reported by FERRETTI *et al.* (this volume). The epiphytic lichen diversity was releved in seven plots (Table 1) out of the 31 covered by the programme. Six plots (namely LOM1, FRI2, TOS1, TOS2, EMI1 and VEN1) were releved in Spring and Autumn 2004 using the new standardized protocol developed by an *ad-hoc* group of experts during the Meeting of the EU/ICP Forests Working Group on Biodiversity held in Sabaudia (Italy) in February 2003 (STOFER *et al.* 2003) (see paragraph on Sampling Protocol for details). Four of these plots were also included in the test phase of the ForestBIOTA European project, together with eight other plots of the network. The data

Table 1 - Selected CONECOFOR Level II plots and sampling status up to September 2005.
Siti CONECOFOR Livello II selezionati e stato del campionamento al settembre 2005.

Code	Plot	Forest Type	Sampling status
LOM1	Val Masino	*Picea abies* high forest	Plots included in the ForestBIOTA test phase and releved with the new standardized protocol (STOFER *et al.* 2003)
FRI2	Tarvisio	*Picea abies* high forest	
TOS1	Colognole	*Quercus ilex* aged coppice forest	
TOS2	Cala Violina	*Quercus ilex* aged coppice forest	
EMI1	Carrega	*Quercus petraea* aged coppice forest	Additional plots not included in the ForestBIOTA test phase but releved with the new standardized protocol (STOFER *et al.* 2003)
VEN1	Pian di Cansiglio	*Fagus sylvatica* high forest	
TRE1	Lavazè	*Picea abies* high forest	Plot included in the ForestBIOTA test phase and releved with the old protocol (NIMIS 1999)
BOL1	Renon	*Picea abies* high forest	Plots included in the ForestBIOTA test phase: sampling phase planned for December 2005.
ABR1	Selva Piana	*Fagus sylvatica* high forest	
ABR2	Rosello	*Abies alba* high forest	
LAZ2	Circeo	*Quercus ilex* aged coppice forest	
SAR1	Marganai	*Quercus ilex* aged coppice forest	
CAL1	Piano Limina	*Fagus sylvatica* high forest	
SIC1	Ficuzza	*Quercus cerris* aged coppice forest	

collection in seven of these additional sites (BOL1, ABR1, ABR2, LAZ2, SAR1, SIC1, CAL1) is planned for December 2005. A further plot (TRE1) was already releved in 2001, but using a different sampling strategy and different grid (Nimis 1999). All these plots were preferentially selected within the network so as to obtain data from different forest types. In particular, preferential selection took into account 3 forest types within the 31 Italian CONECOFOR plots: *Picea abies* high forests, *Quercus ilex* coppice forests, *Fagus sylvatica* high forests.

Sampling protocol: selection of sampling trees in the Level II plots

Lichen monitoring in the Italian CONECOFOR Level II plots followed the sampling protocol developed by a group of European experts during the Meeting of the EU/ICP Forests Working Group on Biodiversity in Sabaudia (Stofer *et al.* 2003) and mainly based on the European guidelines for lichen monitoring (Asta *et al.* 2002; Scheidegger *et al.* 2002). In each plot, only trees with a minimum circumference of 50 cm at breast height were considered. Then, a stratification was carried out on this subset by means of the existing data base (EC – UN/ECE 2003). Four strata were considered, on the basis of two variables:

- the pH of the bark: all trees on the plot were classified into two groups, one with acidic bark (group A), the other with more or less neutral bark (group B);
- the diameter at breast height (DBH): two groups, DBH ≤ 36 cm (group C), DBH > 36 cm (group D). The proportion (p) of trees on the plot in the following four groups was then calculated from the existing data base:

group 1: p1 = N1 / N where N1 = number of common trees in classes A,C)
group 2: p2 = N2 / N where N2 = number of common trees in classes A,D)
group 3: p3 = N3 / N where N3 = number of common tress in classes B,C)
group 4: p4 = N4 / N where N4 = number of common trees in classes B,D)
with N = number of trees on the plot
and p1 + p2 + p3 + p4 = 1.0

For each of the four strata, a proportional number of trees was then randomly selected on the plot according to the following formula:

Ns1 = Ns * p1 where Ns1 = number of sampling trees in group 1
Ns2 = Ns * p2 where Ns2 = number of sampling trees in group 2
Ns3 = Ns * p3 where Ns3 = number of sampling trees in group 3
Ns4 = Ns * p4 where Ns4 = number of sampling trees in group 4
with Ns = number of total sampling trees (Ns = 12)

To achieve better estimation of the species richness of the plot for each of the four pre-stratified groups, additional trees were randomly selected until at least three trees per group were represented.

Relevés of individual sample trees

On each selected tree, epiphytic lichens were releved by means of four 10 x 50 cm grids placed systematically on the cardinal points N, E, S, W at 100 cm above ground level. The Lichen Diversity Value (LDV) (Asta *et al.* 2002) was then calculated as the sum of the frequency of each lichen species occurring within the sampling grid:

$LDV = \Sigma(\Sigma f_{i[North]} + \Sigma f_{i[East]} + \Sigma f_{i[South]} + \Sigma f_{i[West]})$, where f_i is the frequency of the species i within the sampling grid. In the case of the plot Lavazè (TRE1) lichen diversity was releved with a 30 x 50 cm sampling grid placed on the part of the bole with the greatest lichen coverage, according to the protocol described by Nimis (1999).

Identification of lichen specimens

Most of the lichen species were identified in the field. Critical specimens were collected and identified in the laboratory, on the basis of their macro- and micromorphological characteristics, following the keys by Nimis (1987), Clauzade and Roux (1985) and Purvis *et al.* (1992). Chemotaxonomic analysis of the secondary compounds (lichen substances) was performed by means of thin layer chromatography (TLC), following the standardized protocols by Culberson and Ammann (1979); Culberson and Johnson (1982); Culberson and Culberson (1994) and Huneck and Yoshimura (1996). Specimens of critical species were placed in GE, SI, HUT herbaria.

Species traits

Data referred to habitus and reproductive strategies for each lichen species releved in the plots were obtained from the Information System of Italian Lichens (ITALIC 3.0 - Nimis and Martellos 2003). Growth forms, photobionts and reproductive strategies were

Table 2 - Main species traits of epiphytic lichens releved in the plots (descriptions follow Purvis *et al.* 1992).
Principali caratteristiche delle specie licheniche epifite rilevate nei siti (descrizioni secondo Purvis et al. *1992).*

Growth form	Description
Fruticose	Shrub-, beard- or worm-like, of lichen thalli radially simmetrical in cross-section.
Foliose with broad lobes	Leaf-like, of lichen thalli with an upper and lower cortex separable from the substratum and with broad lobes.
Foliose with narrow lobes	Leaf-like, of lichen thalli with an upper and lower cortex separable from the substratum and with narrow lobes.
Crustose, squamulose or leprose	Lichen thalli look like crusts, or with small scales or are completely granular. Without any lower cortex and not easily separable from the substratum.
Photobiont	**Description**
Chlorococcoid green algae	Large division of eukaryotic algae that possess chlorophyll a and b and cellulose cell walls.
Trentepohlia	Yellow algae, are the most common as photobionts in tropical lichens and are dependent on warm-humid conditions.
Cyanobacteria	Photosynthetic bacteria, having chlorophyl a and phycobilins; once thought to be algae: blue-green algae.
Reproductive / Propagative strategy	**Description**
Sexual (apothecia or perithecia)	Reproductive structures of the fungus containing the hymenium with the spores.
Vegetative (soredia)	A non-corticate combination of photobiont cells and fungal hyphae developing into granules variously appearing flour-like castor sugar-like or granular.
Vegetative (isidia)	A photobiont-containing protuberance of the cortex in lichens which may be warty, cylindrical, clavate, scale-like, coralloid simple or branched.

taken into account to detect the characteristics of lichen colonization. A schedule of the main traits of the epiphytic lichens in the plots is reported below (Table 2).

Statistical analyses

Descriptive statistical analyses of six plots releved using the standard protocol (see Table 1) were performed using the software package STATISTICA 6.0 by StatSoft Italia srl (2001). LDV Mean, median, percentile distributions and non-outlier range within the plots were analysed within each strata based on the pH of the bark and diameter and in relation to biological parameters (Table 2) of the lichen species releved. The Kruskal-Wallis ANOVA test was used to test the significance of differences among strata.

Results

Epiphytic lichen diversity in the plots

The Lichen Diversity Value (LDV) in the six plots releved up to September 2004 (EMI1, VEN1, TOS1, TOS2, LOM1, FRI2) is reported in Figure 1. Plots with high and others with very low lichen diversity were observed and great variability also occurred within each plot. High variability of epiphytic lichen diversity related to habitat characteristics is a well known aspect (see *e.g.* Giordani 2003): independently of the possible fonts of anthropic alteration (*e.g.* logging or atmospheric pollution), some habitats have a higher potential lichen diversity than others, due to natural limiting factors affecting the epiphytic lichen diversity in the forests in question. The low diversity in the conifer forests releved (LOM1 and FRI2) is probably connected with the scaly bark of *Picea abies* (Hyvärinen *et al.* 1992). In the *Quercus ilex* forests, light was usually the greatest limiting factor. The two *Quercus ilex* plots releved (TOS1 and TOS2) exhibited quite different lichen diversities, probably due to this ecological variable. The rather low diversity in the oak forest of Carrega (EMI1) was probably due to climate: many detailed studies have proved that lichen diversity varies considerably in different Italian bioclimatic regions (Loppi *et al.* 2002), the Tyhrrenian coastal areas being more prone to lichen colonization than the Po valley and the Adriatic coast, because of the higher humidity. Lastly, very high diversity was found in the Cansiglio forest plot (VEN1). Lichen colonization in

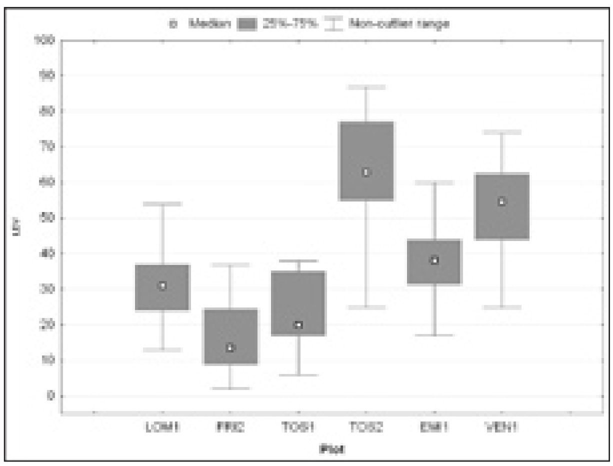

Figure 1 - Lichen Diversity Value (LDV) in the six plots.
Diversità lichenica (LDV) nei sei plot considerati.

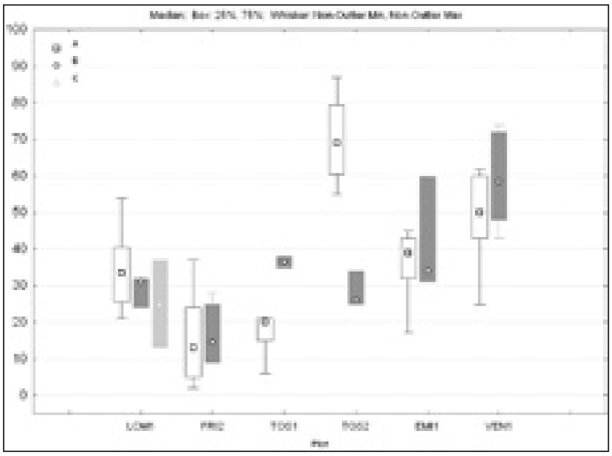

Figure 2 - Lichen Diversity Value (LDV) in relation with the strata based on the diameter of the trunk and on the acidity of the bark. A= A < 36 cm; B= A > 36cm; C= B < 36cm.
Diversità lichenica (LDV) in relazione agli strati basati su diametro del tronco ed acidità della corteccia.

beech forests is a topical and as yet unsolved issue of lichen ecology: as regards Italy, most of the North Apennine beech forests are characterized by low diversity, while high diversity is known to exist in the Southern Apennines and some parts of the Eastern Alps, probably because of different rainfall trends and different forest management methods.

Lichen diversity in relation to the strata

Variability of lichen diversity within individual plots was observed in relation to stratification. Two major strata occurred in the releved areas: trees with acidic bark both with DBH ≤ 36 cm (A≤36 cm) and DBH > 36 cm (A>36 cm). Only in LOM1 we releved trees with neutral bark (B) ≤ 36 cm stratum. Lichen diversity within strata was fairly variable in all the plots (Figure 2), but the differences were statistically significant when analysed using the Kruskal-Wallis ANOVA test (KW = 6.750; 1 d. f., n = 15; $p < 0.01$) only in the Cala Violina (TOS2) plot (Table 3), with a higher diversity on the younger trees than on the older ones. This was probably a question of succession of epiphytic communities (with the trunk of old trees dominated by mosses and consequently with scarce lichen colonization), needing further long-term studies to confirm this hypothesis. In the other plots, we observed a high degree of variability: in some cases a higher diversity occurs in the large diameter class than in the low diameter one (VEN1, FRI2, TOS1), while in other situations LDV was higher in the low diameter classes (EMI1, LOM1). In the case of plot LOM1, a higher diversity was observed in acidic bark

Table 3 - Kruskal-Wallis ANOVA test. * p < 0.01.
*Kruskal-Wallis ANOVA test. *p<0.01*

Plot	Kruskal-Wallis H (d.f., N)
EMI1	0.009 (1, 12)
FRI2	0.231 (1, 12)
LOM1	0.552 (2, 13)
TOS1	1.936 (1, 13)
TOS2	6.750 (1, 15) *
VEN1	1.450 (1, 12)

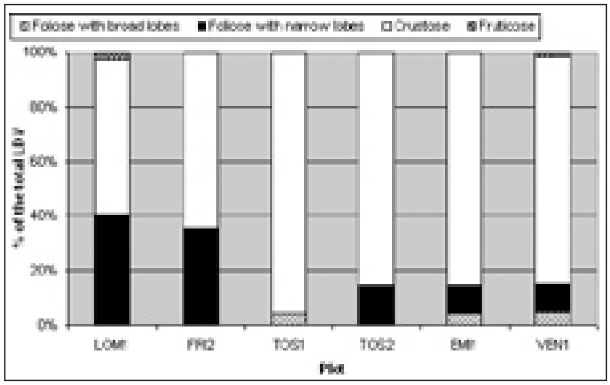

Figure 3 - Relative contribution of species with different growth forms to the total Lichen Diversity Value (LDV).
Contributo relativo di specie con differenti forme di crescita al valore di diversità lichenica (LDV).

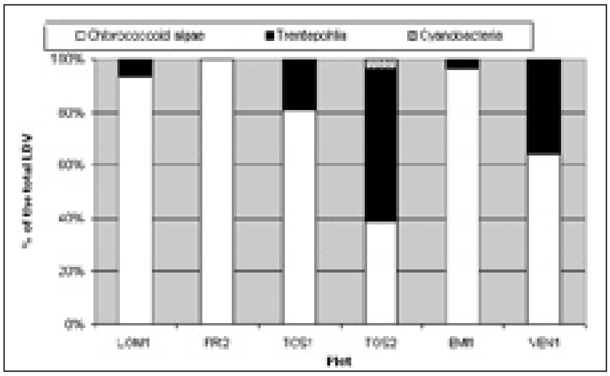

Figure 4 - Relative contribution of species with different photobionts to the total Lichen Diversity Value (LDV).
Contributo relativo di specie con differenti fotobionti al valore di diversità lichenica (LDV).

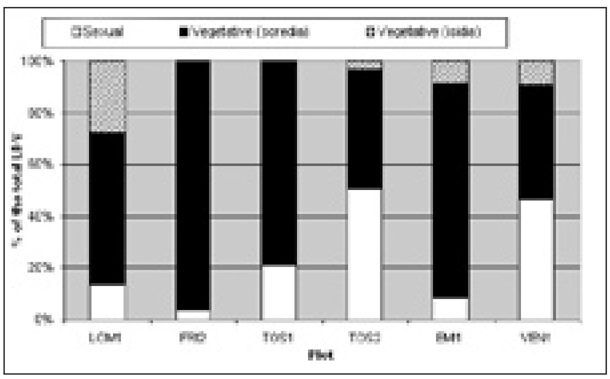

Figure 5 - Relative contribution of species with different reproductive strategy to the total Lichen Diversity Value (LDV).
Contributo relativo di specie con differenti strategie riproduttive al valore di diversità lichenica (LDV).

trees than in sub-neutral ones, but in all these cases the differences were not statistically significant.

Species traits: growth forms, photobionts, reproductive strategies.

The percentage contributions to the total Lichen Diversity Value of each growth form, photobiont and reproductive strategy are reported in Figures 3-5. All the plots were dominated by crustose species (Figure 3), with a percentage frequency usually higher than 50%. Lichens with narrow foliose lobes (such as *Physciaceae*) occurred with frequencies of about 40% in two mountain plots (LOM1 and FRI2). Fruticose lichens (*Ramalina* and *Pseudevernia* species) were only found in LOM1 and VEN1.

Lichens with broad foliose lobes (*Parmeliaceae*) only occurred and with very low percentage frequencies in VEN1, TOS1, EMI1. These results confirmed the general trend of the Italian epiphytic lichen flora (Nimis 2003). Furthermore, a high frequency of crustose lichens can be also related to pioneer colonization stages in young forests (*e.g.* TOS1) or in ecological situations that are limiting for lichens (*e.g. Picea* forests, LOM1). Chlorococcoid green Algae were the most widespread photobionts in the survey plots (Figure 4), with frequencies often higher than 60%, even exclusive in the case of FRI2. *Trentepohlia* and cyanobacteria are photobionts closely associated with humid atmospheric conditions and were found with high frequencies in TOS1, TOS2 and VEN1 plots. A more heterogeneous situation was found as regards the reproductive strategy of epiphytic lichens in the plots (Figure 5). Vegetative propagation by means of soredia (non-corticated propagules containing both fungal hyphae and algal cells) was predominant in the conifer plots (LOM1 and FRI2), TOS1 and EMI1, whereas in TOS2 and VEN1 lichen species adopting sexual reproduction by means of fungal spores exhibited the highest percentage frequencies. Vegetative propagation by means of isidia (corticated propagules) was less common and occurred particularly in LOM1 with a percentage frequency of about 20%.

Long-term monitoring of lichen diversity in the CONECOFOR plots: a case-study from Trentino.

The CONECOFOR plot TRE1 (Passo Lavazè) was monitored in 1992 and 2001, enabling a comparison over a 10-year period. The Lichen Diversity Values (LDV) releved in the two surveys carried out on *Picea excelsa* and *Pinus cembra* respectively within the plot are reported in Figure 6. While statistical testing of change over the years is impossible due to the sampling strategy adopted, Figure 6 reports no obvious difference between the two sampling occasions for the two species examined. A more detailed analysis of the data (Gottardini and Cristofolini *pers. comm.*) gives several indications of the good condition of this forest ecosystem. In particular, the size of the populations of some species very sensitive to atmospheric pollution and harvesting (*e.g. Evernia divaricata* and *Cetrelia olivetorum*) had varied only within the limits of natural fluctuations. In addition, fruticose lichens, which have an important ecological function in the humidity uptake, were abundant.

Conclusions and perspectives

The development of lichen monitoring within the CONECOFOR Level II plots will be planned at the end of the ForestBIOTA test phase. In any case, some possible improvements could be already be discussed. Some examples are reported here:

- Extending epiphytic lichen monitoring to the all the CONECOFOR plots.
- Extending lichen monitoring to other significant microhabitats within the plots, *i.e.* soil, rocks, base of the stems and tree crowns.
- Planning of monitoring of other important biological epiphytic groups such as bryophytes, lignicolous fungi and liverworts, in order to obtain a more detailed picture of the relationship between environmental factors and epiphytic communities.

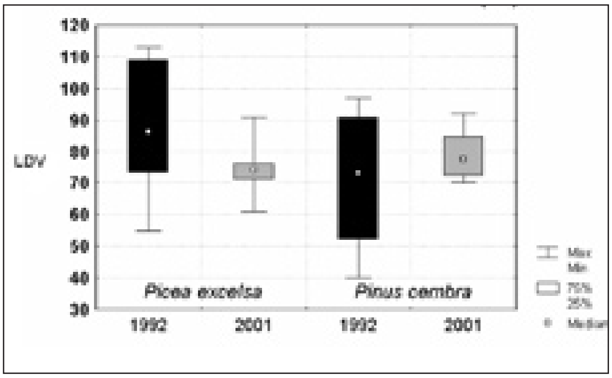

Figure 6 - Lichen Diversity Value (LDV) surveyed on *Picea excelsa* and *Pinus cembra* in two different years (1992 and 2001) in the Lavazè plot (TRE1).
Diversità lichenica (LDV) rilevata su Picea excelsa *e* Pinus cembra *in due indagini (1992 e 2001) nel plot di Lavazè (TRE1).*

- Increasing the number of trees sampled within the plots in order to obtain more precise information.
- Using a suitable statistical estimator for stratified sampling in order to obtain quantitative estimates of mean and variance on plot scale.
- Obtain a complete list of the flora within the plot.

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Aspects of biological diversity in the CONECOFOR plots. IV. The InvertebrateBiodiv pilot project

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Abstract – InvertebrateBiodiv is a pilot project the principal aim of which is to test a standardized low-cost sampling protocol for invertebrates. Twelve Italian level II CONECOFOR plots (2500 m^2) were chosen for this purpose. Sampling was done with one Malaise trap, one window flight trap and four pitfall traps in each plot. The preliminary results of trap sampling in four plots – ABR2 Rosello (Abruzzo), CAL1 Piano Limina (Calabria), SIC1 Ficuzza (Sicily) and SAR1 Marganai (Sardinia) – are presented, together with those of additional sampling carried out using several methods within the Minimum Dynamic Area (MDA) of these 4 sites. Most of the collected material is still under study. Lists of species are provided for the following insect families, collected between June 2003 and June 2005: Stratiomyidae, Syrphidae and Tachinidae (Diptera), Lucanidae and Scolytidae (Coleoptera), Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae and Satyridae (Lepidoptera Rhopalocera). Twenty-one species of Stratiomyidae, 114 of Syrphidae, 206 of Tachinidae, 3 of Lucanidae, 7 of Scolytidae and 18 of Rhopalocera are listed altogether. Seven species of Diptera are newly recorded for Italy, 28 for Sicily and 40 for Sardinia. Three species of Tachinidae new to science, which have already been described, and another possibly new species were also discovered during this survey. For some taxa (e.g. Syrphidae, Tachinidae) a greater number of species was collected with additional sampling within the MDAs than with the traps inside the plots, thus suggesting that the latter may not provide an adequate picture of these taxa in a site. In this framework, possible improvements of the sampling protocol are discussed.

Key words: *sampling, Diptera, Coleoptera, Rhopalocera, new records.*

Riassunto – Aspetti della biodiversità nei plot CONECOFOR. IV. Il progetto pilota InvertebrateBiodiv. InvertebrateBiodiv è un progetto pilota il cui scopo principale è testare un protocollo di campionamento per gli invertebrati, standardizzato e a basso costo. Dodici plot CONECOFOR italiani di livello II (2.500 m^2) sono stati scelti a questo scopo. Il protocollo è basato sull'uso di una trappola Malaise, una trappola a finestra e quattro trappole a caduta in ogni plot. In questo lavoro sono presentati i risultati preliminari ottenuti in quattro siti – ABR1 Rosello (Abruzzo), CAL1 Piano Limina (Calabria), SIC1 Ficuzza (Sicilia) e SAR1 Marganai (Sardegna) – utilizzando il protocollo e campionamenti aggiuntivi effettuati con diversi metodi nell'Area Dinamica Minima (MDA). Gran parte del materiale raccolto è ancora in fase di studio. Sono fornite liste per le seguenti famiglie di insetti, raccolte tra giugno 2003 e giugno 2005: Stratiomyidae, Syrphidae e Tachinidae (Diptera), Lucanidae e Scolytidae (Coleoptera), Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae e Satyridae (Lepidoptera Rhopalocera). In tutto sono elencate 21 specie di Stratiomyidae, 114 di Syrphidae, 206 di Tachinidae, 3 di Lucanidae, 7 di Scolytidae e 18 di Rhopalocera. Sette specie di Diptera sono segnalate per la prima volta per l'Italia, 28 per la Sicilia e 40 per la Sardegna. Inoltre, durante la ricerca sono state scoperte e già descritte 3 nuove specie di Tachinidae, mentre una probabile nuova specie è ancora in fase di studio. Per alcuni taxa (es. Syrphidae, Tachinidae) un numero maggiore di specie è stato raccolto con campionamenti aggiuntivi entro le MDA che con le trappole nei singoli plot, suggerendo che queste ultime forniscono un quadro parziale di questi taxa in un sito. In questo contesto, sono discussi possibili miglioramenti del protocollo di campionamento.

Parole chiave: *campionamento, Diptera, Coleoptera, Rhopalocera, nuovi reperti.*

F.D.C. 145.7: 524.634: (450.5/.7)

Introduction

Invertebrates, particularly insects, are present in all habitats at all latitudes. They play a fundamental role in food chains and are one of the main components of ecosystems, both for number of species and number of individuals. Invertebrates represent the largest part of biodiversity in all terrestrial ecosystems (cf. Pimm *et al.* 1995) and their total biomass is often superior to that of the vertebrates living in the same habitat. Because of their abundance and importance, their study can convey much information on the naturalness and 'health' of habitats. Particularly in forests, the study of saproxylic insects – *i.e.* of species which depend on

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dead wood at some stage of their life cycle (cf. Mason *et al.* 2003) – has become a priority in Europe from the point of view of conservation. Shortsighted forest management policies have in fact caused the local extinction of many saproxylic species and the rarefaction of others (cf. Grove 2002; Mason *et al.* 2003), some of which have been included in the EU Habitats Directive (cf. Ballerio 2003). It is in this framework that the CNBF (National Centre for the Study and Conservation of Forest Biodiversity, Verona – Bosco della Fontana, Italy) has adhered to the CONECOFOR programme (part of the ICP Forests programme) with the pilot project InvertebrateBiodiv, in which a sampling protocol for surveying invertebrates in Level II ICP Forests intensive monitoring plots in Europe has been tested in a few Italian Level II CONECOFOR plots (Figure 1 and Table 1).

When an accurate estimate of the biodiversity of a sylvatic mosaic is needed, a choice can be made between a diachronic and a synchronic monitoring scheme. In the first case a single plot is surveyed during a long period of time (many years); in the second several plots are surveyed during a shorter period, each plot being representative of a different eco-unit (Gilg 2005). All CONECOFOR attributes (cf. Mosello *et al.* 2002; Travaglini *et al.* this volume) are diachronically monitored in single plots, and 12 of these plots were used also to test the sampling protocol for invertebrates. However, given the short duration of the pilot project, additional synchronical research besides standard within-plot sampling was done outside 4 of the 12 investigated plots (Ficuzza-SIC1, Marganai-SAR1, Piano Limina-CAL1, Rosello-ABR2), within a surface at least the size of the Minimum Dynamic Area (MDA). The MDA is "the smallest area with a natural disturbance regime, which maintains internal re-colonisation sources and hence minimizes extinction" (Pickett and Thompson 1978) and corresponds on average to 300 ha in temperate forests (Peterken 1996). The study of a larger area such as the MDA provides a more complete picture of the 'taxonomic distinctness' (Clarcke and Warwick 1999) of an ecosystem and allows testing for the detectability (cf. Yoccoz *et al.* 2001) of taxa. In fact, the communities of many arthropods may vary greatly from one eco-unit to another; for instance, in eco-units in an innovation phase the flower-visiting adults of saproxylic Coleoptera are dominant, whereas in eco-units in a biostatic phase the larval stages of these taxa predominate, but are more difficult to detect and identify to species level.

Table 1 - The 12 level II CONECOFOR plots surveyed during InvertebrateBiodiv.
I 12 plot CONECOFOR di livello II monitorati nell'ambito del progetto pilota InvertebrateBiodiv.

CONECOFOR code	Site name	Region	Province	Beginning of sampling
ABR2	Rosello	Abruzzo	Chieti	June 2003
SIC1	Ficuzza	Sicily	Palermo	July 2003
CAL1	Piano Limina	Calabria	Reggio C.	July 2003
SAR1	Marganai	Sardinia	Cagliari	Sept. 2003
TOS2	Cala Violina	Tuscany	Grosseto	June 2004
TOS1	Colognole	Tuscany	Livorno	June 2004
LAZ2	Monte Circeo	Latium	Latina	April 2004
TRE1	Passo Lavazè	Trentino-A. Adige	Trento	May 2004
BOL1	Renon	Trentino-A.Adige	Bolzano	May 2004
ABR1	Selva Piana	Abruzzo	L'Aquila	June 2004
FRI2	Tarvisio	Friuli	Udine	June 2004
LOM1	Val Masino	Lombardy	Sondrio	May 2004

Figure 1 - Location of the 12 Level II CONECOFOR plots surveyed during the InvertebrateBiodiv pilot project. Drawing by D. Birtele.
Localizzazione dei 12 plot CONECOFOR esaminati durante il progetto pilota InvertebrateBiodiv. Disegno di D. Birtele.

The aim of this paper is to illustrate the sampling protocol and provide preliminary results from the study of some of the insect taxa collected in the plots of Ficuzza, Marganai, Piano Limina and Rosello and in neighbouring localities.

Materials and methods

Sampling began between June and September 2003 in 4 plots (ABR2, CAL1, SAR1, SIC1) and between April and June 2004 in the remaining 8 (Selva Piana-ABR1,

Table 2 - Main features of the 4 level II CONECOFOR plots treated in this paper.
Caratteri principali dei 4 plot CONECOFOR di livello II trattati in questo contributo.

	Rosello	Piano Limina	Ficuzza	Marganai
Region	Abruzzo	Calabria	Sicily	Sardinia
Province	Chieti	Reggio Calabria	Palermo	Cagliari
UTM coordinates	33 T 446086 4639155	33 S 602974 4253876	33 S 359712 4196906	32 S 462853 4355582
Altitude (m)	960	1100	940	700
Slope and aspect	10° NNE	20° NE	20° NNE	5° S
Precipitation (mm)	1000	1500	800	900
Average yearly temperature (°C)	8.5	10	13	14
Biocoenosis	high forest *Quercus cerris, Abies alba* and *Carpinus betulus* forest	high forest *Fagus sylvatica* forest	Old coppice *Quercus cerris* forest	Old coppice *Quercus ilex* forest
Vegetational association	*Abietetosum albae*	*Aquifolium-Fagetum*	*Quercetum gussonei*	*Viburnum-Quercetum ilicis*
Bioclimatic zone	Mediterranean	Mediterranean	Mediterranean	Mediterranean
Altitudinal belt	sub-Atlantic	sub-Atlantic	Mediterranean	Mediterranean
Beginning of sampling	VI.2003	VII.2003	VII.2003	IX.2003
Additional sampling	VI.2003; V.2005	VII.2003; V.2004	VII-VIII.2003; V.2004; VI.2005	IX.2003; VI and IX.2004

Renon-BOL1, Tarvisio-FRI2, Monte Circeo-LAZ2, Val Masino-LOM1, Colognole-TOS1, Cala Violina-TOS2, Passo Lavazè-TRE1) (Table 1). The environmental features of the first 4 plots are summarized in Table 2 and further information on all Level II CONECOFOR plots has been provided by Mosello *et al.* (2002). All investigated CONECOFOR plots have a surface area of 2500 m^2; they are situated in closed forest habitats and are, with few exceptions, fenced in.

Many methods can be used to collect invertebrates in monitoring schemes (cf. Mason *et al.* 2002; Cerretti *et al.* 2003, 2004a), according to the type of information required (*e.g.* target taxa, quantitative or qualitative data, surveying of different heights within a forest) and the availability of human and economic resources. To lay out the sampling protocol for InvertebrateBiodiv, traps were chosen instead of direct sampling methods so as to simplify and standardize field work. Pitfall traps, window flight traps and Malaise traps were chosen because they fulfil the following requisites:

- good sampling capacity;
- easy handling, also by non-experts operating locally;
- reasonably low costs;
- wide use in Europe as supported by the literature;
- efficiency in collecting target taxa.

Pitfall traps (Figure 2) used during the project consisted of a 33 cl plastic glass (top diameter 8.5 cm) 3⁄4 filled with a preservative and attractive saturated white wine vinegar (6% acidity) and table salt solution. Each glass was inserted within another glass of equal size, to simplify its emptying. Pitfall traps are a good method for capturing the ground fauna (*e.g.* Coleoptera Carabidae) (cf. Brandmayr *et al.* 2000).

Window flight traps (Figure 3), which were hung off branches at a height of approximately 1.5 m above the ground, consisted of two crossed transparent Plexiglas panels (60 x 40 cm) attached to a funnel (top diameter 40 cm, end diameter 4.5 cm) conveying intercepted insects towards a plastic container (0.5 l) half filled with 70% ethanol, which is preservative and attractive. Two small holes were cut out in the upper part of the container to allow the overflow of rainwater. Another funnel, placed up side down above the panels, prevented most rainwater and leaves from falling into the container. Window flight traps are ideal for collecting saproxylic Coleoptera flying inside forests and close to tree trunks (cf. Ranius and Jansson 2002).

The Malaise trap (Figure 4) is a tent-like structure made of a very resistant fabric. A central barrier intercepts passing insects, which then fly upwards and are conveyed by an oblique roof into a container. Malaise traps used during the project (maximum height 180 cm, length 170 cm, width 115 cm) were equipped with containers half filled with 70% ethanol. Malaise traps are particularly efficient in collecting well-flying insects such as Diptera and Hymenoptera (cf. Haenni and Matthey 1984).

One Malaise trap, one window flight trap and four pitfall traps were placed in each of the 12 plots surveyed. Pitfall traps were placed randomly, whereas Malaise and window flight traps were placed wherever suitable conditions were found, *i.e.* relatively flat terrain (Malaise) and horizontal branches (window).

The number of traps of each type was chosen in relation to the small surface area of the plots, their

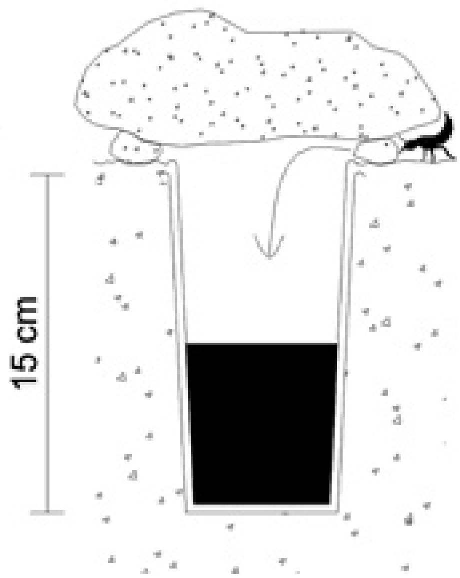


Fig. 2

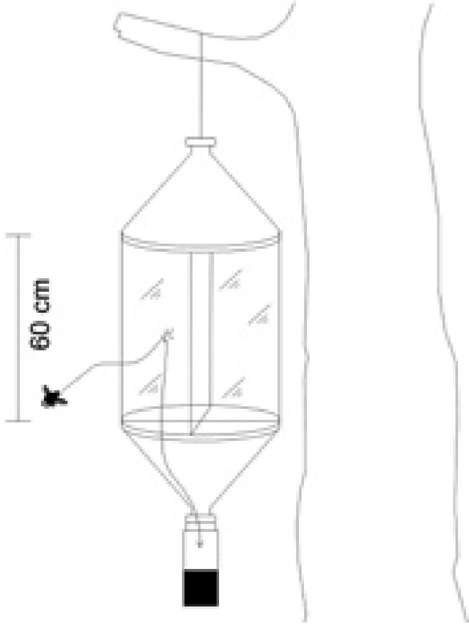


Fig. 3

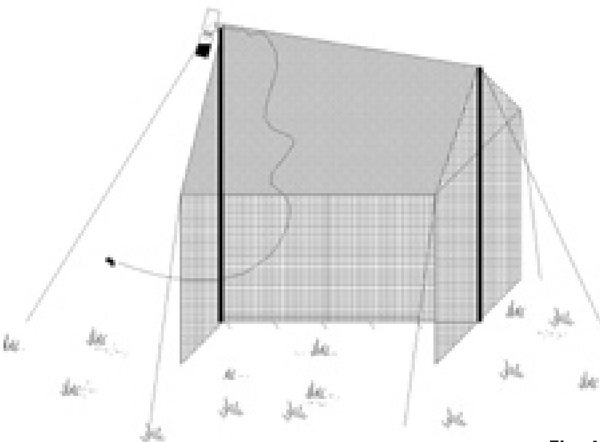


Fig. 4

Figure 2– 4 - Traps: 2 – Pitfall trap; 3 – Window flight trap; 4 – Malaise trap. Drawings by D. Birtele.
Trappole: 2 - trappola a caduta; 3 - trappola a finestra; 4 - trappola Malaise. Disegno di D. Birtele.

environmental uniformity and the results of other similar studies (cf. Mason *et al.* 2002; Cerretti *et al.* 2003, 2004a). The use of 4 pitfall traps also allowed for the continuity of sampling, since these traps can be quite easily damaged by stochastic events (*e.g.* bad weather, animals). All traps were planned to be emptied (and re-filled with new preservative) once every 14 days for a proper conservation of specimens and to gain phenological information. Duration of sampling in each plot was planned to cover all days of the year except at higher altitudes, where traps were removed during the snow period. Samples were collected by local staff (1 or 2 persons per plot) and sent to the CNBF lab for sorting and study (5 persons involved in lab and field activities on average). A meeting was organized by the CNBF in Sabaudia (Circeo National Park, Latium, Italy) from 19th to 21st April 2004, during which CNBF specialists instructed local staff – most of which already involved in other CONECOFOR monitoring activities – on how to handle traps, collect samples and deal with inconveniences such as accidental damage to traps. The planned emptying of traps every 14 days was not always possible due to various local logistic problems, and some samples were lost or arrived in poor conditions at the CNBF lab.

Additional research was carried out by CNBF specialists within the MDAs of Rosello, Piano Limina, Marganai and Ficuzza, which allowed us to obtain larger faunistic lists for the target taxa (see further on) and assess the exhaustiveness of plot trap samples (cf. Yoccoz *et al.* 2001), considering the lack of local checklists for these taxa. An effort was made to survey habitats differing from those of the plots, such as forest-field ecotones, edges of forest tracks or roads, flowered meadows and clearings, shrubland, freshwater habitats, hill tops, old senescent trees, *etc.* The main methods used were: glass trunk traps (cf. Speight 2004), Malaise traps, light traps, pitfall traps, sieves, hand nets and sweep nets. Dates of these additional collecting periods are given in Table 2, and a list of localities situated outside the level II plots is given in Table 3 together with altitudes, UTM coordinates and main habitat features.

All material (about 1750 samples) was sorted in the

Table 3 - Additional localities surveyed within the MDAs of the 4 sites treated in this paper.
Ulteriori località monitorate all'interno dell'Area Dinamica Minima (MDA) in ciascuno dei 4 siti trattati in questo contributo.

Locality	Letter code	Altitude (m)	UTM coordinates	Habitat
Rosello				
Cascate del Verde	a	860	/	mixed forest near waterfall
Colle della Cerasa	b	995	33 T 445393 4638714	grassland
Fonte Volpona	c	980	33 T 446478 4637188	forest, clearing near spring
Coste Petrilli	d	1000	33 T 445947 4637768	hill top with few trees
Torrente Turcano	e	900	33 T 446728 4636707	forest, near brook
Piana del Verde	f	820	33 T 444462 4639228	pasture, near brook, few bushes
Piano Limina				
faggeta di Giffone	g	830	33 S 607406 4253449	road-forest ecotone
Fonte San Bartolomeo	h	810	/	spring in forest
Ficuzza				
Alpe Cucco	i	949	33 S 360228 4192433	low vegetation alongside gravel road
near Masseria Pirrello	j	950	33 S 358012 4189872	pasture near *Eucalyptus* stand
bivio Ponte Casale	k	476	33 S 353645 4190330	abandoned field with *Ammi visnaga* (Apiaceae)
near Masseria Nicolosi	l	613	33 S 356635 4195305	abandoned field with *Ammi visnaga*
Cima Cucco	m	995	33 S 360328 4192550	hill top with trees and exposed rocks
Laghetto Coda di Riccio	n	868	33 S 359323 4192836	edges of artificial reservoirs with *Elaeoselinum asclepium* (Apiaceae)
Alpe Ramosa	o	950	33 S 358029 4191912	open woodland
Pulpito del Re	p	865	33 S 358963 4194405	*Quercus suber* forest with clearings
Torretta Torre	q	950	33 S 359993 4196856	low vegetation alongside gravel road in *Quercus gussonei* forest
Valle Cerasa	r	990	33 S 362075 4190524	grassland with *Ridolfia segetum* (Apiaceae)
Valle Fanuso	s	813	33 S 361659 4192543	open woodland
Marganai				
near agriturismo Perda Niedda	t	350	32 S 466269 4359055	small brook, closed forest
Case Marganai	u	756	32 S 463890 4355925	group of houses in forest
Grotta San Giovanni	v	350	/	forest edge, low vegetation near entrance to large cave
Sa Duchessa	w	308	32 S 463911 4358386	wasteland, abandoned mining area
San Benedetto	x	500	/	low vegetation on scree
Laghetto Siuru	y	307	32 S 467069 4357928	edges of small barrier lake
Tintillonis	z	480	32 S 462292 4354695	edges of forest tracks
Valle d'Oridda	z1	643	32 S 465399 4362770	large xeric grassland near forest

lab and is preserved (in 70% ethanol or dry pinned) in the CNBF collection.

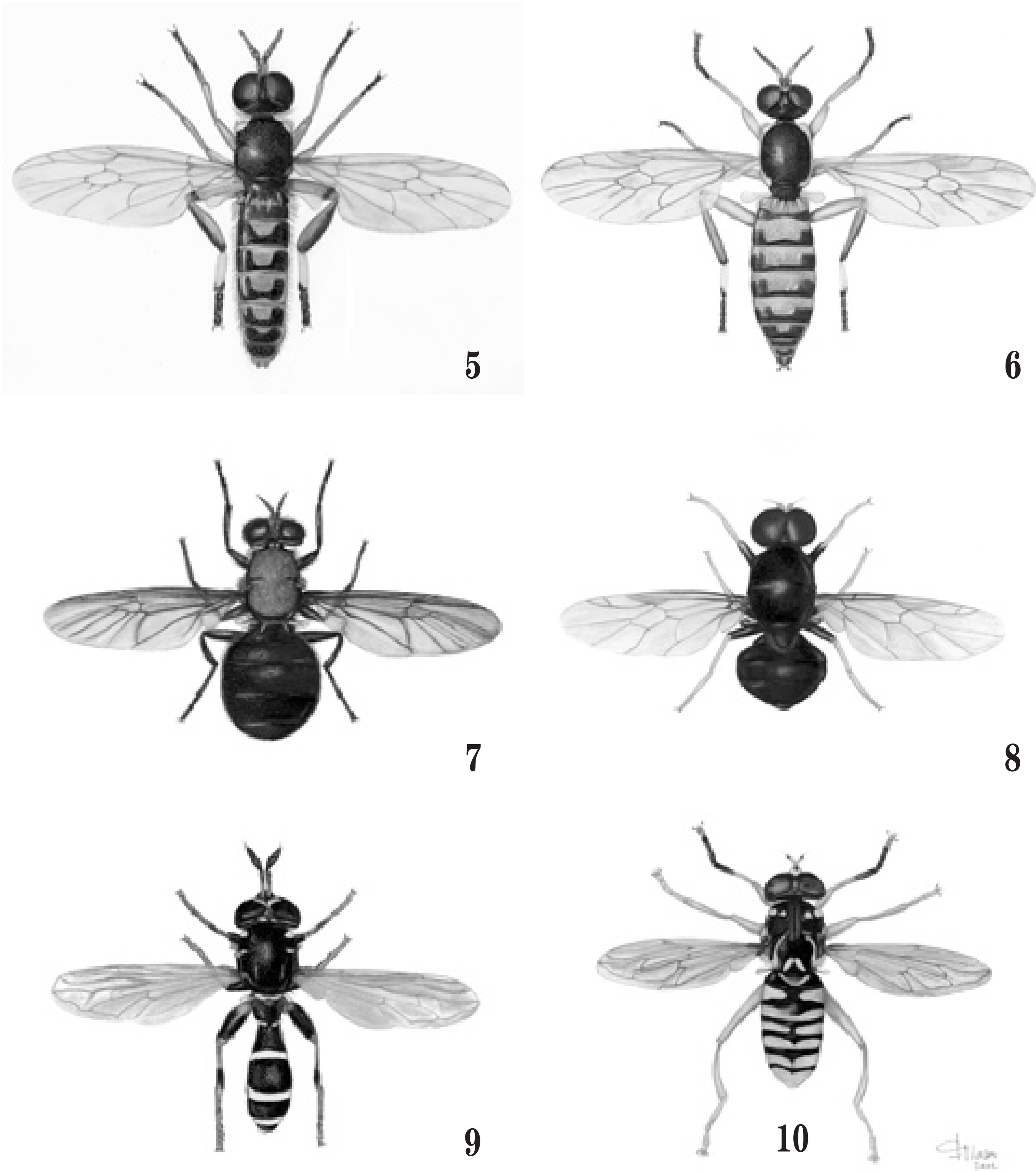
In this pilot phase of the project the choice of taxa to identify was strongly influenced by the scarce economic resources and was limited to some of the groups studied by specialists of the CNBF itself. These groups can nevertheless provide useful information for habitat conservation, thanks to the following characteristics:

– more or less stable systematics;
– well known biology;
– ease of survey;
– wide distribution;
– niche specialization.

The studied taxa are the following:

- Diptera Stratiomyidae (Figures 5–8). Family including several bioindicators which can be used for environmental monitoring and conservation studies (Stubbs and Drake 2001). The Italian fauna included 89 species (Mason 2005; Rozkošný 2005) but during this project a further species was collected, which brings the total to 90. All material was identified by F. Mason using Rozkošný (1979, 1982, 1983).

- Diptera Syrphidae (Figures 9, 10). This family includes about 500 species in Italy (Speight 2005). In Europe a system for assessing biodiversity based on the use of this family has been utilized for some time: Syrph the Net (Speight 2004). This system is based on



Figures 5 - 10 Habitus of some Diptera: 5 – *Chorisops tunisiae*, male from Marganai; 6 – *C. tunisiae,* female from Marganai (Stratiomyidae); 7 – *Clitellaria ephippium,* female from Rosello (Stratiomyidae); 8 – *Eupachygaster tarsalis,* male from Ficuzza (Stratiomyidae); 9 – *Sphiximorpha subsessilis,* male from Rosello (Syrphidae); 10 – *Spilomyia triangulata,* male from Ficuzza (Syrphidae). Drawings by F. Mason.

Alcune specie di Diptera: 5 – Chorisops tunisiae, *maschio da Marganai; 6 –* C. tunisiae, *femmina da Marganai (Stratiomyidae); 7 –* Clitellaria ephippium, *femmina da Rosello (Stratiomyidae); 8 –* Eupachygaster tarsalis, *maschio da Ficuzza (Stratiomyidae); 9 –* Sphiximorpha subsessilis, *maschio da Rosello (Syrphidae); 10 –* Spilomyia triangulata, *maschio da Ficuzza (Syrphidae). Disegni di F. Mason.*

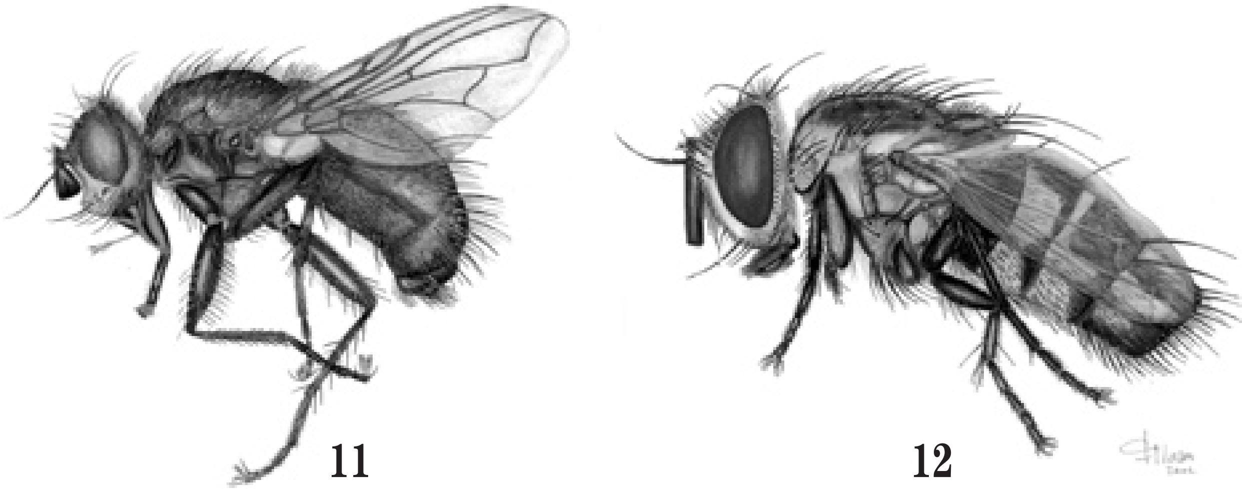


Figure 11 - 12 Habitus of two Tachinidae: 11 – *Chrysosomopsis* sp. cf. *aurata,* male from Ficuzza; 12 – *Dolichocolon paradoxum,* male from Ficuzza. Drawings by F. Mason.
Due specie di Tachinidae: 11 – Chrysosomopsis *sp. cf.* aurata, *maschio da Ficuzza; 12 –* Dolichocolon paradoxum, *maschio da Ficuzza. Disegni di F. Mason.*

the comparison between the species found during a given survey and those expected to occur in the area, deduced from a regional checklist. All material was identified by D. Birtele using chiefly the following works: Bradescu (1991), Hurkmans (1993), Torp (1994), Van Steenis (2000), Stubbs and Falk (2002) and Reemer *et al.* (2004).

- Diptera Tachinidae (Figures 11, 12). This family is now considered the most numerous among the suborder Brachycera (cf. Cerretti in press). In Italy as many as 622 species are recorded (Cerretti *op. cit.*) and certainly others are still to be discovered, as shown also by the results presented here. The Tachinidae are all internal parasitoids of other arthropods, mainly of insects. The larvae of many species feed on defoliating caterpillars and are therefore very useful in limiting the destructive outbreaks of some of them. Some Tachinidae are stenoecious and live in highly natural and well-preserved habitats. All material was identified by P. Cerretti using Cerretti (*op. cit.*).

- Coleoptera Lucanidae (Figure 13). These beetles can provide useful information for habitat conservation, also because all the species occurring in Europe live in forest habitats. Their larvae develop in the dead wood of both broadleaved trees and conifers and may take several years to reach maturity. One species, *Lucanus cervus* (Linnaeus, 1758), is included in the Habitats Directive and is considered threatened in the whole of Europe (cf. Ballerio 2003); others are included in red lists and/or protected by law in some Italian regions (cf. Ballerio 2003). All material was identified by G. Nardi using Franciscolo (1997).

- Coleoptera Scolytidae. These are typical xylophagous beetles, some of which are among the main forest pests. Currently, there are about 130 species recorded for mainland Italy (Alonso-zarazaga 2005). All material was identified by E. Gatti using chiefly Balachowsky (1949) and Pfeffer (1995).

- Lepidoptera Rhopalocera. In Italy, 279 species of Rhopalocera (Hesperiidae, Papilionidae, Pieridae, Riodinidae, Lycaenidae, Nymphalidae, Libytheidae, Satyridae) have been recorded, and their distribution is well known (cf. Balletto *et al.* 2005). The ecological requirements of both the larvae and the adults have been extensively studied. The larvae are dependent on their host plants and specific environmental factors. Butterflies are also relatively easy to catch and identify, which makes them a preferred choice as bioindicators in many terrestrial habitats (*e.g.* Erhardt and Thomas 1989; Boriani *et al.* 2005). All material was

Figure 13 - Habitus of *Platycerus caraboides,* male from Rosello. Photo by P. Cerretti.
Platycerus caraboides, *maschio da Rosello. Foto di P. Cerretti.*

identified by S. Hardersen using chiefly OLIVIER and COUTSIS (1997) and TOLMAN and LEWINGTON (1997).

Family and species names are listed (Tables 4–9) in alphabetical order and follow the systematics and nomenclature of Fauna Europaea (ALONSO-ZARAZAGA 2005; BARTOLOZZI 2005; ROZKOŠNÝ 2005; SPEIGHT 2005) except for the Tachinidae (Diptera), which follow CERRETTI (in press), the Scolytidae, which are given family rank, and the Rhopalocera (Lepidoptera), which follow BALLETTO *et al.* (2005).

Results and discussion

Prior to this project the knowledge of the invertebrate fauna of the 4 sites was patchy (cf. RUFFO and STOCH 2005), even though the Ficuzza area (where the plot SIC1 is located) had been investigated by several generations of naturalists (*e.g.* PINCITORE MAROTT 1873; LUIGIONI and TIRELLI 1913; MASSA and LO VALVO 2000). The existing information is dispersed in many specialistic papers (*e.g.* CARFI and TERZANI 1993; VIGNA TAGLIANTI *et al.* 2001; GASPARO 2003; LIBERTI and BAVIERA 2004; PELLEGRINI 2004; COLONNELLI 2005; GRASSI and ZILLI 2005) and monographic works are lacking except in rare cases (*e.g.* SCIARETTA and ZAHM 2002).

Part of the results obtained during the Invertebrate-Biodiv pilot project have already been published by CNBF staff and collaborators (BIRTELE 2004; CERRETTI 2004a, 2004b, 2005, in press; MERZ 2005; NARDI 2005; GATTI and NARDI 2005). Preliminary species lists of the Stratiomyidae (21 species), Syrphidae (114), Tachinidae (206), Lucanidae (3), Scolytidae (7) and Rhopalocera (18) referring to the sites of ABR2 (Rosello), CAL1 (Piano Limina), SIC1 (Ficuzza) and SAR1 (Marganai) are given in Tables 4–9. Brief comments on the most interesting species are provided here.

• Diptera Stratiomyidae. In this intermediate phase of the project over 600 specimens were studied, for a total of 21 species.

Actina chalybea is a saprophile the larvae of which develop in decaying roots (ROZKOŠNÝ 1982). It was collected in high numbers (208 males and 172 females) in a Malaise trap placed in a clearing between 17th and 23rd May 2005 outside the plot of Rosello. These individuals were probably swarming, a feature which is characteristic of members of the subfamily Beridinae (WOODLEY 2001), to which this species belongs.

Adoxomyia dahlii is probably associated with mature forest and is known in Italy from very few localities (MASON 2005).

Beris fuscipes. New to central-southern mainland Italy. This W-European species was previously known in Italy only from Piedmont (MASON 2005). Its larvae live under tree bark (ROZKOŠNÝ 1982).

Chloromyia speciosa is, like the above saproxylic species, associated with mature forest and is here newly recorded for Abruzzo. It is rare and known from very few localities in Italy (MASON 2005).

Chorisops nagatomii is a Turano-Europeo-Mediterranean species new to southern Italy (MASON 2005).

Chorisops tunisiae (Figures 5, 6). New to the Italian fauna. This species was previously recorded only from few localities in Portugal, Spain, Morocco and Tunisia (ROZKOŠNÝ 1979, 2005). Its larvae and biology are unknown. At Ficuzza it was trapped with the Malaise inside the plot (SIC1), whereas specimens from Marganai were collected on sunlit *Hedera helix* leaves and at night on a garden lamp.

Clitellaria ephippium (Figure 7) is a saproxylic species (SPEIGHT 1989) the larvae of which inhabit the nests of the ant *Lasius fuliginosus* (Latreille, 1798) (ROZKOŠNÝ 1983). This species has become extinct in Norway, seemingly also in Sweden (cf. STUBBS and DRAKE 2001) and is highly threatened all over Europe (SPEIGHT 1989) due to the continuous removal from forests of the senescent trees in which xylophagous ants build their nests.

Eupachygaster tarsalis (Figure 8) is an elusive saproxylic species the larvae of which inhabit the cavities of old trees (STUBBS and DRAKE 2001).

Sargus bipunctatus is a European species new to Sicily.

• Diptera Syrphidae. Ecological and behavioural notes are based on data provided by ROTHERAY (1994), STUBBS and FALK (2002), REEMER *et al.* (2004), SPEIGHT (2004) and BIRTELE (unpublished data); distributional data are taken from BELCARI *et al.* (1995), DACCORDI and SOMMAGGIO (2002), SOMMAGGIO (2005) and SPEIGHT (2005).

Brachyopa insensilis. New to the Italian fauna. This species was collected at Ficuzza with glass trunk traps fixed to *Quercus* trunks and in Emilia-Romagna (Ravenna, Podere Pantaleone, 20-25.IV.2003, Malaise trap, L. Landi legit) (BIRTELE unpublished data). It prefers coniferous (*Abies*) and deciduous (*Quercus* and *Fagus*) forest with old and senescent trees; however, it is also known to occur in suburban parks, as confirmed by the above-cited record from Podere Pantaleone, a park with large trees. The adult is mainly arboreal, rarely descending below 3 m above the ground to feed on sap runs exposed to the sun. The larva lives and feeds inside tunnels dug in wood by the caterpillars of *Cossus cossus* (Linnaeus, 1758) (Lepidoptera Cossidae).

Caliprobola speciosa. New to Sicily. This species lives in deciduous *Castanea*, *Fagus* and *Quercus* forest and in evergreen *Quercus suber* forest with mature and senescent trees. Males are often seen flying close to marcescent, sunlit roots of these trees. The larva has been observed among wet roots and rotting stumps of *Fagus* and *Quercus*.

Callicera fagesii. New to Sicily and Sardinia. This species occurs in deciduous *Fagus* and *Quercus* forest with mature and senescent trees. The arboreal adult descends from the tree crowns to feed on flowers (*e.g.* of *Sorbus*). The biology of the larva is unknown, but it is probably associated with mature trees. Many individuals were collected near the plots with a hand net, off *Quercus* leaves sprayed with an attractive sugar and water solution.

Mallota cimbiciformis. New to Sardinia. This species is recorded from deciduous *Fagus* and *Quercus* forest with very mature and senescent trees, as well as from evergreen *Q. suber* and *Q. ilex* stands. The adult, which is mainly arboreal, descends from the tree crowns into clearings and open spaces among flowering bushes and shrubs. Adults can be observed at the entrance of damp cavities in trees. The larva is saprophagous and lives in tree cavities partly filled with water. The only specimen examined was caught with a hand net off *Quercus* leaves sprayed with an attractive sugar and water solution.

Myolepta dubia. This species is recorded from alluvial forest, *Fagus* and *Quercus* forest and *Q. suber* forest. The adults, which are arboreal, occur on flowers at the forest edge and in clearings. Females have been observed flying around decaying wounds of trees, particularly *Quercus*. The larva inhabits damp tree cavities and was observed by Hartley (1961) in an old *Fagus* trunk. The species was collected at Ficuzza on *Ferula communis* (Apiaceae) flowers with a hand net.

Sphiximorpha garibaldii. New to Sicily. At Ficuzza the only male specimen was caught while flying close to an old hollow *Quercus cerris* at about 1.5 m above the ground. Females were found on flowers of *Ferula communis* in clearings inside a *Quercus suber* stand, as well as in a glass trunk trap fixed to a large *Q. suber* at a height of around 1.5 m.

Sphiximorpha subsessilis (Figure 9). The preferred habitats of this species are alluvial forest with mature *Populus* trees, riparian *Alnus* and *Salix* forest and *Quercus* and *Fagus* forest. A sole specimen was collected at Rosello in a glass trunk trap fixed to an *Abies alba* tree at a height of about 1.5 m.

Spilomyia manicata. The preferred habitat of this species is deciduous *Fagus* forest with very mature trees. The larva has been observed in the cavities of *Acer* and *Populus* trunks. The sole specimen so far examined was captured with a hand net on *Fagus* leaves sprayed with an attractive sugar and water solution.

Spilomyia saltuum. This species occurs in thermophilous *Quercus pubescens* forest and in evergreen *Q. ilex* and *Q. suber* forest with mature trees. The adult, which is mainly arboreal, descends from the tree crowns to feed on flowers. The larva is unknown but probably lives, like those of other congenerics, in old rotting tree cavities. At Ficuzza the adults of this species were collected on flowers of *Foeniculum vulgare* (Apiaceae).

Spilomyia triangulata (Figure 10). New to the Italian fauna. Data regarding this recently described species are few. In France it has been observed in flower-rich alpine meadows (Van Steenis 2000), whereas at Ficuzza it was found on flowerheads of *Ammi visnaga* (Apiaceae).

Besides those above, the following new records were found:

- new records for the Italian fauna: *Eumerus consimilis;*
- new records for central-southern mainland Italy: *Brachyopa pilosa*, *Chrysotoxum lessonae*, *Rhingia campestris;*
- new records for Abruzzo: *Epistrophe eligans*, *E. nitidicollis*, *Meligramma cincta*, *Meliscaeva cinctella;*
- new records for Sardinia: *Callicera macquarti*, *Cheilosia laticornis*, *C. pagana*, *C. scutellata*, *Chrysotoxum vernale*, *Dasysyrphus albostriatus*, *Eumerus amoenus*, *E. argyropus*, *Ferdinandea aurea*, *Helophilus trivittatus*, *Merodon constans*, *M. equestris*, *Pipiza* sp., *Riponnensia splendens*, *Syrphus vitripennis*, *Xanthandrus comtus*, *Xylota sylvarum;*

- new records for Sicily: *Chrysotoxum fasciatum*, *Psilota anthracina*.

• Diptera Tachinidae. Various interesting species were found, including 3 species new to science – *Pales abdita*, *P. marae* and *Pseudogonia metallaria* (Cerretti 2004a, 2005) – which deserve special mention. *Pseudogonia metallaria* belongs to a small genus of 5 species, widely distributed in the Old World. At the present state of knowledge it is a Sardinian endemic known only from the type locality, and is therefore of high conservation value. *Pales marae* is also a Sardinian endemic; however, unlike *Pseudogonia metallaria*, it was quite common at Marganai where it was found from spring until autumn, which means it probably has several generations per year. This species is particularly interesting from a phylogenetic point of view, since it differs strongly from its congenerics and no likely sister species is currently known on the continent (Cerretti 2005). *Pales abdita* on the other hand is widespread in the Mediterranean and was previously confused with the closely related *P. pavida*. All three species are strictly Mediterranean (cf. Cerretti 2004a, 2005). Noteworthy is also the finding, in several specimens at Marganai, of an undescribed species of *Estheria* Robineau-Desvoidy, 1830.

Besides these species, the following new records were found:

- new records for the Italian fauna: *Gymnosoma desertorum*, *Macquartia nudigena*, *Rioteria submacula;*
- new records for Sicily: *Bithia immaculata*, *Blondelia nigripes*, *Campylocheta* sp. cf. *praecox*, *Catagonia aberrans*, *Catharosia flavicornis*, *C. pygmaea*, *Chetoptilia puella*, *Erycia fatua*, *Gaedia connexa*, *Kirbya moerens*, *Macquartia tenebricosa*, *Myxexoristops stolida*, *Panzeria argentifera*, *Peribaea discicornis*, *Phorinia aurifrons*, *Senometopia excisa*, *Solieria fenestrata*, *S. pacifica*, *Wagneria cunctans*, *Xylotachina diluta*, *Zeuxia cinerea*, *Z. erythraea;*
- new records for Sardinia: *Actia pilipennis*, *Athrycia trepida*, *Catagonia aberrans*, *Cyrtophleba ruricola*, *Macquartia tenebricosa*, *M. tessellum*, *Masicera pavoniae*, *Medina separata*, *Meigenia dorsalis*, *M. majuscula*, *M. simplex*, *Pales processioneae*, *Phasia obesa*, *Phryxe vulgaris*, *P. magnicornis*, *Pseudoperichaeta nigrolineata*, *Siphona geniculata*, *Triarthria setipennis*, *Voria ruralis*, *Winthemia quadripustulata*, *W. variegata.*

• Coleoptera Lucanidae. Three species of this family were collected.

Platycerus caraboides (Figure 13) is not very common in Italy, despite being recorded from all the peninsular regions (Franciscolo 1997; Bartolozzi and Maggini 2005). It is protected by the Tuscan Regional law n. 56/2000 (cf. Ballerio 2003).

Lucanus tetraodon is also protected by this law and is a central-Mediterranean species which inhabits broadleaved forest (Franciscolo 1997). In Italy it is distributed in Liguria, the central-southern regions, Sicily and Sardinia (Bartolozzi and Maggini 2005).

Dorcus parallelipipedus is the most common Lucanidae in Italy and was also collected in the two Tuscan plots (Cala Violina and Colognole). It is replaced in Sardinia by *D. musimon* Gené, 1836, a Maghrebi-Sardinian species which has so far not been found at Marganai, despite having been recorded from various neighbouring localities (cf. Franciscolo 1997; Bartolozzi and Maggini 2005).

Still during the InvertebrateBiodiv project, also *Ceruchus chrysomelinus* (Hochenwart, 1785) and *Lucanus cervus cervus* were found, at Tarvisio (cf. Gatti and Nardi 2005) and Cala Violina, respectively. *Ceruchus chrysomelinus* is of outstanding interest: it is an endangered bioindicator species, everywhere extremely rare and localized and recorded in Italy from very few localities (cf. Gatti and Nardi 2005). *Lucanus cervus* is included in the Habitats Directive and is protected by the Tuscan Regional law n. 56/2000 (cf. Ballerio 2003). It was already recorded for Cala Violina (Bartolozzi and Maggini 2005). Altogether, 5 of the 9 species of Lucanidae recorded for Italy (Bartolozzi and Maggini 2005) were found in 6 out of the 12 investigated sites.

• Coleoptera Scolytidae. The species identified so far are widely distributed in Europe and are associated with broadleaved trees. Some (*Ernoporicus fagi*, *Xyleborinus saxesenii*, *Xyleborus* spp.) are typical of mature forest (cf. Balachowsky 1949; Pfeffer 1995). All the studied material was collected with window flight traps except for very few individuals taken with Malaise traps.

• Lepidoptera Rhopalocera. As not all samples have been studied yet, the list is still largely incomplete. Moreover, the traps used during the project (see Materials and methods) are not appropriate for a detailed study on this group, a hand net being the best method for collecting butterflies. Despite such limits, this list gives a first impression of the species diversity taken with the above traps.

The only butterfly collected in 3 out of 4 sites is *Pararge aegeria*, a heliophobous species living almost exclusively in forest (cf. Tolman and Lewington 1997; Balletto *et al.* 2005). Its absence from the traps does not indicate that the species is not present at Rosello, also because it was collected there by Sciarretta and Zahm (2002). Given the fact that all CONECOFOR plots are situated in forest areas, it was to be expected that *Pararge aegeria* would be the most widespread species.

The most interesting species collected is certainly *Parnassius mnemosyne*, which is included in the Habitats Directive and the Bern Convention (cf. Ballerio 2003). It was taken with a Malaise trap at Colle della Cerasa, within the MDA of Rosello. This species was not recorded by Sciarretta and Zahm (2002) for this area.

Conclusions

Despite being preliminary, the data presented here contribute to a better knowledge of biodiversity in Italy, by providing new records which update the national database of the Nature Protection Department of the Italian Ministry for the Environment (cf. Ruffo and Stoch 2005). Although only 11 families of insects have been studied so far, as many as 4 species new to science have been discovered, as well as 7 species new to the Italian fauna (1 Stratiomyidae, 3 Syrphidae and 3 Tachinidae), 40 species new to Sardinia and 28 species new to Sicily. These species, many of which are of high biogeographical interest, considerably increase the conservation value of the studied areas. This implies a greater responsibility for managers, who must be conscious of the fact they are preserving unique 'natural jewels'. The safeguard of these areas depends on the allocation of funds dedicated to both basic research and to the popularization of results which may stimulate a naturalistic interest in local communities, the only solid basis for long-term conservation.

One of the main problems encountered during the project was the irregularity of trap emptying by local staff. Indeed, only in some of the 12 plots was the fourteen-day frequency respected, and a quantitative analysis of data (*e.g.* species phenology) will be possible only for these few plots. Results obtained so far have shown that for most of the studied taxa a far greater number of species was collected with additional sampling within the MDA, thus indicating that sampling with traps within a single plot of limited size (2500 m^2) may be insufficient to obtain a good representativeness of the biodiversity of a site. According to very first results, higher representativeness in the plots is expected for the Carabidae. This taxon would appear to be one of the most appropriate for long-term monitoring of invertebrates within level II ICP Forests plots, not only because it fulfils the above-mentioned requisites (see Materials and methods), but also because a European network of taxonomists is available for the identification of large numbers of specimens (cf. Brandmayr *et al.* 2000). A network of taxonomists also exists for the Syrphidae. However, for this group (and possibly others) to be used in monitoring schemes an improvement of the InvertebrateBiodiv protocol would have to be considered, in which the complexity of the forest ecosystem as a whole is taken into account, not just a small and rather homogeneous area like the CONECOFOR plot. For long-term monitoring of the Syrphidae a study at the level of MDA would be desirable, for instance by stratifying each forest and surveying more than one plot according to forest structure types, habitat types, *etc.* (cf. Speight 2004). Given the enormous quantity of material collected, the amount of subsequent work involved (*e.g.* sorting, labelling, species identification) and the current limited man power, a sampling protocol of this kind could reasonably only be applied to a smaller number of representative biocoenoses (cf. Mosello *et al.* 2002).

With the repetition of invertebrate surveys in time (*e.g.* every 5–10 years) (cf. Koop 1989) and the acquisition of long time series, the protocol used during InvertebrateBiodiv could – best if improved – provide indications on effects of atmospheric pollution and climate change, also by relating results with those of other ICP Forests analyses (cf. Mosello *et al.* 2002; Travaglini *et al.*, this volume) and traditional forest structure and dynamics analyses (*e.g.* Cerretti *et al.* 2004b). Moreover, the analysis of long-term entomological data in relation to those obtained with additional new technologies (*e.g.* hemispheric photography, hyperspectral airborne laser scanners) for the analysis of landscape and forest structure (cf. Davison *et al.* 1999; Jonckheere *et al.* 2004; Weiss *et al.* 2004; Coren and Sterzai in press a, b) is likely to offer new insights into ecological processes of these important Italian forests.

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Table 4 - List of the Diptera Stratiomyidae collected so far in the 4 sites. Symbols used: a–z1 = localities (see Table 3) of collection with additional sampling within the MDA; + = presence in CONECOFOR plots;* = species new to the Italian fauna.
Lista dei Diptera Stratiomyidae sinora rinvenuti nei 4 siti esaminati. Simboli usati: a–z1 = località (vedi Tabella 3) all'internodell'MDA oggetto di campionamenti aggiuntivi; + = presenza nei plots CONECOFOR; = specie nuova per la fauna italiana.*

	Rosello (Abruzzo)		Piano Limina (Calabria)		Ficuzza (Sicily)		Marganai (Sardinia)	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
1 *Actina chalybea* Meigen, 1804		b, c, e						
2 *Adoxomyia dahlii* (Meigen, 1830)						i, r		
3 *Beris fuscipes* Meigen, 1820		c						
4 *B. geniculata* Curtis, 1830		c						
5 *Chloromyia formosa* (Scopoli, 1764)	+	b, f			+	p		
6 *C. speciosa* (Maquart, 1834)		c						u
7 *Chorisops nagatomii* Rozkošný, 2003	+		+					
8 **C. tunisiae* (Becker, 1915)					+			u
9 *Clitellaria ephippium* (Fabricius 1775)		c						
10 *Eupachygaster tarsalis* (Zetterstedt, 1842)						i, r		
11 *Lasiopa pseudovillosa* Rozkošný, 1983	+					r		
12 *L. villosa* Fabricius, 1764		c						
13 *Odontomyia annulata* (Meigen, 1922)		a						
14 *Oxycera morrisii* Curtis, 1833						r		
15 *Pachygaster atra* (Panzer, 1768)						r		
16 *Sargus bipunctatus (*Scopoli, 1763)					+			u
17 *S. cuprarius* (Linnaeus, 1758)	+					r		
18 *S. flavipes* Meigen, 1822		c						
19 *S. iridatus* (Scopoli, 1763)						o		
20 *Stratiomys longicornis* (Scopoli, 1763)						k, n		
21 *S. potamida* Meigen, 1822	+							
Tot.	5	9	1	0	3	9	0	3
Tot.	13		1		11		3	

Table 5 - List of the Diptera Syrphidae collected so far in the 4 sites (symbols as in Table 4).
Lista dei Diptera Syrphidae sinora rinvenuti nei 4 siti esaminati (simboli come in Tabella 4).

	Rosello (Abruzzo)		Piano Limina (Calabria)		Ficuzza (Sicily)		Marganai (Sardinia)	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
1 *Baccha elongata* (Fabricius, 1775)	+	c				s		
2 **Brachyopa insensilis* Collin, 1939						q		
3 *B. pilosa* Collin, 1939	+	c						
4 *Brachypalpoides lentus* (Meigen, 1822)	+	c	+	g				
5 *Caliprobola speciosa* (Rossi, 1790)		c				p, q		
6 *Callicera fagesii* Guérrin-Méneville, 1844					+	q	+	u, w, z
7 *C. macquarti* Rondani, 1844								u
8 *Ceriana vespiformis* (Latreille, 1804)						i, l		v, z1
9 *Cheilosia canicularis* (Panzer, 1801)		c						
10 *C. laticornis* Rondani, 1857								u
11 *C. pagana* (Poda, 1761)								u
12 *C. scutellata* (Fallèn, 1817)		c						u, w, z
13 *C. soror* Zetterstedt, 1843		c						
14 *Chrysotoxum bicinctum* (Linnaeus, 1758)		c				r		
15 *C. cautum* (Harris, 1776)				g				
16 *C. cisalpinum* Rondani, 1845						q		u
17 *C. elegans* Loew, 1841	+	c						
18 *C. fasciatum* (Müller, 1764)						n, q		
19 *C. intermedium* Meigen, 1822						i		
20 *C. lessonae* Giglio-Tos, 1890	+	c						u, v, z, z1
21 *C. octomaculatum* Curtis, 1832	+	c						
22 *C. vernale* Loew, 1841							+	z
23 *Criorhina berberina* (Fabricius, 1805)	+	c						
24 *Dasysyrphus albostriatus* (Fallén, 1817)								u, v, z, z1
25 *Didea fasciata* Macquart, 1834	+	c				j, o, p, r		u, w
26 *Epistrophe eligans* (Harris, 1780)		c			+	m, r		u
27 *E. nitidicollis* (Meigen, 1822)								
28 *Episyrphus balteatus* (De Geer, 1776)	+	c	+	g	+	p	+	t, u, v, z
29 *Eristalinus aeneus* (Scopoli, 1763)						l		u, v, w, z1
30 *E. taeniops* (Wiedemann, 1818)				g		i, l		z1
31 *Eristalis arbustorum* (Linnaeus, 1758)				g		i, l, p, q, r		z, z1
32 *E. pertinax* (Scopoli, 1763)	+	c		g				
33 *E. similis* (Fallén, 1817)						p, q, r		u, z1
34 *E. tenax* (Linnaeus, 1758)		c		g		i, p, r		u, v, z1
35 *Eumerus amoenus* Loew, 1848								z
36 *E. argyropus* Loew, 1848								z1
37 **E. consimilis* Simic & Vujic, 1996						l		
38 *E. ornatus* Meigen, 1822		c						
39 *E. pulchellus* Loew, 1848								w, y
40 *E. sulcitibius* Rondani, 1868						r		u, y, z1
41 *Eupeodes* corollae (Fabricius, 1794)								u
42 *E. luniger* (Meigen, 1822)						r, s		
43 *Ferdinandea aurea* Rondani, 1844								u
44 *F. cuprea* (Scopoli, 1763)	+	c			+	p, q		u, z, z1
45 *Helophilus pendulus* (Linnaeus, 1758)		c						
46 *H. trivittatus* (Fabricius, 1805)								z1
47 *Heringia latitarsis* (Egger, 1865)		c						
48 *Lejogaster tarsata* (Meigen, 1822)						n		
49 *Mallota cimbiciformis* (Fallén, 1817)		c						z
50 *Melangyna umbellatarum* (Fabricius, 1794)		c						
51 *Melanostoma mellinum* (Linnaeus, 1758)			+	g				u, v, z, z1
52 *M. scalare* (Fabricius, 1794)	+	c	+	g		m		u, z1
53 *Meligramma cincta* (Fallén, 1817)	+	c						
54 *Meliscaeva auricollis* (Meigen, 1822)								u, w
55 *M. cinctella* (Zetterstedt, 1843)	+	c						
56 *Merodon aberrans* Egger, 1860						o, r		
57 *M. aeneus* Meigen, 1822						p		w, z1
58 *M. armipes* Rondani, 1843		c						
59 *M. avidus* (Rossi, 1790)		c				m, o, p, r		
60 *M. clavipes* (Fabricius, 1781)								u, v
61 *M. constans* (Rossi, 1794)				g				u, v, y, z1
62 *M. equestris* (Fabricius, 1794)								z
63 *M. funestus* (Fabricius, 1794)								u, v, z1
64 *M. natans* (Fabricius, 1794)								y
65 *M. nigritarsis* Rondani, 1845		c						
66 *M. trochantericus* A. Costa, 1884								w, z1
67 *Milesia crabroniformis* (Fabricius, 1775)				g		i, l		
68 *M. semiluctifera* (Villers, 1789)						i, l		
69 *Myathropa florea* (Linnaeus, 1758)	+	c	+	g		i, l, q		u, v, z, z1
70 *Myolepta dubia* (Fabricius, 1803)						r		
71 *Neoascia obliqua* Coe, 1940		f						
72 *Paragus albifrons* (Fallén, 1817)						s		
73 *P. bicolor* (Fabricius, 1794)						n, r		y
74 *P. coadunatus* Rondani, 1847						r		
75 *P. haemorrhous* Meigen, 1822				g		o		z
76 *P. majoranae* Rondani, 1857						s		u
77 *P. quadrifasciatus* Meigen, 1822				g		r		
78 *P. strigatus* Meigen, 1822						r		
79 *Parhelophilus versicolor* (Fabricius, 1794)						q		

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	Rosello (Abruzzo)		Piano Limina (Calabria)		Ficuzza (Sicily)		Marganai (Sardinia)	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
80 *Pipiza* sp.								w
81 *P. austriaca* Meigen, 1822		c						
82 *P. lugubris* (Fabricius, 1775)		c						
83 *Pipizella* sp.		c				m		
84 *Platycheirus albimanus* (Fabricius, 1781)		c						
85 *P. scutatus* (Meigen, 1822)					+			
86 *Psilota anthracina* Meigen, 1822						p		
87 *Rhingia campestris* Meigen, 1822	+	c						
88 *Riponnensia longicornis* (Loew, 1843)						r		
89 *R. splendens* (Meigen, 1822)						m		u
90 *Scaeva albomaculata* (Macquart, 1842)								u
91 *S. dignota* (Rondani, 1857)						q		
92 *S. pyrastri* (Linnaeus, 1758)								u, v, w, z, z1
93 *S. selenitica* (Meigen, 1822)		c						u
94 *Sphaerophoria scripta* (Linnaeus, 1758)					+	p		
95 *Sphegina clunipes* (Fallèn, 1816)		f						
96 *Sphiximorpha garibaldii* Rondani, 1860						s		
97 *S. subsessilis* Illiger, 1807		c						
98 *Spilomyia manicata* (Rondani, 1865)				g				
99 *S. saltuum* (Fabricius, 1794)					+	i, q		
100 **S. triangulata* van Steenis, 2000						i		
101 *Syritta flaviventris* Macquart, 1842								y, z1
102 *S. pipiens* (Linnaeus, 1758)						l		u, w, y, z1
103 *Syrphus ribesii* (Linnaeus, 1758)						s		w
104 *S. torvus* Osten Sacken, 1875		c						
105 *S. vitripennis* Meigen, 1822						m		u, w
106 *Volucella bombylans* (Linnaeus, 1758)	+	c						
107 *V. inanis* (Linnaeus, 1758)				g		q		
108 *V. inflata* (Fabricius, 1794)	+	c						
109 *V. pellucens* (Linnaeus, 1758)		c		g				
110 *V. zonaria* (Poda, 1761)						i		u, w
111 *Xanthandrus comtus* (Harris, 1780)		c						u, z1
112 *Xanthogramma pedissequum* (Harris, 1776)						o, p, q, r, s		w, z
113 *Xylota segnis* (Linnaeus, 1758)		e		g	+			w
114 *X. sylvarum* (Linnaeus, 1758)	+	c		g			+	w
Tot.	19	46	5	19	8	54	4	55
Tot.	46		19		56		55	

Table 6 - List of the Diptera Tachinidae collected so far in the 4 sites (symbols as in Table 4).
Lista dei Diptera Tachinidae sinora rinvenuti nei 4 siti esaminati (simboli come in Tabella 4).

	Rosello (Abruzzo)		Piano Limina (Calabria)		Ficuzza (Sicily)		Marganai (Sardinia)	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
1 *Actia crassicornis* (Meigen, 1824)		b				m, r		
2 *A. infantula* (Zetterstedt, 1844)				g		m, n		
3 *A. pilipennis* (Fallén, 1810)						r	+	
4 *Admontia seria* (Meigen, 1824)	+							
5 *Allophorocera ferruginea* (Meigen, 1824)	+							
6 *Alsomyia capillata* (Rondani, 1859)						m, r		
7 *Aphria longirostris* (Meigen, 1824)	+	d						
8 *Aplomya confinis* (Fallén, 1820)		a, c		g		m, q, r		z, z1
9 *Athrycia trepida* (Meigen, 1824)								z
10 *Bessa parallela* (Meigen, 1824)		c		g				
11 *Besseria reflexa* Robineau-Desvoidy, 1830	+							
12 *B. zonaria* (Loew, 1847)						r		
13 *Billaea adelpha* (Loew, 1873)						s		
14 *B. lata* (Macquart, 1849)						i		
15 *Bithia immaculata* (Herting, 1971)						n		
16 *B. modesta* (Meigen, 1824)						n		
17 *Blepharipa pratensis* (Meigen, 1824)		c						z
18 *Blepharomyia pagana* (Meigen, 1824)		d						
19 *Blondelia nigripes* (Fallén, 1810)						p		
20 *Bothria subalpina* Villeneuve, 1910				g				
21 *Buquetia musca* Robineau-Desvoidy, 1847		c				l		
22 *Campylocheta praecox* (Meigen, 1824)					+			
23 *Carcelia dubia* (Brauer & Bergenstamm, 1891)				g				
24 *C. falenaria* (Rondani, 1859)	+	c, e		g		m, r		
25 *C. iliaca* (Ratzeburg, 1840)						m, n, p		
26 *C. laxifrons* Villeneuve, 1912								z1
27 *C. lucorum* (Meigen, 1824)		c				j, m, n, p, r		
28 *C. rasella* Baranov, 1931								z
29 *Catharosia pygmaea* (Fallén, 1815)					+	m, r		
30 *C. flavicornis* (Zetterstedt, 1859)						m		
31 *Cavalieria genibarbis* Villeneuve, 1908								u, z

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	Rosello (Abruzzo)		Piano Limina (Calabria)		Ficuzza (Sicily)		Marganai (Sardinia)	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
32 *Ceranthia lichtwardtiana* (Villeneuve, 1931)			+					
33 *Ceromasia rubrifrons* (Macquart, 1834)		c						
34 *Ceromya bicolor* (Meigen, 1824)	+							
35 *Cestonia cineraria* Rondani, 1861						n		
36 *Chetina setigena* Rondani, 1856						m, r		
37 *Chetogena acuminata* (Rondani, 1859)						l		
38 *C. fasciata* (Egger, 1856)			+					
39 *C. media* Rondani, 1859						l		
40 *Chetoptilia puella* (Rondani, 1862)						m		
41 *Chrysosomopsis* sp. cf. *aurata* (Fallén, 1820)					+	m, r		
42 *Clairvillia biguttata* (Meigen, 1824)		c				k, l, n		
43 *C. pninae* Kugler, 1971						n, r		
44 *Clausicella suturata* Rondani, 1859						m	+	v, z
45 *Clemelis pullata* (Meigen, 1824)		c				l, n		v, z
46 *C.* cf. *pullata* (Meigen, 1824)								z
47 *Clytiomya sola* (Rondani, 1861)		c				l, n		
48 *Compsilura concinnata* (Meigen, 1824)	+	c	+	g	+	l, m, s	+	z1
49 *Cylindromyia auriceps* (Meigen, 1838)						l, n, r		z
50 *C. bicolor* (Olivier, 1811)						l, m, n, r		v, z, z1
51 *C. intermedia* (Meigen, 1824)						n		
52 *C. pilipes* (Loew, 1844)						l, n		z, z1
53 *C. rubida* (Loew, 1854)+A28								x, y, z
54 *Cyrtophleba ruricola* (Meigen, 1824)								v, z
55 *Cyzenis albicans* (Fallén, 1810)	+			g				
56 *Dexia rustica* (Fabricius, 1775)			+	g				
57 *Dinera carinifrons* (Fallén , 1817)		c	+	g				
58 *D. ferina* (Fallén, 1817)	+	c	+	g				
59 *Dionaea aurifrons* (Meigen, 1824)								z, z1
60 *Dolichocolon paradoxum* Brauer & Bergenstamm, 1889						l		
61 *Drino vicina* (Zetterstedt, 1849)		c						
62 *Ectophasia crassipennis* (Fabricius, 1794)		c				l, n		
63 *E. leucoptera* (Rondani, 1865)						l, q, r		v, z, z1
64 *E. oblonga* (Robineau-Desvoidy, 1830)						k, l, n		z1
65 *Eliozeta helluo* (Fabricius, 1805)						p		
66 *E. pellucens* (Fallén, 1810)	+							
67 *Eloceria delecta* (Meigen, 1824)	+		+	g		m, n, p		
68 *Elomya lateralis* (Meigen, 1824)						k		
69 *Epicampocera succincta* (Meigen, 1824)	+	c	+					
70 *Erycesta caudigera* (Rondani, 1861)								z
71 *Erycia fatua* (Meigen, 1824)		c				r		
73 *Estheria* sp.								u, w
72 *Estheria cristata* (Meigen, 1826)				g, h				
74 *Ethilla aemula* (Meigen, 1824)								v, z
75 *Eumea mitis* (Meigen, 1824)			+	g				
76 *Eurithia connivens* Zetterstedt, 1844				g				
77 *Eurysthaea scutellaris* (Robineau-Desvoidy, 1848)	+							
78 *Exorista grandis* (Zetterstedt, 1844)						r, s		
79 *E. nova* (Rondani, 1859)		c						
80 *E. rustica* (Fallén, 1810)	+	b, c		g				
81 *E. segregata* (Rondani, 1859)								v, y, z1
82 *Fischeria bicolor* Robineau-Desvoidy, 1830								y
83 *Gaedia connexa* (Meigen, 1824)						r		
84 *Gastrolepta anthracina* (Meigen, 1826)					+	l, m, n, q	+	v, x, z
85 *Gonia bimaculata* Wiedemann, 1819						l		
86 *G. vacua* Meigen, 1826	+			g				
87 *G. distinguenda* Herting, 1963						m		
88 *Graphogaster vestita* Rondani, 1868						i, k, m, r		
89 *Gymnophryxe inconspicua* (Villeneuve, 1924)								v, z1
90 *Gymnosoma clavatum* (Rohdendorf, 1947)								z, z1
91 **G. desertorum* (Rohdendorf, 1947)								x
92 *G. nitens* Meigen, 1824				g				
93 *G. rotundatum* (Linnaeus, 1758)		c		g				z
94 *G. rungsi* (Mesnil, 1952)								z
95 *G. siculum* Dupuis & Genduso, 1981						k		
96 *Hebia flavipes* Robineau-Desvoidy, 1830	+	c				m, p		z, z1
97 *Hemyda vittata* (Meigen, 1824)		c						
98 *Huebneria affinis* (Fallén, 1810)						m		
99 *Leucostoma semibarbatum* Tschorsnig, 1991						m		
100 *L. simplex* (Fallén, 1815)		a, c				r		
101 *L. turonicum* Dupuis, 1964				g				
102 *Ligeria angusticornis* (Loew, 1847)						m		
103 *Linnaemya frater* (Rondani, 1859)			+	g				
104 *L. lithosiophaga* (Rondani, 1859)						l, n		z, z1
105 *L. media* Zimin, 1954				g				
106 *L. picta* (Meigen, 1824)			+	g				
107 *L. soror* Zimin, 1954						i, q, r		u, x
108 *L. vulpina* (Fallén, 1810)		c				l, n		
109 *Loewia rondanii* (Villeneuve, 1919)								u, v, z
110 *Lomachantha parra* (Rondani, 1859)		c						

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	Rosello (Abruzzo)		Piano Limina (Calabria)		Ficuzza (Sicily)		Marganai (Sardinia)	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
111 *Lydella stabulans* (Meigen, 1824)						p		
112 *Macquartia chalconota* (Meigen, 1824)				g				
113 *M. dispar* (Fallén, 1820)	+	c		g				
114 *M. grisea* (Fallén, 1810)			+		+	i, q, r		
115 **M. nudigena* Mesnil, 1972			+					
116 *M. praefica* (Meigen, 1824)						m, p, q		
117 *M. tenebricosa* (Meigen, 1824)						j, r		v, z, z1
118 *M. tessellum* (Meigen, 1824)						j	+	z
119 *Masicera pavoniae* (Robineau-Desvoidy, 1830)		c						v, z1
120 *Medina collaris* (Fallén, 1820)				g				
121 *M. separata* (Meigen, 1824)		c		g				t, u, v
122 *Meigenia dorsalis* (Meigen, 1824)		c						z
123 *M. majuscula* (Rondani, 1859)					+	m, p, q		x
124 *M. mutabilis* (Fallén, 1810)		c	+			m, r		
125 *M. simplex* Tschorsnig & Herting, 1998								z
126 *Microphthalma europaea* Egger, 1860						l, n		
127 *Microsoma exiguum* (Meigen, 1824)						m, r		z
128 *Mintho compressa* (Fabricius, 1787)								z
129 *M. rufiventris* (Fallén, 1817)						m, n	+	z1
130 *Myxexoristops stolida* (Stein, 1924)					+			
131 *Neaera atra* Robineau-Desvoidy, 1850								v
132 *Nemoraea pellucida* (Meigen, 1824)	+			g		p		
133 *Nemorilla maculosa* (Meigen, 1824)						l		v, z, z1
134 *Neophryxe vallina* (Rondani, 1861)		c						
135 *Nilea hortulana* (Meigen, 1824)				g				
136 *Ocytata pallipes* (Fallén, 1820)					+	m, p	+	
137 *Pales abdita* Cerretti, 2005						l		
138 *P. marae* Cerretti, 2005								t, v, z, z1
139 *P. pavida* (Meigen, 1824)	+	c				m, n, p, q, r, s	+	t, u, v, z, z1
140 *P. processioneae* (Ratzeburg, 1840)		c	+					z1
141 *P. pumicata* Meigen, 1824						l		
142 *Panzeria argentifera* (Meigen, 1824)						m		
143 *P. connivens* (Zetterstedt, 1844)			+	g				
144 *P. consobrina* (Meigen, 1824)				g				
145 *Parasetigena silvestris* (Robineau-Desvoidy, 1863)	+							
146 *Paratryphera barbatula* (Rondani, 1859)					+	l, m, n, q		
147 *Peleteria abdominalis* Robineau-Desvoidy, 1830						m, r		
148 *P. meridionalis* (Robineau-Desvoidy, 1830)						q		
149 *P. rubescens* (Robineau-Desvoidy, 1830)				g		l		
150 *P. ruficornis* (Macquart, 1835)						l		w, y
151 *P. varia* (Fabricius, 1794)		c				l, n, r		
152 *Peribaea apicalis* Robineau-Desvoidy, 1863		c	+	g	+	l, m, n	+	z
153 *P. discicornis* (Pandellé, 1894)						m, r		
154 *P. tibialis* (Robineau-Desvoidy, 1851)				g		m, n		z, z1
155 *Phasia hemiptera* (Fabricius, 1794)				g				
156 *P. mesnili* (Draber-Monko, 1965)						l		
157 *P. obesa* (Fabricius , 1798)						p		z, z1
158 *P. pusilla* Meigen, 1824				g				y, z1
159 *Phebellia nigripalpis* (Robineau-Desvoidy, 1847)	+					m, p, r		
160 *Phorinia aurifrons* (Robineau-Desvoidy, 1830)	c			g		m		
161 *Phorocera assimilis* (Fallén, 1810)					+	m, p, q	+	u, v, z, z1
162 *Phryno vetula* (Meigen, 1824)	+			g	+	m, p, q, r		u, z, z1
163 *Phryxe magnicornis* (Zetterstedt, 1838)		c						z
164 *P. nemea* (Meigen, 1824)		c		g				
165 *P. semicaudata* Herting, 1959						p		
166 *P. vulgaris* (Fallén, 1810)						j, r		v, z1
167 *Platymya antennata* (Brauer & Bergenstamm, 1891)			c					
168 *P. fimbriata* (Meigen, 1824)			+			m, r		
169 *Prosopea nigricans* (Egger , 1861)						l, p		
170 *Pseudogonia metallaria* Cerretti, 2004								w, z1
171 *P. parisiaca* (Robineau-Desvoidy, 1851)						k, l		
172 *P. rufifrons* (Wiedemann, 1830)						k, l, n		
173 *Pseudoperichaeta nigrolineata* (Walker, 1853)								v, z
174 *Ptesiomyia alacris* (Meigen, 1824)	+					p		
175 *Ramonda spathulata* (Fallén, 1820)	+			g				
176 **Rioteria submacula* Herting, 1973							+	
177 *Rondania fasciata* (Macquart, 1834)	+							
178 *Senometopia excisa* (Fallén, 1820)		c				p		
179 *Siphona geniculata* (DeGeer, 1776)			+	g				x, z1
180 *Smidtia amoena* (Meigen, 1824)								z1
181 *S. conspersa* (Meigen, 1824)	+	b, c, d, e		g		m, p		
182 *Solieria fenestrata* (Meigen, 1824)						r		
183 *S. pacifica* (Meigen, 1824)	+					m		
184 *Spallanzania rectistylum* (Macquart, 1847)								x, y
185 *Stomina caliendrata* (Rondani, 1862)						l, m		x, z, z1
186 *Tachina casta* (Rondani, 1859)						m		
187 *T. fera* (Linnaeus, 1761)	+	c		g		l, m, n	+	u, v, z, z1
188 *T. grossa* (Linnaeus , 1758)	+							

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	Rosello (Abruzzo)		**Piano Limina (Calabria)**		**Ficuzza (Sicily)**		**Marganai (Sardinia)**	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
189 *T. lurida* (Fabricius, 1781)						m, p, q		
190 *T. magnicornis* (Zetterstedt, 1844)						i, p, q		
191 *T. nupta* (Rondani, 1859)						n		z
192 *T. praeceps* Meigen, 1824						n		
193 *Thelyconychia solivaga* (Rondani, 1861)			+					
194 *Tlephusa cincinna* Rondani , 1859		c						
195 *Triarthria setipennis* (Fallén, 1810)	+	c			+	l, m		z
196 *Trigonospila transvittata* (Pandellé, 1896)								w, z
197 *Voria ruralis* (Fallén, 1810)		c				s		v, z, z1
198 *Wagneria cunctans* (Meigen, 1824)						r		
199 *Winthemia quadripustulata* (Fabricius, 1794)								v
200 *W. rufiventris* (Macquart, 1849)								v, z, z1
201 *W. variegata* (Meigen, 1825)								z, z1
202 *Xylotachina diluta* (Meigen, 1824)					+			
203 *Xysta holosericea* (Fabricius, 1805)								v, z1
204 *Zaira cinerea* (Fallén, 1810)						n, p		
205 *Zeuxia cinerea* Meigen, 1826						k, n		
206 *Z. erythraea* (Egger, 1856)						k		
Tot.	30	48	20	43	15	112	12	72
Tot.	66		52		115		75	

Table 7 - List of the Coleoptera Lucanidae collected so far in the 4 sites (symbols as in Table 4).
Lista dei Coleoptera Lucanidae sinora rinvenuti nei 4 siti esaminati (simboli come in Tabella 4).

	Rosello (Abruzzo)		**Piano Limina (Calabria)**		**Ficuzza (Sicily)**		**Marganai (Sardinia)**	
	plot	MDA	plot	MDA	plot	MDA	plot	MDA
1 *Dorcus parallelipipedus* (Linnaeus, 1758)			+		+			
2 *Lucanus tetraodon* Thunberg, 1806			+		+	i, q, r		
3 *Platycerus caraboides* (Linnaeus, 1758)		c, e						
Tot.	0	1	2	0	2	1	0	0
Tot.	1		2		2		0	

Table 8 - List of the Coleoptera Scolytidae collected so far in the 4 sites (symbols as in Table 4).
Lista dei Coleoptera Scolytidae sinora rinvenuti nei 4 siti esaminati (simboli come in Tabella 4).

	Rosello (Abruzzo)		**Piano Limina (Calabria)**		**Ficuzza (Sicily)**		**Marganai (Sardinia)**	
	plot	MDA	plot	MDA	plot	MDA	plot	
1 *Ernoporicus fagi* (Fabricius, 1798)			+					
2 *Hylesinus toranio* (Danthoine, 1788)					+			
3 *Scolytus intricatus* (Ratzeburg, 1837)	+							
4 *Trypodendron domesticum* (Linnaeus, 1758)			+					
5 *Xyleborinus saxesenii* (Ratzeburg, 1837)	+		+				+	
6 *Xyleborus dispar* (Fabricius, 1792)	+		+		+			
7 *X. monographus* (Fabricius, 1792)	+						+	
Tot.	4	0	4	0	2	0	2	0
Tot.	4		4		2		2	

Table 9 - List of the Lepidoptera Rhopalocera so far identified from the 4 sites (symbols as in Table 4).
Lista dei Lepidoptera Rhopalocera sinora rinvenuti nei 4 siti esaminati (simboli come in Tabella 4).

		Rosello (Abruzzo)		**Piano Limina (Calabria)**		**Ficuzza (Sicily)**		**Marganai (Sardinia)**	
		plot	MDA	plot	MDA	plot	MDA	plot	MDA
1 Hesperiidae	*Carcharodus alceae* (Esper, 1780)		b						
2 Hesperiidae	*Erynnis tages* (Linnaeus, 1758)		e						
3 Lycaenidae	*Aricia agestis* ([Denis & Schiffermüller], 1775)		b						
4 Lycaenidae	*Callophrys rubi* (Linnaeus, 1758)		b						
5 Lycaenidae	*Polyommatus icarus* (Rottemburg, 1775)							+	
6 Nymphalidae	*Argynnis paphia* (Linnaeus, 1758)	+		+					
7 Nymphalidae	*Charaxes jasius* (Linnaeus, 1766)							+	
8 Nymphalidae	*Limenitis reducta* Staudinger, 1901					+			
9 Nymphalidae	*Nymphalis polychloros* (Linnaeus, 1758)							+	
10 Papilionidae	*Parnassius mnemosyne* (Linnaeus, 1758)		b						
11 Pieridae	*Anthocharis cardamines* (Linnaeus, 1758)		e						
12 Pieridae	*Pieris napi* (Linnaeus, 1758)			+					
13 Satyridae	*Hipparchia aristaeus* (Bonelli, 1826)					+			
14 Satyridae	*Lasiommata maera* (Linnaeus, 1758)		b						
15 Satyridae	*L. megera* (Linnaeus, 1767)		b						
16 Satyridae	*Maniola jurtina* (Linnaeus, 1758)							+	
17 Satyridae	*Melanargia galathea* (Linnaeus, 1758)					+			
18 Satyridae	*Pararge aegeria* (Linnaeus, 1758)			+		+		+	
	Tot.	1	8	3	0	4	0	5	0
	Tot.	9		3		4		5	

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Aspects of biological diversity in the CONECOFOR plots. V. Deadwood surveying experiments in alpine and mediterranean forest ecosystems

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Abstract – In recent years, deadwood has become more and more considered as indicator in the assessment of the biodiversity and naturalness of forest ecosystems. Its occurrence, in an appropriate proportion according to forest use, is fundamental for the maintenance of biological diversity, since it represents a microhabitat for hundred of species of invertebrates, fungi, bryophytes, lichens, amphibians, small mammals and birds. Having acknowledged its importance in forest coenoses, quantification of deadwood components in a given habitat, in relation to forest type and type of management, becomes essential. In our study, different survey designs were tested and compared for assessing deadwood components: stumps, lying coarse wood pieces and lying fine wood pieces. As expected, the experiments carried out show that sample-based estimates of ground necromass tend to be more accurate as the quantity of necromass present within the area to be surveyed and the size of the sampling units increase. The adoption of four 7-m-radius subplots in a systematic configuration has proved to be a good compromise between accuracy and survey costs for volume estimation of stumps and lying wood pieces within the examined experimental forest stand plot.

Key words: *dead wood, biodiversity, forest management, survey design, forest inventory.*

Riassunto – Esperienze sperimentali di rilevamento della necromassa legnosa in cenosi forestali alpine e mediterranee. Negli ultimi anni, il legno morto è sempre più considerato un indicatore per valutare la biodiversità e la naturalità di un sistema forestale. La sua presenza, nelle opportune proporzioni commisurate anche alle finalità di coltivazione della foresta, è fondamentale per il mantenimento della diversità biologica, rappresentando il microhabitat per centinaia di specie di invertebrati, funghi, briofite, licheni, anfibi, piccoli mammiferi ed uccelli. Riconosciuta l'importanza della necromassa legnosa nelle cenosi forestali, diviene fondamentale la sua quantificazione in un determinato ambiente, distinguendone la presenza in funzione dei tipi forestali e delle forme di gestione. A tal fine, in questo studio sono state sperimentate e valutate comparativamente differenti strategie di rilievo di alcune componenti della necromassa legnosa a terra: ceppaie, rami grossi e rami fini. Come atteso, la sperimentazione mostra che la stima della necromassa grossolana e fine a terra tende ad essere più accurata all'aumentare della quantità di legno morto presente e all'aumentare delle dimensioni della superficie di rilevamento. Nelle condizioni esaminate, l'adozione di quattro subplots di 7 m di raggio in configurazione sistematica è risultato un buon compromesso tra accuratezza e costi di indagine per la stima del volume delle ceppaie e del legno morto a terra.

Parole chiave: *legno morto, biodiversità, gestione forestale, schema di rilevamento, inventario forestale.*

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Introduction

The protection of European forests is now focused on the application of systemic sylviculture (Ciancio *et al.* 1999, 2003) and the conservation of biodiversity, two aspects which have been discussed during the various Ministerial Conferences for the Protection of Forests in Europe, in which biodiversity management is dealt with in an ecosystemic approach (MCPFE AND EfE/PEBLDS 2004). One of the themes of this approach is the need for protection of the forest environment as a whole, by adopting conservation strategies and exploitation techniques ever-nearing the natural model. Starting from the 1980s, attention

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to deadwood has progressively grown. Actually, its ecological role was well known long time before (Haapannen 1965; Elton 1966). In recent years, deadwood has become more and more considered as indicator in the assessment of the biodiversity and naturalness of forest systems (Keddy and Drummond 1996; McComb and Lindenmayer 1999; Skogsstyrelsen 2001). Its occurrence, in an appropriate proportion according to forest use, is fundamental for the maintenance of biological diversity, since it represents a microhabitat for hundred of species of invertebrates (Heliövaara and Väisänen 1984; Kirby and Drake 1993; Samuelsson *et al.* 1994; Siitonen 2001), fungi (Heilmann-Clausen 2001; Mason 2003; Sippola and Renvall 1999; Rydin *et al.* 1997), bryophytes (Söderström 1988; Lesica *et al.* 1991; Ódor and Standovár 2001), lichens (Humphrey *et al.* 2002), amphibians (Herbeck and Larsen 1999; Raymond and Hardy 1991), small mammals (Harmon *et al.* 1986) and birds (Hunter 1990; Sandström 1992; Mikusinski and Angelstam 1997; McComb and Lindenmayer 1999).

Deadwood can be considered as an array of microhabitats continuously evolving in time (WWF 2004), which to be correctly managed, needs to be well known and distinguished also with respect to the associated species (Table 1). The quantity of deadwood occurring in natural forests in the different European regions depends on many factors, and its correct estimation must consider forest type (species' composition and structure), development stage, type and frequency of natural disturbance in the region (Nocentini 2002), type of management, but also soil and climatic characteristics, which together contribute to complete the formation and decomposition cycle of deadwood (Christensen *et al.* 2003).

Deadwood and old hollow trees do not generally represent a threat to forest health (Mason 2002). Nonetheless, quantities of deadwood have strongly decreased since the middle of the nineteenth century due to intense forest exploitation (Linder and Ostlund 1998; Siitonen *et al.* 2000; Nilsson *et al.* 2001) and widespread burning of small wood pieces and other leftovers, and to the removal of all physical obstacles to sylvicultural activity. Moreover, classical forest management is usually based on rotations shorter than longevity of species and so the number of old big trees in forest is usually poor (Nocentini 2003). Presence of deadwood can be related to the intensity of sylvicultural actions and the way these are carried out (Guby and Dobbertin 1996; Green and Peterken 1997). This is why deadwood quantities (woody necromass)

Table 1 - Deadwood microhabitats and associated species (In: USDA Forest Service Pacific Southwest Division, updated 2002).
Microhabitat del legno morto e specie associate (In: USDA Forest Service Pacific Southwest Division, aggiornamento 2002).

	Microhabitat type	Associated biodiversity
Ancient trees	Very old trees with an ample crown, useful as perching and nesting sites	Large raptors such as the golden eagle *(Aquila chrysaetos*), black stork *(Cigonia nigra)*
	Cavities on very old trees	Nesting sites for owls
	Deadwood on live trees	Coleoptera and lignicolous fungi
Standing dead trees	Very old trees with large wood pieces, useful as perching and nesting sites	Birds, squirrels, other animals feeding on or under bark (e.g. Coleoptera) and their predators
	Standing trunks (snags) in different states of decay	Colonized by fungi, lichens, invertebrates and a high number of nesting in trunks (e.g. woodpeckers)
	Standing trunks (snags) with large-sized cavities capable of hosting large animals	Brown bear
	Young dead trees	Fungi, bacteria and associated algae
Deadwood on the ground	Recently fallen logs with bark and small wood pieces	Fungi and large Coleoptera
	Partially intact logs, the wood of which is beginning to soften inside	Coleoptera and fungi, but with different species' compositions
	Logs devoid of bark and small wood pieces, and partly sunken into the ground	Many insect species, including Coleoptera and Diptera; few fungi
	Logs in an advanced state of decay, devoid of bark and small wood pieces, completely sunken into the ground	Specialized insects and fungi
	Nearly totally decomposed logs, the wood of which is crumbly but still whole	Arthropods, millipedes, etc. This faunal component facilitates the sprouting of conifers and of some broadleaved trees such as alders
	Uprooted trees with their root system still present	The roots may host birds' nests and insects
Litter layer and water	Large woody debris	The wood becomes a substrate for many species of bryophytes and higher plants
	Woody fragments including wood pieces, fine wood pieces and bark	Specialized fungi and arthropods
	Coarse wood	Algae, insect larvae, fry

Table 2 - Main characteristics of the CONECOFOR study areas.
Principali caratteristiche delle aree di studio CONECOFOR.

Test area n	Location (acronym)	Administrative region	Altitude m	Slope degrees	Orientation	FTBAs subtype	INFC subcategory
1	Renon (BOL1)	Trentino Alto Adige	1740	35	SW	Subalpine and montane spruce and montane mixed spruce-fir-forests	Subalpine spruce forest
2	Colognole (TOS1)	Tuscany	150	10	N	Mesomediterranean oakwoods dominated by *Q. ilex, Q. rotundifolia, Q. suber, Q. calliprinos, Q. alnifolia*	Mixed forest of *Q. ilex* and *F. ornus*
3	Piano Limina (CAL1)	Calabria	1100	20	NE	Apennine-Corsican montane beech forests	Beech forest with *Ilex aquifolium*
4	Marganai (SAR1)	Sardinia	700	5	S	Mesomediterranean oakwoods dominated by *Q. ilex, Q. rotundifolia, Q. suber, Q. calliprinos, Q. alnifolia*	Coastal *Q. ilex* forest
5	Passo Lavazè (TRE1)	Trentino Alto Adige	1775	10	N-NW	Subalpine and montane spruce and montane mixed spruce-fir-forests	Subalpine spruce forest

in managed forests are considerably lower than in forests left to evolve naturally: it has been estimated that only 2 to 30% of the deadwood found in non-managed forests occurs in managed ones (Lesica *et al.* 1991; Green and Peterken 1997; Kirby *et al.* 1998; Jonsson 2000). Therefore, in the interest of conservation, attempts are being made to increase woody necromass in productive areas (*e.g.* Hodge and Peterken 1998; Harmon 2001; Mason 2003).

In 1989 Speight was the first to draw attention to the saproxylic organisms' conservation issue in an organized account of the European Council, the basic principles of which are summarized in the R (88) 10 Recommendation of the European Council Ministers' Committee. In Italy the problem has not been faced until recently: locally, in the year 2000, with the emission by the autonomous province of Bolzano of the "Regolamento dell'Ordine Forestale" (Regulation of the Foresters Organization); nationally, in 2001, with Legislative Decree 227/2001 "Orientamento e modernizzazione del settore forestale" (Orientation and modernization of the forestry sector). A series of multidisciplinary initiatives are developing in Europe regarding the deadwood issue: *e.g.* the "Xylobius" project in Belgium and the "ageing islands" of the Romersberg State forest in France. Also worth remembering are the LIFE Nature projects carried out by the Swedish National Forests Office with the cooperation of forest owners, and the LIFE Nature project "Techniques for re-establishment of deadwood for saproxylic fauna conservation" carried out in 2003 in the "Bosco della Fontana" state forest in the Po plain (Italy), in the framework of urgent actions for the conservation of relict habitats (Mason 2003).

Highest biodiversity seems to occur in large-sized deadwood in an advanced state of decay (Bader *et al.* 1995; Høiland and Bendiksen 1997; Kruys and Jonsson 1999), even though it has been demonstrated that smaller pieces are just as important (Kruys and Jonsson 1999; Heilmann-Clausen and Christensen 2002). Also important is the presence of "habitat trees", *i.e.* old trees often rich in rotten cavities which are active during the whole life-span of the tree and continually evolve, until they form complex and stable habitats where most specialized and rare saproxylic fauna species occur (Mason *et al.* 2002). The quantification of the deadwood component in a given habitat, in relation to forest type and type of management, is essential to define more sustainable management choices. Nonetheless it is still an open question how to carry out these measurements, given the lack of standardized, useful, reliable and economically affordable methods (Chirici and Travaglini 2002; Chirici *et al.* 2003; Schuck *et al.* 2004). Aiming to contribute to fill this gap, different sample-based survey designs were implemented and compared in this study, assessing different deadwood components on the forest ground: stumps, lying coarse wood pieces, lying fine wood pieces.

Material and Methods

Experimentation of techniques for surveying deadwood on the ground was carried out in five permanent plots of the Italian CONECOFOR (Control of Forest Ecosystems) monitoring network (Table 2): Renon (BOL1), Colognole (TOS1), Piano Limina (CAL1), Marganai (SAR1) and Passo Lavazè (TRE1).

According to the forest types for Biodiversity Assessment classification pattern proposed at European level (Marchetti and Barbati 2004), the forest formations in the plots can be assigned to the following forest types and subtypes:

- Alpine coniferous forest, subtype subalpine and montane spruce and montane mixed spruce-fir forests;
- Montane beech forest, subtype Apennine-Corsican montane beech forest;
- Mediterranean and Macaronesian sclerophyllous forest, subtype mesomediterranean oakwoods dominated by *Quercus ilex*, *Q. rotundifolia*, *Q. suber*, *Q. calliprinos*, *Q. alnifolia*.

The vegetation in the plots can also be classified within the following forest categories and subcategories proposed for the Italian "Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio" (National Inventory of Forests and Forest Carbon Reserves):

- Spruce forest, subcategory subalpine spruce forest;
- Beech forest, subcategory beech forest with *Ilex aquifolium;*
- *Quercus ilex* forest, subcategory coastal *Q. ilex* forest;
- *Quercus ilex* forest, subcategory mixed *Q. ilex* and *Fraxinus ornus* forest.

Inventoried attributes

The following deadwood components were considered: stumps, lying coarse wood pieces and lying fine wood pieces.

Stumps, of natural or artificial origin, were considered when their diameter at the cutting or breaking point was equal to or greater than 10 cm (d ≥ 10 cm). Lying coarse wood pieces were considered when their maximum diameter was equal to or greater than 10 cm (d_{max} ≥ 10 cm). Wood pieces with a maximum diameter comprised between 5 and 10 cm (5≤ d_{max} <10) were considered and classified as lying fine wood pieces. In each experimental area, a 50-m-side square plot was delimited and a complete survey (census) of deadwood on the ground was carried out (Table 3). The volume of each stump situated in the plot was calculated by means of the formula:

$$v_{stump} = \frac{\pi}{4} d^2 h \qquad [1]$$

where: v_{stump} = volume of the stump;
d = diameter of the stump at the cutting or breaking point;
h = height of the stump.

The volume of lying wood pieces was calculated using Huber's formula [2]:

$$v_{lying} = \frac{\pi}{4} d^2_{0.5l}\, l \qquad [2]$$

where: v_{lying} = volume of the wood piece;
$d_{0.5l}$ = diameter of the wood piece at half length;
l = length of the wood piece.

Adding to real observations, simulation data have been considered in order to better assess the accuracy of the different survey designs for increasing woody necromass levels. Two dataset series have been generated randomly distributing examined attributes on 50-m-side square plots, with woody necromass from about 0.5 m^3ha^{-1} to around 10 m^3ha^{-1} for fine wood pieces, 20 m^3ha^{-1} for stumps and 40 m^3ha^{-1} for coarse wood pieces (Table 4).

Experimental designs

Reference methodological protocol

During the 4th Meeting of the Working Group on Biodiversity Assessment in Forests, held in 2003 in Sabaudia (Italy) in the framework of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forest), a methodology for surveying the woody necromass in European ICP Forest level-II monitoring areas was

Table 3 - Volumes of stumps, large wood pieces and fine wood pieces censused in the CONECOFOR areas.
Volume delle ceppaie, dei rami grossi e dei rami fini rilevato per censimento nelle aree CONECOFOR.

Experimental area n	Location (acronym)	Inventoried attributes	Volume at plot level m^3ha^{-1}
1	Renon (BOL1)	Stumps	11.700
		Lying coarse wood pieces	0.000
		Lying fine wood pieces	0.060
		Total	11.760
2	Colognole (TOS1)	Stumps	3.652
		Lying coarse wood pieces	1.236
		Lying fine wood pieces	3.416
		Total	8.304
3	Piano Limina (CAL1)	Stumps	3.620
		Lying coarse wood pieces	1.076
		Lying fine wood pieces	0.360
		Total	5.056
4	Marganai (SAR1)	Stumps	0.304
		Lying coarse wood pieces	1.128
		Lying fine wood pieces	2.204
		Total	3.636
5	Passo Lavazè (TRE1)	Stumps	8.368
		Lying coarse wood pieces	2.888
		Lying fine wood pieces	0.572
		Total	11.828

Table 4 - Main dimensional characteristics of simulation datasets 1 and 2.
Principali caratteristiche dimensionali dei dataset di simulazione 1 e 2.

	Dataset 1						Dataset 2					
	Diameter cm		Length m		Volume m^3ha^{-1}		Diameter cm		Length m		Volume m^3ha^{-1}	
	min	max	min	max	min	max	min	max	min	max	min	max
Lying fine wood pieces	5	9	0.1	7	0.5	10	5	9	0.1	2.9	0.5	10
Lying coarse wood pieces	10	29	0.2	5.9	0.5	40	10	29	0.1	3.9	0.5	40
Stumps	10	39	0.1	0.9	0.5	20	20	60	0.1	0.5	0.5	20

proposed. This methodology consists of an inventory scheme based on a magnetic north-oriented 50 m side square plot, within which is positioned a cluster of four circular subplots associated with sample line transects (Figure 1). The subplots, of 7 m radius, are centred on the corners of a magnetic north-oriented 26 m side square.

The sample line transects (three for each subplot) depart from the centre of the circular areas at 120° angles from one another. One of the sample line transects is oriented towards the magnetic north. Inventory protocol asks for a complete census of all standing dead trees (standing deadwood or snags) and downed dead trees within the 50-m plot, and calculates their mass using double-entry volume tables. The coarse lying necromass (stumps and large wood pieces) is surveyed within the subplots and their volume is assessed by means of formulas [1] and [2]; volumes in m^3 are then added up at subplot level and transformed into m^3ha^{-1}. The volume of stumps and large wood pieces in m^3ha^{-1} is finally calculated for the whole plot, as an average of estimates for each of the four subplots.

The estimate of the fine lying necromass is carried out at subplot level by Line Intersect Sampling (LIS) (Corona 2000): the diameter of each thin wood piece intercepted by a line transect is measured at the point of interception. The mass per hectare estimate is then calculated at subplot level using formula [3], considering the three sample line transects of each subplot as a single sampling unit:

$$v_{lying\_fine} = \frac{\pi^2}{8L} \sum_{i=1}^{n} d_i^2 \qquad [3]$$

where:
v_{lying_fine} = volume (in m^3ha^{-1}) of fine wood pieces at subplot level;
L = total length (in m) of sample line transects;
d = diameter (in cm) of the i-th fine wood piece intercepted by the sample line transects within the subplot;
n = total number of fine wood pieces intercepted by the sample line transects within the subplot.
The volume per hectare of fine wood pieces is finally calculated at plot level, as an average of estimates for each of the four subplots.

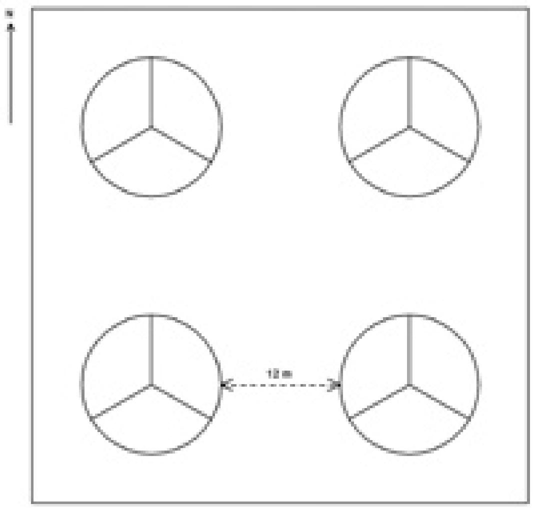


Figure 1 - Survey design for estimating woody necromass within ICP Forest level-II monitoring areas, as proposed by the 4th Meeting of the Working Group on Biodiversity Assessment in Forests, held in 2003 in Sabaudia (Italy). The lines within each 7-m radius subplot are used to estimate fine lying necromass by LIS.
Schema di rilevamento per la stima della necromassa legnosa nelle aree di monitoraggio ICP Forest level-II, proposto nel corso del 4th Meeting of the Working Group on Biodiversity Assessment in Forests, tenutosi nel 2003 a Sabaudia (Italia). Le linee all'interno di ciascun subplot circolare di 7 m di raggio sono usate per la stima della necromassa fine a terra tramite campionamento per intersezione lineare.

Tested survey designs

Three different survey designs for estimating the lying woody necromass (stumps, large wood pieces, fine wood pieces) in 50-m-side square plots were defined:

a) design type 1 - the first experimental design uses the same inventory scheme presented at Sabaudia in 2003, based on a cluster of four circular subplots associated with sample line transects and centred on the geometrical centre of the 50-m-side plot;

b) design type 2 - the second experimental design uses a single subplot associated with sample line transects, centred on the geometrical centre of the 50-m-side plot;

c) design type 3 - the third experimental design, defined exclusively for estimating the mass of fine wood pieces, consists of 50-m north-south oriented sample line transects traced from a point randomly selected along the south margin of the 50-m-side plot.

In order to assess estimate accuracy according to survey area size, both increasing radiuses of subplots in designs 1 and 2 and a greater number of line transects in design 3 were tested. In particular:

- for design type 1, circular areas of 4, 7, 10 and 12 m radius were tested;
- for design type 2, circular areas of 4, 7, 10, 12 and 15 m radius were tested;
- for design type 3, an increasing amount of sample line transects (from 1 to 10) were used.

In order to be compared, designs 1 and 2 were tested by randomly positioning the subplots within the plot and randomly orienting the sample line transects (random configuration), nevertheless maintaining a 120° angle between them.

The above survey designs were tested on the five CONECOFOR study areas as well as on two simulation datasets. Altogether, 28 experimental tests were performed (Table 5, Table 6). The relative accuracy of the estimates obtained using the considered survey designs for each component of the woody necromass was quantified by comparison with the real values provided by the censuses carried out in the studied areas:

$$Absolute\_Bias = \left| \frac{v_e - v_t}{v_t} \right| \cdot 100 \qquad [4]$$

where:

Absolute_Bias = absolute deviation of the estimate from the true value (%);

v_e = volume estimated by survey design;

v_t = true volume.

In the context of experimentation carried out, where test areas can be viewed as repetitions, the mean value of the absolute bias for a given survey design represent the percent bias expected for the implementation of the design in a single case.

Operating modes

Survey design types 1 and 2 were used to estimate the mass of stumps (d≥10 cm), large wood pieces (d_{max}≥10 cm) and fine wood pieces (5≤ d_{max} <10). Large wood pieces and stumps were surveyed within subplots and their volume was assessed by means of formulas [1] and [2]. Volumes in m^3 were added up at subplot level and transformed into m^3ha^{-1}. In the case of design 2, values thus obtained express the volume of stumps and large wood pieces in m^3ha^{-1} at plot level. In design 1, volume in m^3ha^{-1} at plot level was calculated as the average of estimates made for each of the four subplots.

The survey of fine wood pieces was done both with LIS (formula [3]), calculating mass in m^3ha^{-1} at subplot level, and by measuring the half-way diameter of pieces situated within the subplots, using formula [2] for calculating their volume. When LIS was applied to survey design type 2, the value obtained using formula [3] directly expressed the volume in m^3ha^{-1} at plot level, whereas when it was applied to survey design type 1, the necromass of fine wood pieces in m^3ha^{-1} at plot level was calculated as the average of estimates obtained in all four plots by means of formula [3]. Survey design type 3 was tested only for the estimation of fine wood piece mass, calculated by means of formula [3].

Results

The application of the survey designs to the five CONECOFOR study areas provided the results shown in Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6. Survey design type 1 was more accurate than survey design type 2 in estimating coarse necromass on the ground (stumps and lying coarse wood pieces). The radius of subplots providing the best results is not the same for all test areas. No substantial differences were found among designs 1 in systematic or random configurations. As far as fine necromass is concerned, tests carried out by surveying all pieces within the subplots produced more accurate estimates compared to those obtained from LIS, as can be observed in areas CAL1 Piano Limina (v_{lying_fine} = 0.360 m^3ha^{-1}) and TRE1 (v_{lying_fine} = 0.572 m^3ha^{-1}). In both cases, survey design type 1 in systematic configuration with a 7 m subplot

Table 5 - Tests carried out using survey designs 1 and 2.
Quadro riassuntivo dei test sperimentali effettuati con lo schema di rilevamento 1 e 2.

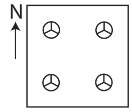
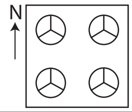
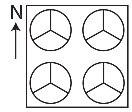
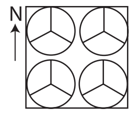
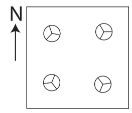
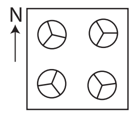
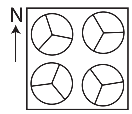
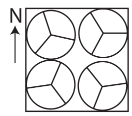
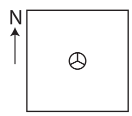
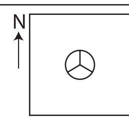
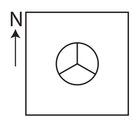
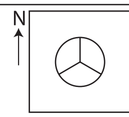
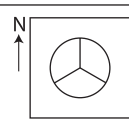
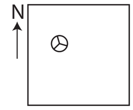
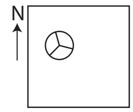
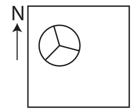
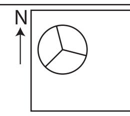
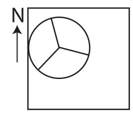
Survey design n	Inventoried attributes	Survey unit	Survey unit configuration	Radius of subplots m	Total length of line transects m	Survey design type 1 and 2
1	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Systematic	4	48	
2	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Systematic	7	84	
3	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Systematic	10	120	
4	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Systematic	12	144	
5	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Random	4	48	
6	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Random	7	84	
7	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Random	10	120	
8	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplots Subplots Subplots or sample line transects	Random	12	144	
9	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Systematic	4	12	
10	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Systematic	7	21	
11	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Systematic	10	30	
12	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Systematic	12	36	
13	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line	Systematic	15	45	

Table 5 - (continuing) Tests carried out using survey designs 1 and 2.
(continua) Quadro riassuntivo dei test sperimentali effettuati con lo schema di rilevamento 1 e 2.

Survey design n	Inventoried attributes	Survey unit	Survey unit configuration	Radius of subplots m	Total length of line transects m	Survey design type 1 and 2
14	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Random	4	12	
15	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Random	7	21	
16	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Random	10	30	
17	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Random	12	36	
18	Stumps Lying coarse wood pieces Lying fine wood pieces	Subplot Subplot Subplot or sample line transects	Random	15	45	

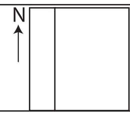
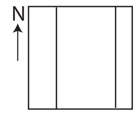
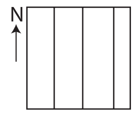
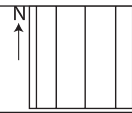
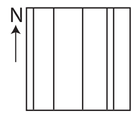
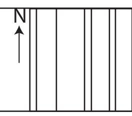
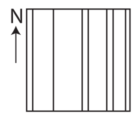
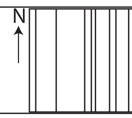
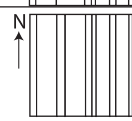
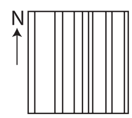
radius was most accurate, with an 8% absolute bias at Piano Limina and a 20% absolute bias at Passo Lavazè. In the BOL1 plot (v_{lying_fine} = 0.060 m^3ha^{-1}), where only one fine wood piece was present within the 50 m side plot, all tests produced an absolute bias equal or superior to 100%. In the remaining areas, TOS1 (v_{lying_fine} = 3.416 m^3ha^{-1}) and SAR1 (v_{lying_fine} = 2.204 m^3ha^{-1}), the most accurate estimates were obtained using LIS: at Colognole, survey design type 1 in random configuration and with 4-m subplot radius produced an absolute bias of 2%; at SAR1, a 4% absolute bias was recorded both with survey design type 1 in random configuration and 7-m subplot radius and with survey design 2 in systematic configuration and 7-m subplot radius. At TOS1, design type 1 was better than design type 2 using tests in systematic configuration: with a 4-m subplot, LIS produces estimates (absolute bias = 16%) that are similar to those obtained by measuring pieces within the circular subplots, whereas with greater radius LIS was progressively more accurate (11% of absolute bias with a 12-m radius).

Results obtained with survey design type 3 indicate a progressive reduction of the absolute bias for increasing total length of line transects traced within the 50-m-side plot. However, estimate accuracy was always lower than that of the best estimates obtained using survey design types 1 and 2, except in SAR1 (1% of absolute bias with a total segment length of 200 m).

The mean values of absolute biases computed for each survey design tested and for each deadwood component across all the examined CONECOFOR plots are reported in Table 7, 8 and 9. These figures show few significant differences among the tested designs. However, as a trend, it can be observed that estimates by the survey designs of type 1 tend to be more accurate than those obtained by the survey designs of types 2 and 3; furthermore, in the case of lying fine wood pieces, the survey of all the pieces within the subplots tends to provide more accurate results than those obtained by LIS.

The tests carried out on the two simulation dataset series evidence that the absolute value of bias between the samples of simulation data and total simulated data decreases as the quantity of woody necromass on the ground increases. For stumps, survey design type 1 with systematic positioning of subplots produced a absolute bias lower than 40% for mass values over 4 m^3ha^{-1}, which decreased further (<25%) for values over 10 m^3ha^{-1}, with no clear dependence on

Table 6 - Tests carried out using survey design 3.
Quadro riassuntivo dei test sperimentali effettuati con lo schema di rilevamento 3.

Survey design n	Inventoried attributes	Survey unit	Survey unit configuration	Total length of line transects m	Survey design type 3
19	Lying fine wood pieces	Line transect	Random	50	
20	Lying fine wood pieces	Line transects	Random	100	
21	Lying fine wood pieces	Line transects	Random	150	
22	Lying fine wood pieces	Line transects	Random	200	
23	Lying fine wood pieces	Line transects	Random	250	
24	Lying fine wood pieces	Line transects	Random	300	
25	Lying fine wood pieces	Line transects	Random	350	
26	Lying fine wood pieces	Line transects	Random	400	
27	Lying fine wood pieces	Line transects	Random	450	
28	Lying fine wood pieces	Line transects	Random	500	

the size of the area considered. However, the best results were obtained using the subplots with largest diameter: absolute bias below to 10% for quantities of necromass on the ground over 2 m^3ha^{-1}. All other factors being equal, no substantial differences were assessed between designs in systematic and in random configuration. Survey design type 2 applied to the two simulation dataset series showed contrasting results. In the case of dataset 1, circular areas of 15 m radius were the best in both the systematic and random configurations: absolute bias below 10% for mass values higher than 8 m^3ha^{-1}. In the case of dataset 2, the margin was lower than 40% in all tests only for mass values over 12 m^3ha^{-1}. Indeed, below this threshold the simulated distribution of stumps shows a greater concentration towards the edges of the 50-m-side plot. This is the reason why the inventory scheme tends to underestimate necromass in the plot.

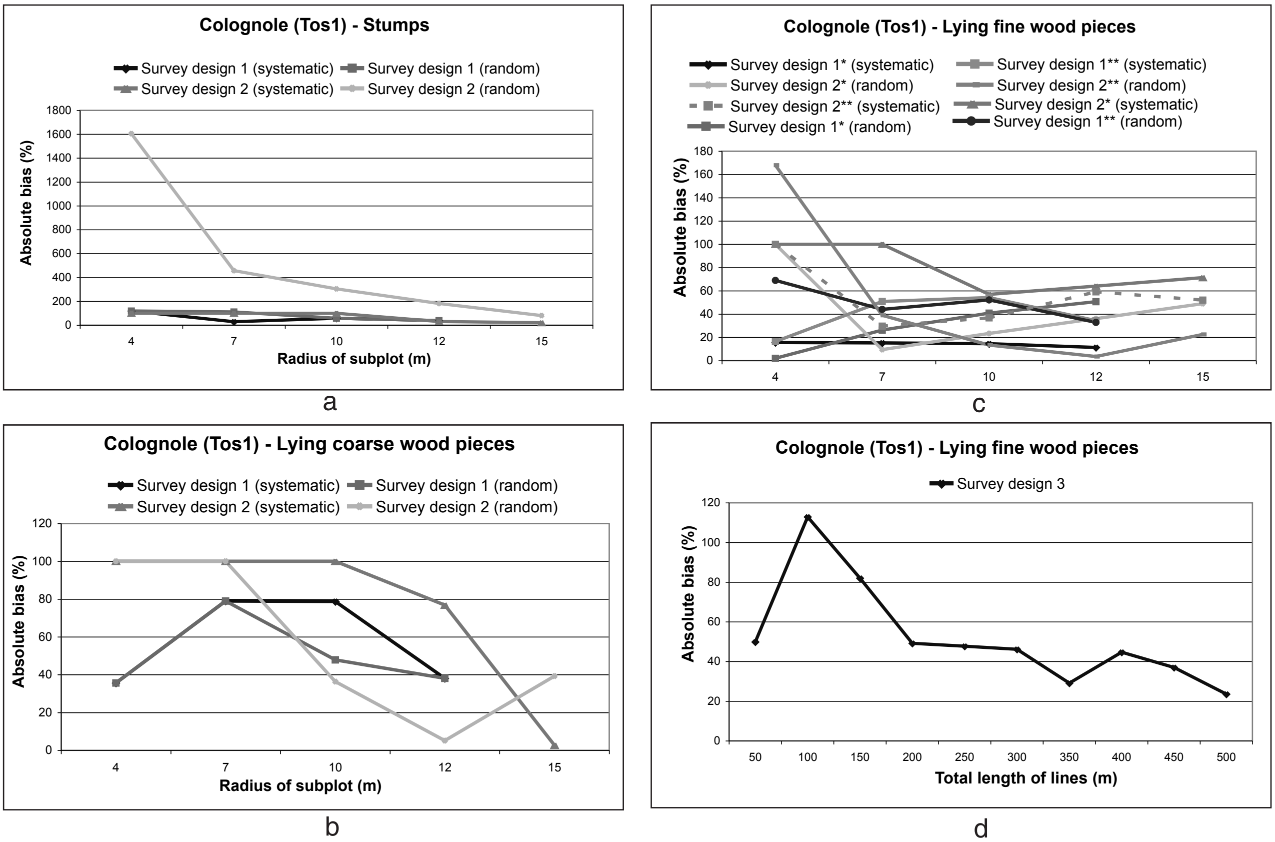


Figure 2 - Results obtained by applying survey designs 1, 2 and 3 to the Colognole study area (TOS1): a) stumps, b) large wood pieces, c) fine wood pieces (* surveying of fine wood pieces with LIS; ** surveying of fine wood pieces within the circular areas), d) fine wood pieces (survey design 3).
Risultati ottenuti applicando lo schema di rilevamento 1, 2 e 3 all'area di studio Colognole (TOS1): a) ceppaie, b) rami grossi, c) rami fini (rilevamento dei rami fini con campionamento per intersezione lineare; ** rilevamento dei rami fini all'interno delle aree circolari), d) rami fini (schema di rilevamento 3).*

Table 7 - Stumps: mean value of the absolute biases across the five CONECOFOR experimental areas by tested survey designs (* see Table 5). Means with different letters are significantly different (p=0.05) according to HSD Tukey test.
Ceppaie: valore medio degli scarti (in valore assoluto) ottenuti nelle cinque aree sperimentali CONECOFOR con gli schemi di rilevamento testati (vedi Tabella 5). Le medie con lettere differenti sono significativamente differenti secondo il test HSD di Tukey (p=0.05).*

Survey design*	Overall mean %	
8	21	A
4	23	A
3	48	AB
2	49	AB
7	50	AB
12	50	AB
13	56	AB
6	65	AB
18	68	AB
11	68	AB
1	69	AB
10	80	AB
9	84	AB
5	90	AB
17	93	AB
16	120	AB
15	136	AB
14	416	B

Table 8 - Lying coarse wood pieces: mean values of the absolute biases across the five CONECOFOR experimental areas by tested survey designs (* see Table 5). Means with different letters are significantly different (p=0.05) according to HSD Tukey test.
Rami grossi: valore medio degli scarti (in valore assoluto) ottenuti nelle cinque aree sperimentali CONECOFOR con gli schemi di rilevamento testati (vedi Tabella 5). Le medie con lettere differenti sono significativamente differenti secondo il test HSD di Tukey (p=0.05).*

Survey design*	Overall mean %	
4	32	A
5	39	A
8	43	A
1	48	A
13	53	A
3	59	A
7	61	A
2	66	A
6	66	A
15	68	A
14	80	A
18	92	A
12	105	A
16	140	A
17	140	A
11	158	A
10	322	AB
9	986	B

For large wood pieces, the threshold above which survey design type 1 in systematic configuration generates an absolute bias below 60% is 10 m^3ha^{-1}. Also in this case the best results were obtained in the largest subplots (radius = 12 m): absolute bias below 27% for mass values grater than 2 m^3ha^{-1}. Survey design type 2 generally produced more accurate estimates for mass quantities over 20 m^3ha^{-1}.

For fine wood pieces, the best results provided by the use of survey design types 1 and 2 were obtained with survey design type 1, assessing pieces within 12 m radius subplots. In this case, the observed absolute bias was less than 25% for all simulated necromass quantities. Results obtained with survey design type 3 show a progressive reduction of the absolute bias as volume of lying fine wood pieces and/or number of traced line transects increase. In the case of dataset 1, tests carried out with a total line transect length over 350 m produced an absolute bias which was always less than 22%.

Conclusions

Sample-based survey methods would be useful in estimating those descriptive attributes of forest stands, such as the dead wood, generally considered as accessory compared to the more usual dendrometric data.

As expected, the experiments carried out show that sample-based estimates of ground necromass tend to be more accurate as the quantity of necromass present within the area to be surveyed and the size of the

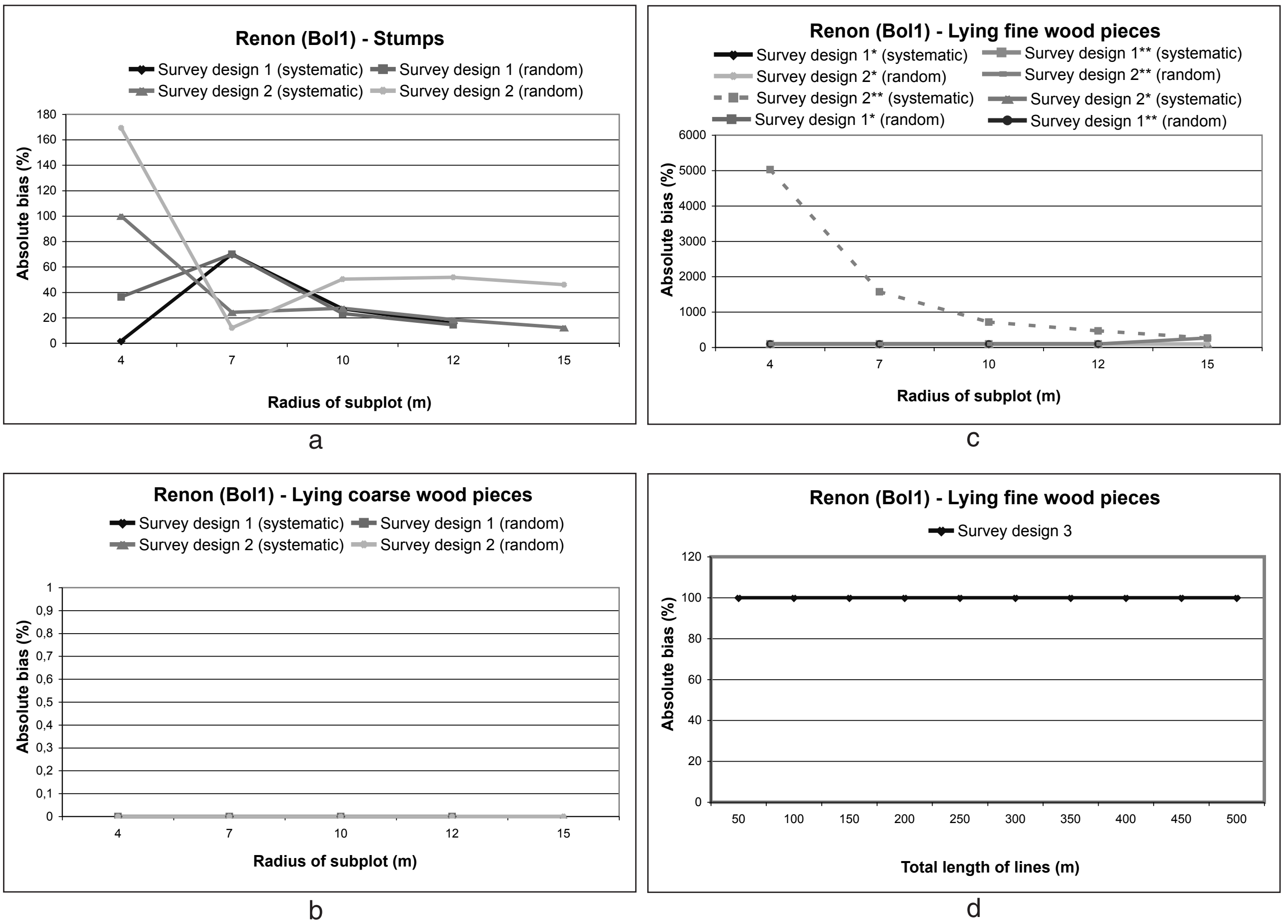


Figure 3 - Results obtained by applying survey designs 1, 2 and 3 to the Renon study area (BOL1): a) stumps, b) large wood pieces, c) fine wood pieces (* surveying of fine wood pieces with LIS; ** surveying of fine wood pieces within the circular areas), d) fine wood pieces (survey design 3).
Risultati ottenuti applicando lo schema di rilevamento 1, 2 e 3 all'area di studio Renon (BOL1): a) ceppaie, b) rami grossi, c) rami fini (rilevamento dei rami fini con campionamento per intersezione lineare; ** rilevamento dei rami fini all'interno delle aree circolari), d) rami fini (schema di rilevamento 3).*

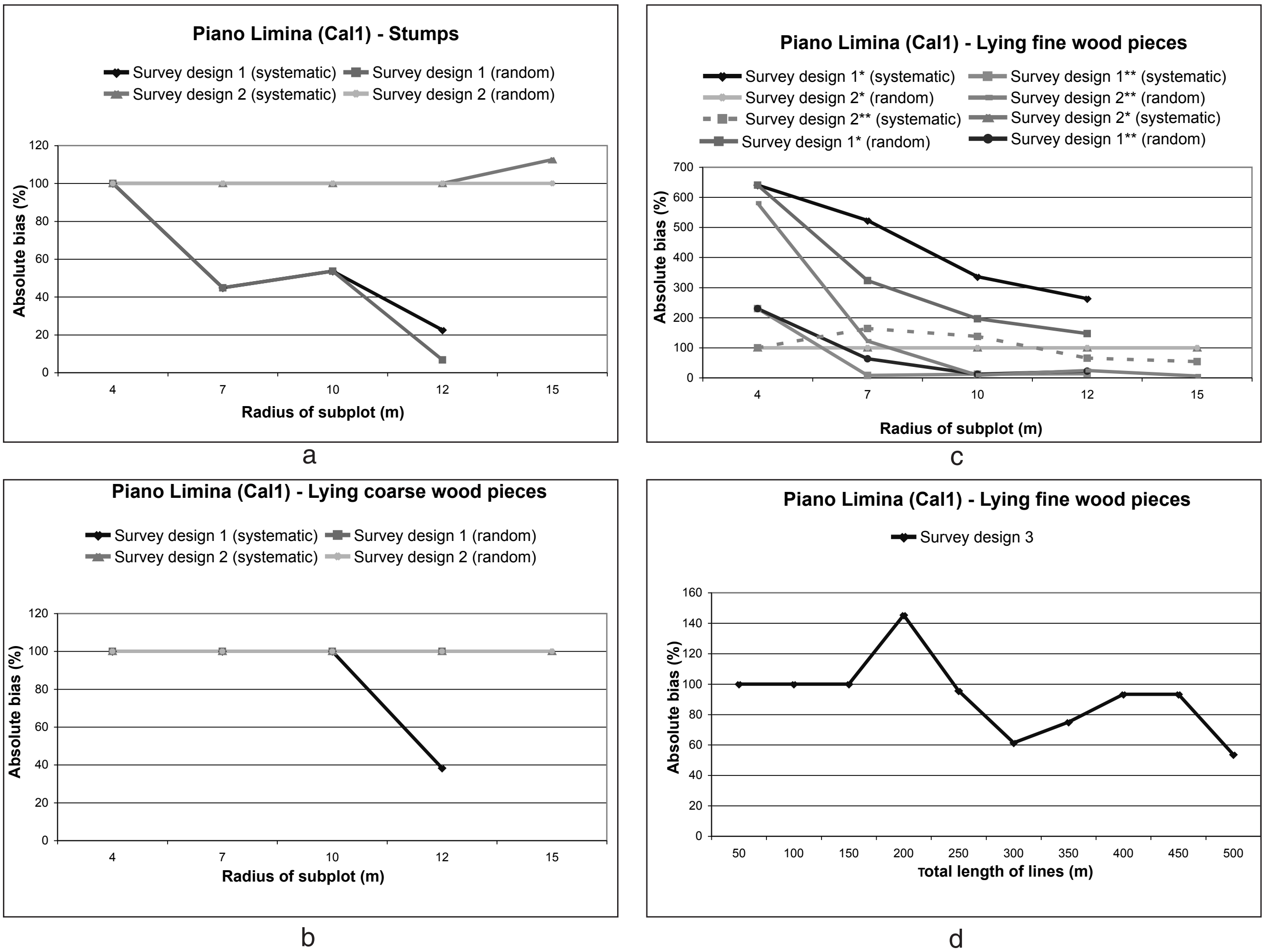


Figure 4 - Results obtained by applying survey designs 1, 2 and 3 to the Piano Limina study area (CAL1): a) stumps, b) large wood pieces, c) fine wood pieces (* surveying of fine wood pieces with LIS; ** surveying of fine wood pieces within the circular areas), d) fine wood pieces (survey design 3).
Risultati ottenuti applicando lo schema di rilevamento 1, 2 e 3 all'area di studio Piano Limina (CAL1): a) ceppaie, b) rami grossi, c) rami fini (rilevamento dei rami fini con campionamento per intersezione lineare; ** rilevamento dei rami fini all'interno delle aree circolari), d) rami fini (schema di rilevamento 3).*

survey unit increase. As far as lying coarse necromass and stumps are concerned, in the examined areas survey design type 1 with systematic positioning of subplots tends to be more efficient than survey design type 2. As for fine wood pieces, survey design type 1 in a systematic configuration tends to be more accurate than survey design types 2 and 3. In the conditions here examined, LIS turned out to be worse than direct survey within subplots in the presence of low quantities of fine necromass on the ground.

According to the overall results within the CONECOFOR areas selected for this study and on the basis of a trade-off between relative accuracy by the experimented survey designs for the different necromass components (Table 7, 8, 9) and survey costs, the use of four 7-m-radius subplots in a systematic configuration (Figure 7) should be advised.

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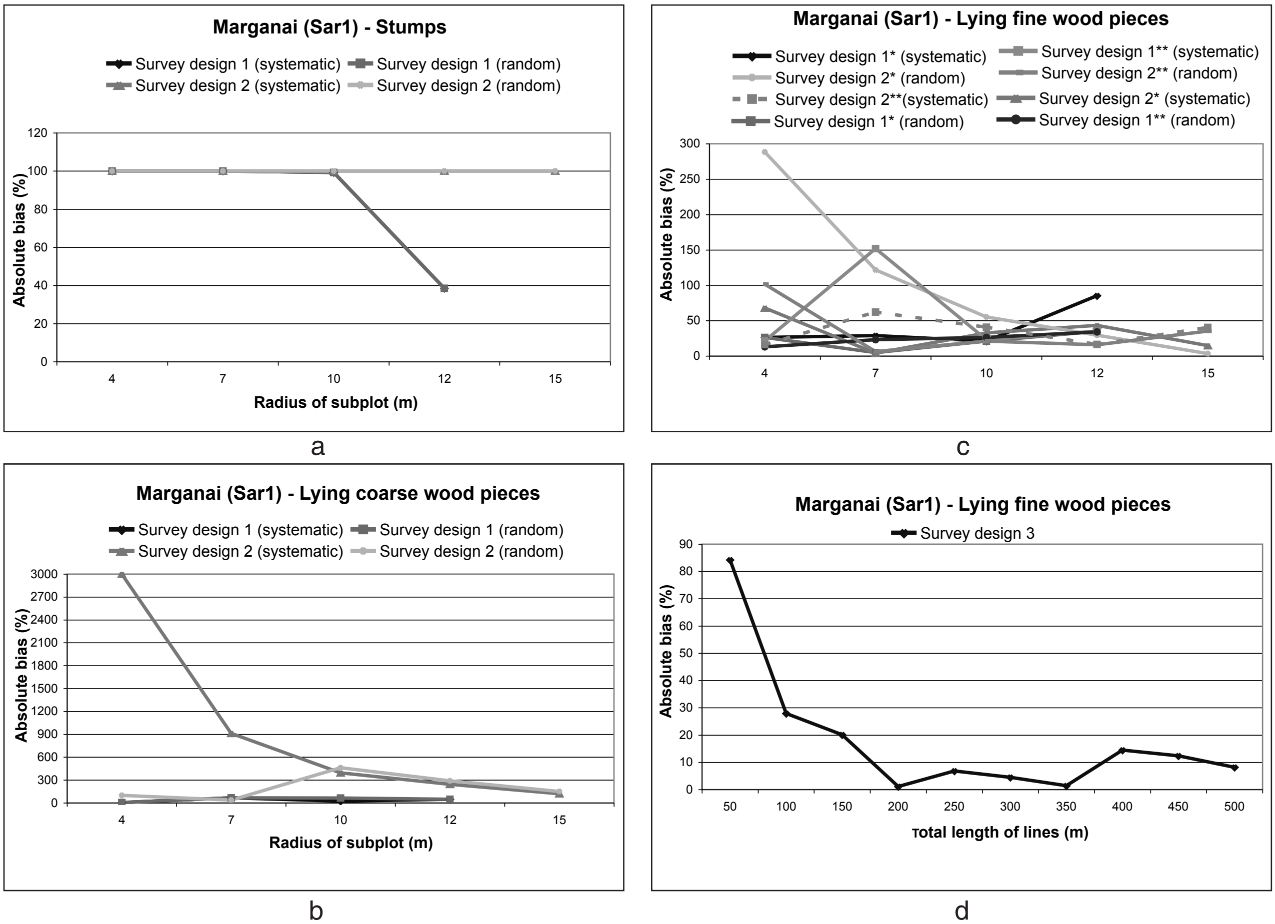

Figure 5 - Results obtained by applying survey designs 1, 2 and 3 to the Marganai study area (SAR1): a) stumps, b) large wood pieces, c) fine wood pieces (* surveying of fine wood pieces with LIS; ** surveying of fine wood pieces within the circular areas), d) fine wood pieces (survey design 3).
Risultati ottenuti applicando lo schema di rilevamento 1, 2 e 3 all'area di studio Marganai (SAR1): a) ceppaie, b) rami grossi, c) rami fini (rilevamento dei rami fini con campionamento per intersezione lineare; ** rilevamento dei rami fini all'interno delle aree circolari), d) rami fini (schema di rilevamento 3).*

Table 9 - Lying fine wood pieces: mean value of the absolute biases across the five CONECOFOR experimental areas by tested survey designs (* see Table 5). Means with different letters are significantly different (p=0.05) according to HSD Tukey test.
Rami fini: valore medio degli scarti (in valore assoluto) ottenuti nelle cinque aree sperimentali CONECOFOR con gli schemi di rilevamento testati (vedi Tabella 5). Le medie con lettere differenti sono significativamente differenti secondo il test HSD di Tukey (p=0.05).*

Survey design*	Survey unit	Overall mean %	
8	Subplot	42	A
28	Line transects	45	A
4	Subplot	46	A
3	Subplot	46	A
7	Subplot	46	A
6	Subplot	50	A
24	Line transects	50	A
25	Line transects	53	A
27	Line transects	59	A
23	Line transects	62	A
26	Line transects	65	A
2	Subplot	66	A
22	Line transects	69	A
21	Line transects	80	A
17	Subplot	85	A
8	Line transects	87	A
19	Line transects	87	A
20	Line transects	88	A
7	Line transects	92	A
9	Line transects	94	A
1	Subplot	94	A
18	Subplot	94	A
6	Line transects	111	A

Survey design*	Survey unit	Overall mean %	
13	Subplot	111	A
13	Line transects	115	A
16	Subplot	118	A
5	Subplot	136	A
12	Line transects	139	AB
4	Line transects	145	AB
3	Line transects	147	AB
2	Line transects	153	AB
11	Line transects	154	AB
5	Line transects	174	AB
1	Line transects	177	AB
12	Subplot	178	AB
15	Subplot	193	AB
10	Line transects	207	AB
18	Line transects	231	AB
11	Subplot	277	AB
17	Line transects	284	AB
16	Line transects	336	AB
14	Subplot	464	AB
10	Subplot	474	AB
15	Line transects	476	AB
14	Line transects	558	AB
9	Subplot	1225	B

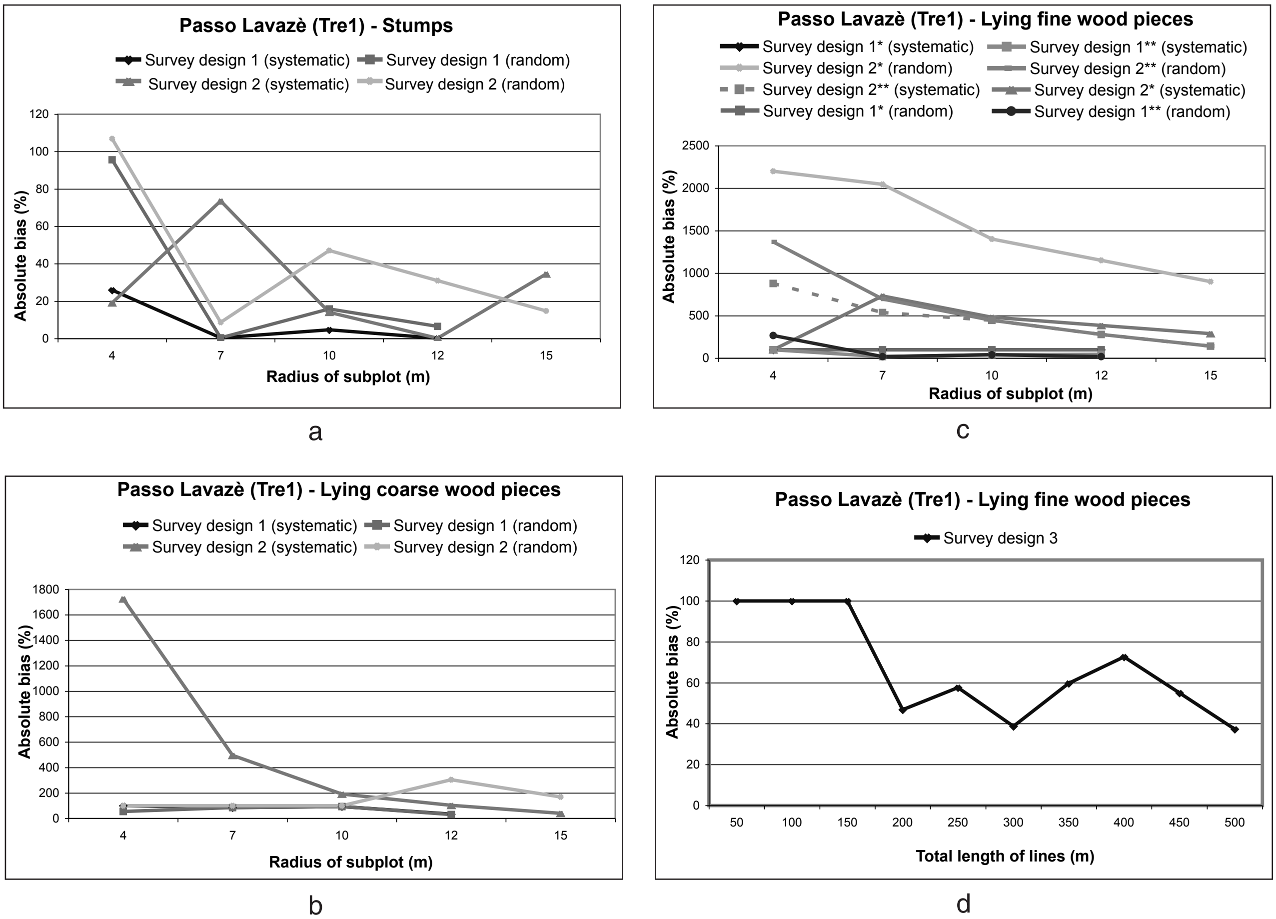

Figure 6 - Results obtained by applying survey designs 1, 2 and 3 to the Passo Lavazè study area (TRE1): a) stumps, b) large wood pieces, c) fine wood pieces (* surveying of fine wood pieces with LIS; ** surveying of fine wood pieces within the circular areas), d) fine wood pieces (survey design 3).
Risultati ottenuti applicando lo schema di rilevamento 1, 2 e 3 all'area di studio Passo Lavazè (TRE1): a) ceppaie, b) rami grossi, c) rami fini (rilevamento dei rami fini con campionamento per intersezione lineare; ** rilevamento dei rami fini all'interno delle aree circolari), d) rami fini (schema di rilevamento 3).*

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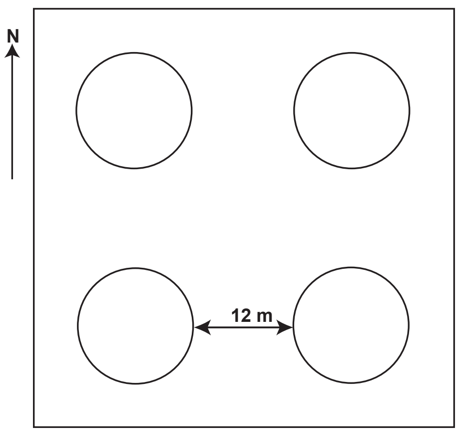

Figure 7 - Survey design with four 7-m-radius subplots proposed according to the present experimentation to monitor deadwood from stumps and lying large and fine wood pieces.
Schema di rilevamento con quattro subplot circolari di 7 m di raggio proposto sulla base della presente sperimentazione per il monitoraggio del legno morto derivante da ceppaie, rami grossi e rami fini a terra.

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Aspects of biological diversity in the CONECOFOR plots. VI. Studies on biological capacity and landscape biodiversity

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Abstract – Even if the "species diversity" still represents the main interest of researchers, each level of biological organisation needs a proper biodiversity assessment. Therefore, while studying the biological level of landscape, it is not sufficient to refer only to species diversity. That is why, for instance, the phytosociological approach is not completely adequate for the evaluation of the state of landscape vegetation. A new method able to estimate the structural ψ and functional τ landscape diversity has been recently proposed: it is based on the biological territorial capacity of vegetation (BTC) and it is useful especially to measure the organisational aspects of biodiversity. This method helps in the ecological diagnosis of forested landscapes, too. An application of the preliminary stage of this method to 10 CONECOFOR permanent plots in Mediterranean and Boreal forests and a synthetic anticipation on the diagnostic evaluation of a forest landscape unit is presented in this paper.

Key words: *landscape, forest evaluation, biodiversity, BTC.*

Riassunto – Aspetti della biodiversità nelle aree CONECOFOR.VI. Il potenziale di naturalità, tendenze dinamiche e capacità biologica. Anche se la diversità di specie rappresenta tuttora l'interesse maggiore dei ricercatori, ogni livello dell'organizzazione biologica necessita di misure sulla propria biodiversità. Di conseguenza nello studio del paesaggio non è sufficiente un riferimento limitato alla diversità di specie: per questo, ad esempio, l'approccio fitosociologico non è del tutto adeguato nello studio della vegetazione del paesaggio stesso. Recentemente, è stato proposto un nuovo metodo, basato sulla capacità biologico-territoriale della vegetazione (BTC), per rilevare la diversità strutturale ψ e funzionale τ del paesaggio e soprattutto la diversità di organizzazione dei sistemi ecologici. Questo metodo aiuta a formulare la diagnosi ecologica dei paesaggi forestati. Viene quindi presentata in questo scritto una applicazione della parte preliminare di tale metodo su 10 aree permanenti CONECOFOR in foreste mediterranee e boreali e una sintetica anticipazione della valutazione diagnostica di una unità di paesaggio forestata.

Parole chiave: *paesaggio, valutazione forestale, biodiversità, BTC.*

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Introduction

The basic importance of biodiversity is out of discussion. Each level of biological organisation, from genetic biodiversity to the entire ecosphere has to be characterised by a proper degree of diversity, and not exclusively the species diversity in an ecosystem, in a landscape or in an ecoregion (Massa and Ingegnoli 1999). In addition, the equation "greater biodiversity equals healthy ecological status" is not applicable in every ecological system. In recent years, it has been acknowledged that it was not sufficient to limit the concept of biodiversity to the scale of species, because of the Principle of Emerging Properties (Naveh 1984; Odum 1993) and the theory of non-equilibrium thermodynamics (Prigogine 1972, 1996). The Principle of Emerging Properties states that - in a complex system - the information about the whole is larger than the sum of information about its parts (Weiss 1969); the theory of non-equilibrium thermodynamics states that when an intense energy flux passes through a system, some dissipative structures appear, in a state of instability. The self-organised living systems are able to capture this kind of energy and to utilise it to produce new structures. Order through fluctuation, writes Prigogine.

As pointed out by many authors (Walter 1973; Naveh 1984, 1990; Forman 1995; Pignatti 1994, 1996; Ingegnoli 1997, 2002), these are also the main reasons confirming that the phytosociological approach, the auto-ecological one and the species biodiversity are not completely adequate for the evaluation of the eco-

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logical state of vegetation. Remember that vegetation is a basilar component of the landscape: it is not only a question of spatial scale, while of complex adaptive living system. Moreover, the analysis of forested tesserae needs to be referred to the landscape context to get a complete diagnostic evaluation. It is crucial to bypass the concept of sustainability, arriving to the concept of *strategic rebalance* (Ingegnoli 2004) of ecological systems. That is, to pass from a local, limited ecological rebalance to a broader one, available to influence an entire environmental system considered as a living entity.

An ecological diagnosis depends on the comparison between the conditions of the examined system and the conditions of a state considered as normal. Therefore, this evaluation needs the integration of local and species parameters with biodiversity measurements at landscape organisation level. A landscape ecological method of vegetation survey is needed, as it will be shown further. The final objective of this research will be the diagnosis of the permanent forested areas in relation with their landscape units; for the moment the assessment is limited to the plot areas and in some cases to their forested tesserae. Following these concepts, 10 permanent CONECOFOR forest plots have been assessed in 2003-2004 (Petriccione 2002). These plots can be divided into three groups: (I) Boreal forests: TRE1 (Lavazè), BOL1 (Renon), FRI2 (Tarvisio), LOM1 (Val Masino); (II) Mediterranean forests: TOS1 (Colognole), TOS2 (Cala Violina), LAZ2 (Monte Circeo), SAR1 (Marganai); (III) Temperate forest: CAL1 (Piano Limina).

Methods

Biodiversity depends on two aspects: (a) the diversity of the components of ecological systems and (b) the diversity of their relations in the organisation of these systems. Both aspects change with the scale. In order to account for diversity of components and diversity of relationship between components, the *biological territorial capacity* has been used in this paper. The *biological territorial capacity*, or BTC (Ingegnoli 1991,1999, 2002; Ingegnoli and Giglio 1999), is a synthetic function referred to a vegetational ecocoenotope and based on: (1) the concept of resistance stability; (2) the principal types of ecosystems of the ecosphere; (3) their metabolic data (biomass, gross primary production, respiration, R/PG, R/B). These data are processed to measure the degree of the relative metabolic capacity and the degree of the relative anti-thermic maintenance of the principal ecosystems. This function, reported in Mcal m^{-2} year $^{-1}$, can represent the state of an ecological system and it is proportional to the metastability of the vegetated tesserae. Thus the BTC indexes allow the recognition:

(i) of regional thresholds of landscape replacement (*i.e.* metastability thresholds) during time;
(ii) especially of the transformation modalities controlling landscape changes, through vegetation changes;
(iii) but also of the second aspect of biodiversity (*i.e.* the diversity of the relations between components in the ecological systems), which concerns the organisation level of an ecological system.

The study of the first aspect of biodiversity (diversity of components) in a landscape presents two evaluations: functional and structural. After having analysed the BTC values of the components of a landscape unit, and using appropriate BTC classes, it is possible to consider a landscape functional diversity. Taking into account that in complex adaptive self-organised systems the diversity of their components must consider both heterogeneity and information, the proposed landscape diversity index is:

$$H\ (3{+}D) = \tau$$

where:
H is the Shannon diversity;
D the dominance;
τ the synthetic landscape diversity (Ingegnoli 2002).
The same equation can be applied also to measure the structural diversity of a landscape, when referred to the types of tesserae or ecotopes: in this case the structural diversity is named ψ (Giglio and Ingegnoli 2005).

In the present CONECOFOR research on landscape biodiversity, the measures mentioned above have been applied only in one case: the plot TRE1, at Lavazè, because of the necessity to study a landscape unit (LU), not simply the permanent plot. The second aspect of biodiversity (relationships between components) was evaluated in every plot, through the estimation of the BTC.

One of the useful form in which vegetational characters can be related to landscape ecology is through a survey schedule, a proper one for each type of vegetation, for the evaluation of a vegetated tessera. The schedule has been designed to check the organisation level and to estimate the metastability of a tessera considering both general ecological and landscape ecological characters: T = landscape element characters (*e.g.* tessera, corridor); F = plant biomass above ground; E = ecocoenotope parameters (*i.e.* integration of community, ecosystem and microchore); U = relation among the elements and their landscape parameters, as indicated by INGEGNOLI 2002 and GIGLIO and INGEGNOLI 2005. In considering a set of vegetated tesserae, this schedule is very useful to check and compare the ecological state of each group of parameters (T, F, E, U), to verify a level of quality (Q) of each tessera and to estimate the biological territorial capacity of the vegetation (BTC).

Results

For the moment, only two sets of data concerning the boreal forests (4 plot areas and 2 tesserae) and the Mediterranean one (5 plot areas) are availavle. The assessment is referred:

(1) To the quality (Q) of the 4 main groups of parameters. T, F, E and U) are assessed in percentage on their maximum possibility:

T. *TESSERA (Ts) CHARACTERS* : T1- Vegetation high (meters), T2- Trees cover (%), T3- Structural differentiation, T4- Interior-margin ratio (%), T5- Type of forest, T6- Permanence (years).

F. *VEGETATIONAL BIOMASS (ABOVE GROUND):* F1- Dead plant biomass in Ts, F2- Litter depth of the Ts, F3 - pB volume (m^3/ha).

E. *ECOCENOTOPE PARAMETERS:* E1- Dominant species, E2- Species richness, E3- Key species presence (%),E4- Allochthonous sp. (%), E5- Infesting plants, E6- Threatened plants, E7- Plant forms (n°), E8- Vertical stratification, E9- Renew capacity, E10- Dynamic state.

U. *LANDSCAPE UNIT (LU) PARAMETERS:* U1- Boundaries connections, U2- Source (vs. surroundings), U3- Role in the landscape unit, U4- Disturbance incorporation, U5- Geo-physic instability, U6- Permeant fauna interest, U7- Transformations reason of the Ts as landscape element, U8- Landscape pathology interference, U9- Permanence (year).

(2) To the BTC of the plot areas (in 2 cases even of their tesserae) and their ratio versus the BTC threshold

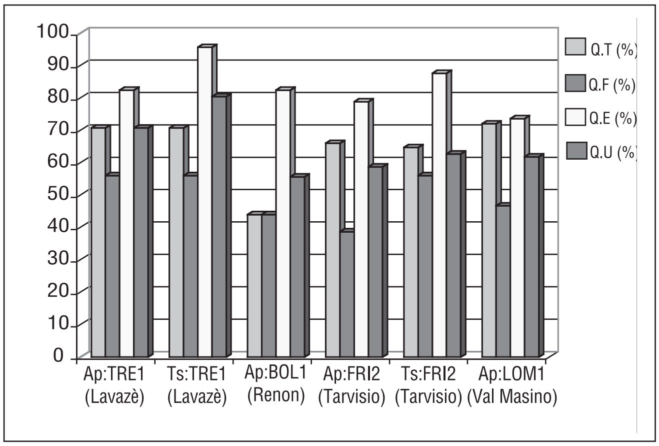

Figure 1 - Evaluation of the main groups of parameters referred to the plot areas and tesserae of the boreal forests in North Italy (2004): T = landscape element characters (*e.g.* tessera, corridor); F = plant biomass above ground; E = ecocoenotope parameters (*i.e.* integration of community, ecosystem and microchore); U = relation among the elements and their landscape parameters).
Valutazione dei principali gruppi di parametri riferita alle aree permanenti e alle tessere di foresta boreale nel Nord Italia (2004): T= parametri dell'elemento del paesaggio (e.g. tessera, corridoio); F= fitomassa del soprassuolo; E = parametri di ecocenotopo (i.e. integrazione di comunità, ecosistema e struttura spaziale); U = relazioni fra gli elementi del paesaggio e i loro parametri.

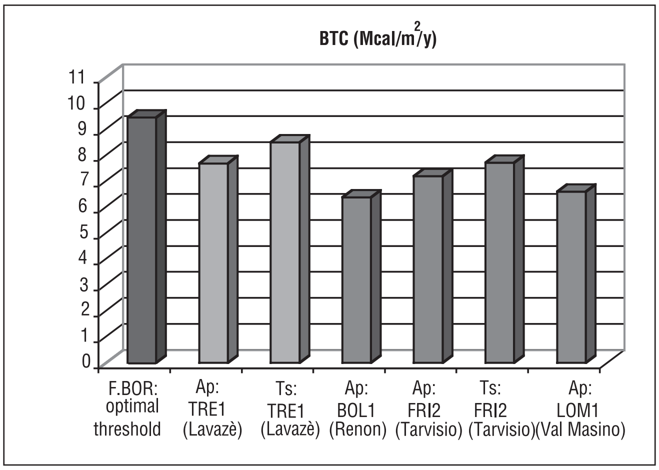

Figure 2 - Evaluation of the biological territorial capacity (BTC) of the plot areas and tesserae referred to the boreal forests in North Italy (2004). Note the comparison with the optimal BTC threshold of maturity for this type of forest. Ap = plot areas, Ts = tesserae (landscape ecological omogeneous element, sensu Zonneveld 1995)
Valutazione della capacità biologico-territoriale (BTC) delle aree permanenti e delle tessere riferita alle foreste boreali nel Nord Italia (2004). Si noti il confronto con la soglia ottimale di maturità per questo tipo di foresta. Ap = aree permanenti, Ts = tessere (elementi paesaggistici omogenei, sensu Zonneveld 1995).

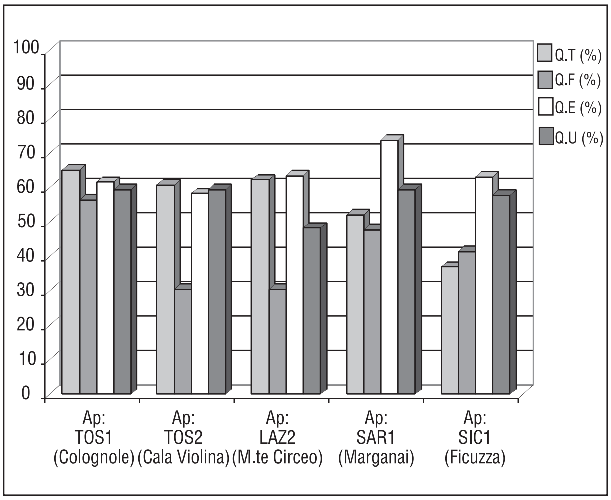

Figure 3 - Evaluation of the main groups of parameters referred to the plot areas of the Mediterranean forests in Central and South Italy (2004): (T = landscape element characters (*e.g.* tessera, corridor); F = plant biomass above ground; E = ecocoenotope parameters (*i.e.* integration of community, ecosystem and microchore); U = relation among the elements and their landscape parameters.
*Valutazione dei principali gruppi di parametri riferita alle aree permanenti e alle tessere di foresta mediterranea nell'Italia Centrale e Meridionale (2004): T= parametri dell'elemento del paesaggio (*e.g. *tessera, corridoio); F= fitomassa del soprassuolo; E = parametri di ecocenotopo (*i.e. *integrazione di comunità, ecosistema e struttura spaziale); U = relazioni fra gli elementi del paesaggio e i loro parametri.*

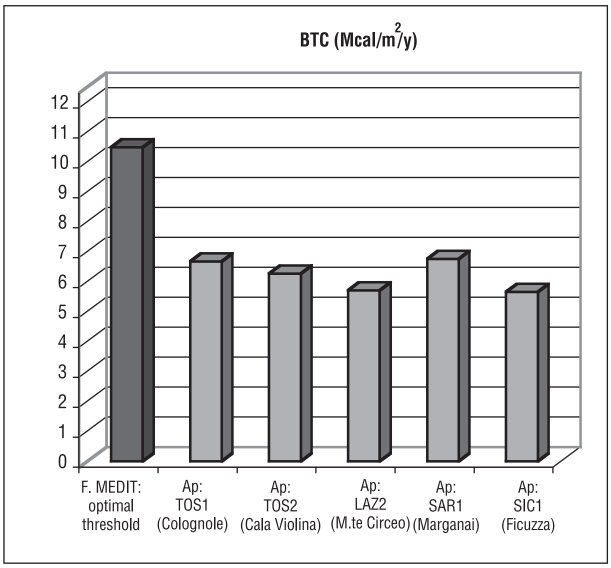

Figure 4 - Evaluation of the biological territorial capacity (BTC) of the plot areas and tesserae referred to the Mediterranean forests in central and South Italy (2004). Note the comparison with the optimal BTC threshold of maturity for this type of forest. Ap = plot areas.
Valutazione della capacità biologico-territoriale (BTC) delle aree permanenti e delle tessere riferita alle foreste mediterranee nell'Italia Centrale e Meridionale (2004). Si noti il confronto con la soglia ottimale di maturità per questo tipo di foresta. Ap = aree permanenti, Ts = tessere (elementi paesaggistici omogenei, sensu Zonneveld 1995).

of mature forest (*i.e.* fluctuation, *sensu* Falinski 1998).

These data are plotted in Figures 1 and 2 for the boreal forests and in Figures 3 and 4 for the Mediterranean forests, then ranked in Table 1. A synthetic aspect of the study on landscape biodiversity (the structural ψ and functional τ) at Lavazè will be presented at the end of this paragraph. Figure 1 shows that the best quality of the mentioned parameters pertains to the ecocoenotope (E), the worst to the vegetational biomass (F). Landscape parameters are more variable. It seems to be mainly an effect of the management of these forests. Figure 2 shows that no one of these forested areas reach the BTC threshold of maturity and, when both the plot area and its tessera have been assessed, the BTC of the tessera is a bit higher. These results may be again due to the management, but also to the spatially too limited plot area (at least in assessing landscape characters). Figure 3 shows a remarkably different situation for the Mediterranean forests, which present lower values and no dominant parameter, probably due to the transitional stage between coppice and high forest. Even in Figure 4, the differences with boreal forest types are evident: they present about 10% lower BTC, and 22% lower distance from maturity (always for management reasons).

Further results concern an assessment related to the diversity of component at the landscape level, but this is limited only to the plot TRE1. This small landscape unit, about 175 ha, dominated by Homogino-Piceetum forest was analysed over three time periods: 2004, 1998, 1930-40. The unit is composed by 4 ecotopes and presents 11 types of landscape elements: spruce forest, damaged/cut forest patch, routes/paths, bog area, grass patches in forest, meadows and pastures, shrub patch, pond, built area, road and parking, ski path. The measures of functional and structural landscape diversity (τ and ψ) are reported in Table 2, together with the overall landscape metastability, LM = τ • BTC. As shown in Table 2, the growing of τ and ψ are not similar: 3.4% *vs* 14.3%. This means an altered situation in the landscape unit, confirmed with the decrease of LM over the concerned time period (- 4.9%).

Conclusions

This research is today in progress. It represents a new and original way to assess the landscape ecologi-

Table 1 - Summary of the assessments on the plot areas of forest pertaining to the CONECOFOR programme in the years 2003-2004 referred to the landscape ecological biodiversity.
Sintesi dei rilievi sulle aree permanenti del programma CONECOFOR negli anni 2003 - 2004 riferiti alla biodiversità ecologico-paesistica.

Plot areas (Ap) and tesserae (Ts)	Q.T (%)	Q.F (%)	Q.E (%)	Q.U (%)	BTC (Mcal/m²/y)	BTC/BTC$_s$ (%)*	*H* (*m*)	*vFM* (*m³/ha*)
BOREAL FOREST								
Ap: TRE1 (Lavazè)	70,7	56	82,4	70,7	7,69	81,3	*29,3*	*696*
Ts: TRE1 (Lavazè)	70,7	56	95,6	80,4	8,50	90,0	*29,5*	*739*
Ap: BOL1 (Renon)	44	44	82,4	55,6	6,38	67,4	*27,1*	*471*
Ap: FRI2 (Tarvisio)	66	38,7	78,8	58,7	7,19	76,0	*31,1*	*841*
Ts: FRI2 (Tarvisio)	64,7	56	87,6	62,7	7,72	81,7	*30,5*	*827*
Ap: LOM1 (Val Masino)	72	46,7	73,6	61,8	6,60	69,8	*22,8*	*431*
MEDITERRANEAN FOREST								
Ap: TOS1 (Colognole)	65,2	56,5	61,7	59,4	6,68	63,7	*15*	*203*
Ap: TOS2 (Cala Violina)	60,9	30,4	58,3	59,4	6,26	59,7	*14,7*	*260*
Ap: LAZ2 (Monte Circeo)	62,3	30,4	63,5	48,3	5,71	54,4	*10,9*	*173*
Ap: SAR1 (Marganai)	45,5	47,8	73,9	59,4	6,76	64,4	*16,6*	*304*
Ap: SIC1 (Ficuzza)	37	41,5	63,1	57,8	5,64	53,5	*13,9*	*204*
TEMPERATE FOREST								
Ap: CAL1 (Piano Limina)	72	69,7	63,2	69,7	7,68	75,2	*27,1*	*587*

Q.T= quality of the landscape element
Q,F= quality of the plant biomass
Q.E= quality of the ecocoenotope parameters
Q.U= quality
(*)BTCs= threshold of mature forest (*i.e.* fluctuation, sensu Falinski), deduced from the model of Ingegnoli
H= heigh of canopy
vFM= plant biomass volume (measured with the "spiegel relaskope"),

Table 2 - Lavazé forest landscape unit. Measures of functional and structural landscape diversities (τ and ψ).
Unità di paesaggio forestale di Lavazé. Misure di diversità funzionale e strutturale del paesaggio (τ e ψ).

	1930-40	1998	2004
Landscape functional diversity, τ	4.69	4.78	4.85
Landscape structural diversity, ψ	4.63	4.99	5.29
Landscape metastability, LM	24.27	24.16	23,09

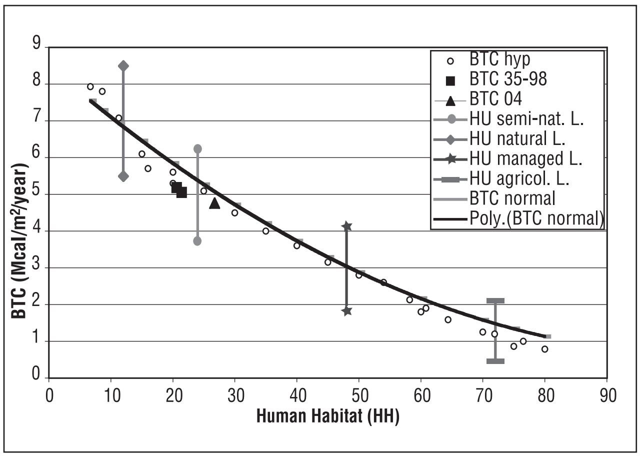

Figure - 5 Diagnostic evaluation of the forested landscape unit of Lavazé Pass (Trentino-Alto Adige). The transformation of this unit has passed through a significant threshold from a semi-natural to a managed type of forested landscape (diagnostic model from Ingegnoli & Giglio 2005). HH is the human habitat estimated in the landscape unit (LU). Legend: BTChyp = hypothesis of estimation of the BTC values varying HH in the same LU structure; BTC normal = data derived from the HH/BTC model (Ingegnoli 2005); Poly. (BTC normal) = polynomial curve related to the BTC normal data; vertical segments are the thresholds among different landscape types (HH<12%: natural L., 12-24 % semi-nat.L., 24-48 % managed forest L., 48-72 % agricol. L., HH > 72 % rural L.). Landscape types with HH > 80% are not plotted in this figure.
Valutazione diagnostica dell'unità di paesaggio forestale del Passo di Lavazé (Trentino-Alto Adige). La trasformazione di questa unità ha passato la soglia significativa fra un paesaggio forestale di tipo seminaturale e uno di tipo subantropico (modello diagnostico secondo Ingegnoli e Giglio, 2005). HH è l'habitat umano stimato nell'unità di paesaggio (LU). Legenda: BTChyp = ipotesi di stima dei valori di BTC variando HH nella struttura della stessa LU; BTC normal = dati derivati dal modello HH/BTC (Ingegnoli 2005); Poly.(BTC normal) = curva polinomiale riferita ai precedenti valori (BTC normal); i segmenti verticali (HH semi-nat.L., etc.) distinguono le soglie di passaggio fra i tipi di paesaggio: HH < 12% naturale, 12-24% seminaturale, 24-48% forestale gestito, 48-72% agricolo, HH > 72% rurale).

cal characters of vegetation, particularly important to evaluate forested landscape units and their dynamic trends. The results from this research seem to be helpful in biological conservation and land planning applications. Anyway, it is necessary to remember, as expressed in the introduction, that the final objective of this research would be the diagnosis of the permanent forested areas in their landscape units. Only studying the landscape unit it is possible to understand the ecological state of a forest, to improve its management and to plan the correct human activities. In this work the evaluation of landscape biodiversity, in both its aspects of structural heterogeneity and order differentiation, is simply indispensable. A first experience in the diagnostic study started in 2004, analysing and evaluating the forested landscape unit around the plot TRE1 (Lavazè). This study is not yet finished, but it may be useful to anticipate a diagnostic model (GIGLIO and INGEGNOLI 2005), in which the exceedance of a significant threshold (from a semi-natural to a managed type of forested landscape) of the examined landscape unit of Lavazè (Figure 5) is shown. This exceedance was completed in recent few years, mainly due to the tourist pressure and ski paths.

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Aspects of biological diversity in the CONECOFOR plots. VII. Naturalness and dynamical tendencies in plant communities

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Abstract – On the basis of the knowledge on plant communities of the selected 12 plots for biodiversity test-phase (ForestBIOTA project), an analysis of the main dynamical tendencies in progress and a preliminary evaluation of their degree of naturalness has been attempted. A new original methodology for a rapid assessment of naturalness at stand level, based on vascular species, has been tested on 9 selected plots, by direct observation in the field. First results pointed out that fluctuation is the commonest ongoing process. Regeneration is also widespread. The new proposed method for the assessment of naturalness showed a good performance and proved to be reliable.

Key words: *vegetation, plant communities, permanent plots, naturalness, dynamical tendencies.*

Riassunto – Aspetti della biodiversità nelle aree di saggio CONECOFOR.VII. Naturalità e tendenze dinamiche nelle comunità vegetali. Sulla base della conoscenza approfondita delle comunità vegetali di 12 aree permanenti (selezionate per la fase test sulla biodiversità nell'ambito del progetto ForestBIOTA), è stata tentata un'analisi delle principali tendenze dinamiche in atto nella vegetazione ed una valutazione del suo grado di naturalità. E' stata per la prima volta sperimentata una metodologia messa a punto per una valutazione speditiva del grado di naturalità a livello di comunità vegetale, basata sulle specie vascolari, in 9 aree permanenti, attraverso osservazioni dirette sul campo. I primi risultati indicano che la fluttuazione è il processo dinamico più diffuso, seguita dalla rigenerazione. Il nuovo metodo proposto per la valutazione della naturalità si è dimostrato realistico ed affidabile.

Parole chiave: *vegetazione, comunità vegetali, aree permanenti, naturalità, tendenze dinamiche.*

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Introduction

Phytosociological knowledge of plant communities and their synecological allocation are the reference basis of the CONECOFOR Programme from its initial phase (Petriccione 2002). The knowledge on plant communities traits provide a good basis to analyse the main dynamical tendencies and to evaluate their degree of naturalness. These two synthetic traits are very important to understand and evaluate the other biodiversity indicators in a correct framework (Petriccione 2004).

The level of naturalness, defined like the degree of self-functioning of the natural processes and the intensity of human interventions on the function and structure of ecosystems, is a very important criterion for maintenance, conservation and enhancement of biological diversity in forest ecosystems (MCPFE 2002).

A high level of naturalness in forest ecosystems is considered (1) a baseline for high qualitative biodiversity, under the UN Convention on Biological Diversity (UNEP 1992), and (2) a potential for mitigation of climate changes and for a better conservation of water resources, under the UN Framework Convention on Climate Change (UN 1992). In a wide context, naturalness can be considered equivalent to the concept of environmental quality (Ploeg and Vlijm 1978; Margules and Usher 1981; Greco and Petriccione 1991) and measured by specific indicators based on vegetation composition and structure (Petriccione 1994). Recently, a "biodiversity intactness index (BII)" has been described and tested in southern Africa (Scholes and Biggs 2005). BII is very promising, but is fundamentally based on expert judgements about the interaction of species richness with land use changes. The new method proposed in this paper tries to increase the objectivity level of the evaluation,

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by means of detailed field observations. Preliminary results are reported.

Materials and methods

Field relevés at community level (2500 m^2 sample plots) were performed by the author, as part of the activities of the CONECOFOR National Focal Centre (National Forest Service - CONECOFOR), on the selected 12 plots for biodiversity test-phase (Forest-BIOTA project), as well as syntaxonomical and synecological allocation of plant communities in all plots. Dynamical tendencies in the vegetation (fluctuation, regeneration, degeneration and regression, according to FALINSKI 1986, 1989) have been identified on the basis of species composition and, secondarily, vertical structure. A check-list of indicator species of dynamical processes has been used (PETRICCIONE and CLARONI 1996), as well as the few published papers including dynamical traits of forest vegetation in Italy (among them, FALINSKI and PEDROTTI 1990, 1991, CANULLO and PEDROTTI 1993). Naturalness was evaluated following a new original methodology for a rapid assessment at stand level (PETRICCIONE 2005), based on vascular species, that has been tested on 9 selected plots for the first time, by direct observation in the field: (1) comparing real and potential vegetation types, (2) assuming like “reference” the nearest comparable undisturbed (or less disturbed) stand and (3) comparing values of six specific indices measured in the sample plots and in their “reference” stands (PETRICCIONE 1992, 1994, vegetation disturbances, chorotypes coherence, site-original species, species richness and diversity, evenness or dominance). The applied method is a stepwise-type: (1) the tree layer species provides the basis for a preliminary comparison of real and potential vegetation types; (2a) if the real type are different from the potential one, the naturalness value is *0.0*, in the case of a plantation by not native species, and *0.2* in the case of a plantation by native (but not-original) species; (2b) if the real type corresponds to the potential one (site-original species in the tree layer), the naturalness value can be range between *0.2* and *5.0* (maximum value). In the last case, the naturalness value is calculated by a simple average of the values of the following six indices, obtained by a comparison with the “reference” stands (values arranged into 5 classes, according to the ratio of coincidence with the indices values measured in the “reference” plots, Table 2): (1) VD – vegetation disturbance – total coverage of potential-like vegetation type, taking in account the secondary substitute micro-communities; (2) CC – chorotypes coherence – total sum of species with local chorological types *vs.* alien and large-distribution types; (3) SS – site-original species – n° of site-original species *vs.* non site-original and alien species; (4) SR – species richness – total n° of vascular species; (5) SD – species diversity – Shannon index calculated on phytosociological tables, taking in account the coverage values of each species; (6) EV – evenness – evenness index calculated on phytosociological tables, taking in account the coverage values of each species.

Results

Analysis of the main dynamical tendencies (Table 1) in the studied forest communities shows that fluctuation is the most common ongoing process (occurring mostly in beech and primary spruce forests). Regeneration is also widespread, following the recent general abandonment of wood exploitation and coppicing, whereas regression and degeneration have been identified only in a few plots. Kind of dynamical tendency does not seem linked with species richness values. The first vegetation changes seen during the first 10 years of investigation are slight and of very low significance. The temporal variation, however, is generally positive, with a fair increase in the number of species. Further assessment is required to evaluate the ongoing trends. Preliminary results (Table 2) point out that forests in fluctuation stage show the highest naturalness values (4.7-5.0, plots ABR2, TRE1 and TOS2), whereas lower values occur in the case of forests in regression stage (2.8-3.3, plots BOL1 and TOS1). Secondary forests resulting by plantation/colonisation of native (but not site-original) species are placed in a very peculiar situation, with the lowest naturalness level (0.2 in plots FRI2 and LOM1), slowly increasing by a small natural regeneration process in progress.

Conclusions

A preliminary analysis of the main dynamical tendencies points out that fluctuation is the commonest ongoing process. Regeneration is also widespread, occurring mostly in secondary spruce forests. Regression is recorded in a few plots, becoming predominant in some *Quercus cerris*- and *Quercus ilex*-dominated

Table 1– Vegetation data (cumulated for community and population level) for the selected plots for biodiversity assessment.
Dati vegetazionali (cumulati per i livelli di comunità e popolazione) per le aree selezionate per la determinazione della biodiversità.

PLOT	Vegetation survey years	Syntaxon	Vascular species n°	Tree layer species n°	Vegetation main dynamical tendency
ABR1	1996-2005	*Polysticho-Fagetum*	48	1	regeneration
CAL1	1996-2005	*Aquifolio-Fagetum*	73	3	fluctuation (regeneration)
FRI2	1996-2005	*Veronico uticifoliae-Piceetum*	78	5	regeneration
LOM1	1996-2005	*Veronico uticifoliae-Piceetum*	92	14	regeneration (fluctuation)
TRE1	1996-2005	*Homogyno-Piceetum*	31	2	fluctuation
BOL1	2002-2005	*Homogyno-Piceetum*	54	5	regression
SIC1	1996-2005	*Quercetum gussonei*	81	1	regression
ABR2	2002	*Aceri lobelii-Fagetum abietetosum albae*	66	12	fluctuation
SAR1	1996-2005	*Viburno-Quercetum ilicis*	38	5	regression
TOS2	1999-2005	*Viburno-Quercetum ilicis*	20	5	fluctuation
TOS1	1996-2005	*Orno-Quercetum ilicis*	54	15	regression
LAZ2	2002-2005	*Orno-Quercetum ilicis*	29	6	regeneration

Table 2– Naturalness level (from 0.0 to 5.0), based on simple average of indices values (according to 5 classes: 1: 0-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%).
Livello di naturalità (da 0.0 a 5.0) basato sulla media semplice dei valori degli indici (5 classi).

PLOT	vegetation disturbance	chorotypes coherence	site-original species	species richness	species diversity	evenness (dominance)	NATURALNESS
ABR1	5	5	5	4	5	4	**4.6**
FRI2	----- secondary community (plantation by native species) -----						**0.2**
LOM1	----- secondary community (colonisation by native species) -----						**0.2**
TRE1	3	5	5	5	5	5	**4.7**
BOL1	2	4	5	2	2	2	**2.8**
ABR2	4	5	5	5	5	5	**4.8**
TOS1	3	5	5	2	2	3	**3.3**
LAZ2	3	5	5	4	3	4	**4.0**
TOS2	5	5	5	5	5	5	**5.0**

forests, whereas degeneration has not been recorded in the selected plots. A preliminary evaluation of the new proposed method for a rapid assessment of the naturalness degree shows a good performance, its suitability and reliability. Further assessment is still required to refine the method.

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Factors influencing vascular species richness in the CONECOFOR permanent monitoring plots

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Abstract – Relationship between number of vascular species and site, stand, soil and atmospheric variables were investigated on 19 permanent monitoring plots (ranging from one-storied beech and irregular-stratified Norway spruce high forests to stored oak coppices) over the period 1999-2003. Variables were selected by Principal Components Analysis (PCA) and subsequently used in multivariate analysis by Generalized Linear Models (GLM) and Ordinary Least Square Regression (OLSR) with mean number of species over the period 1999-2003 as response indicator. GLM provide inconclusive results (D^2_{adj} < 11%), while OLSR based on PCA factors scores allowed a significant model (R^2_{adj} =0.53; P=0.007) to be identified. The model was based on soil and stand factors. Univariate analysis identified the number of tree species in the plot as a significant predictor of the mean number of vascular species. On beech plots, significant correlations were observed between number of vascular species, soil N and N deposition. Model residuals with respect to annual data were used in univariate regression against annual values of precipitation, maximum temperature, late frost index, N deposition and tree defoliation. Only in one case significant correlations were observed between number of species and N deposition and defoliation.

Key words: *number of species, forest ecosystems, environmental influences, multivariate analysis.*

Riassunto – Fattori che influenzano la ricchezza di specie vascolari nelle aree permanenti CONECOFOR. Sono state analizzate le relazioni tra numero di specie ed una serie di variabili stazionali, forestali, pedologiche e atmosferiche sulla base dei dati misurati in 19 aree di saggio della rete CONECOFOR. Le aree includono fustaie monoplane di faggio, fustaie irregolari e stratificate di abete rosso e cedui in invecchiamento di specie quercine. Le variabili, selezionate attraverso un'analisi delle componenti principali, sono state utilizzate in analisi multivariata mediante modelli lineari generalizzati (Generalized Linear Models, GLM) e regressione multipla (Ordinary Least Square Regression, OLSR) con il numero medio di specie sul periodo 1999-2003 nel ruolo di variabile di risposta. I GLM utilizzati non hanno fornito risultati significativi (D^2_{adj} < 11%). Viceversa, OLSR basata sugli score dei fattori della PCA è risultata in un modello significativo (R^2_{adj}=0.53; P=0.007), basato essenzialmente su fattori relativi al suolo ed alla struttura forestale. Un'analisi univariata condotta sia su tutte le aree che su quelle di faggeta, ha evidenziato che più elevata è la diversità di specie arboree presenti nell'area, maggiore è il numero totale di specie vascolari. Per le faggete, sono state evidenziate correlazioni significative tra numero di specie e situazione dell'area per l'N nel suolo e nelle deposizioni atmosferiche. I residui del modello multivariato, calcolati rispetto ai valori annuali misurati, sono stati analizzati in funzione dei valori annuali di precipitazione, deposizione totale di azoto, temperatura massima e defogliazione. Solo in un caso sono state osservate relazioni significative tra numero di specie e deposizione di N e defogliazione.

Parole chiave: *numero di specie, ecosistemi forestali, influenze ambientali, analisi multivariata.*

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Introduction

Biological diversity is a priority area in forest research and a central issue in forest management. The need for its assessment, monitoring and conservation is stressed in several international conventions aimed at promoting a sustainable forest management (SFM) (*e.g.* Hall 2001; Linser 2003). In this paper we will consider the richness of vascular plant species, an important (and easy to communicate) aspect of the total diversity of a forest ecosystem. As such, it is important to understand what factors are involved, and with which

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role, in determining the species richness of a forest ecosystem (Lähde *et al.* 1999; Ohlemüller *et al.* 2004). Knowledge of determinants of species richness will favour the understanding of the underlying processes and this will help in promoting suited environmental policy and forest management practices. In addition, knowledge of correlates of species richness can help in finding possible *proxy* indicators of biodiversity that may be useful in routine assessment, large-scale monitoring and predictive modelling. In this perspective, long-term integrated monitoring provide a chance to study how species, and group of species, respond to local forest stand structure (*e.g.* age, spatial and vertical organization), landscape matrix (*e.g.* fragmentation) and site and environmental (local, regional) factors (soil, climate, atmospheric deposition) and their changes through time. In particular, studies on vascular plant species richness carried out (i) on plot of fixed size, (ii) according to standard methods and (iii) in sites where a number of other attributes measured are of value (Ohlemüller *et al.* 2004). Within the CONECOFOR programme, vascular plant species richness has been monitored in a consistent way since 1999 (Canullo *et al.* this volume) together with site, soil, stand and atmospheric variables (Ferretti *et al.* this volume; Ferretti *et al.* 2000; 2003; Mosello *et al.* 2002). This offers the chance to investigate the possible role of environmental factors in determining the species richness of a given site. The aim of this paper is to investigate possible factors related to differences in the richness of vascular plant species at the 0.25 ha CONECOFOR Permanent Monitoring Plots (PMPs).

Materials and methods

Assumption and limitations

In this paper, a number of attributes (number of vascular species, LAI, soil properties,...) averaged at plot level are used as predictor and/or response indicators. This approach requires a number of assumptions (Ferretti and Chiarucci 2003). They include (i) the ability of the available data to provide reliable, unbiased estimates of population parameters (*e.g.* mean number of species) at plot level (see Canullo *et al.* this volume); and (ii) the reliability of species richness data. The assessment of the number of species is subject to observer bias (see Canullo *et al.* this volume): to carry out the analysis, we assumed that data were comparable through space and time, but we invite readers to be careful when considering this aspect. A further, strong limitation to the analysis was the small number of plots for which data were available (max. 19 plots) and the high number of possible predictors (>40). This has caused some complication in the analysis (see below).

Dataset

Data collected on 19 PMPs out of the 20 ones selected in 1996 were used (Table 1). After a Correspondence Analysis (Greenacre 1984; Carrol *et al.* 1986; Hoffman *et al.* 1986), the PMPs could be classified according to three major groups: (i) the beech-dominated plots (*Fagus sylvatica* L.), mostly one-storied high forests; (ii) the Norway spruce-dominated plots (*Picea abies* (L.) Karst.), mostly stratified and irregular; and (iii) the oak-dominated plots (mostly *Quercus cerris* and *Quercus ilex*), mostly two-storeied stored coppices. See Ferretti *et al.* (this volume) for location and characteristics of PMPs.

Response variables

Vascular plant species richness in terms of mean number of species per 100 m^2 was used as response (dependent) variable (see Canullo *et al.* this volume, for details). Mean vascular species richness (which includes woody species) was reported to be a relatively good indicator of the total number of plant species observed in the plot (Canullo *et al.* this volume) (Figure 1).

Selection of predictor variables

Possible predictor (independent) variables included site (SITE), stand (STAND), soil, (SOIL) meteorological (METEO) and deposition (DEPOSITION) data (Table 1). Because of the large number of variables (>40) compared to the number of available cases (plots) (max. 19), there was the need to select a subset of variables. This has been done by summarizing the variables by means of Principal Components Analysis (PCA) (Jolliffe 1986; Jackson 1991). After the PCA, a Matlab® routine (Varcum2) was used to calculate the cumulative amount of variance of each variable explained by the selected PCs. This allowed the identification of the variables that explain the most part of the variance within each PC (Leardi, pers. comm.). For the same reason (unfavourable ratio cases: variables), PCA was carried out on separate datasets (see below). Two different options were considered:

- Option 1: analyzing all the available databases

Table 1 – Variables used in the analyses: range and median value.
Variabili utilizzate nell'analisi: campo di variazione e valore mediano.

Variable	Reporting unit	No. of plots	Min	Median	Max
Geography					
Latitude	UTM	20	375432	432896	462928
Longitude	UTM	20	65555	121457	161047
Elevation	m a.s.l.	20	6	958	1800
Stand					
Stand age	years	20	35	50	140
Tree density	n ha-1	20	228	929	4540
Tree species in the PMP	n°	20	1	3	13
Tree species dominant/upper layer	n°	20	1	2	8
MTS dominant/upper layer	%	20	29	99	100
Mean diameter at breast height (dbh)	cm	20	10	23	51.5
Basal area (total)	m^2	20	23.94	37.87	53.89
Basal area (dominant/upper layer)	m^2	20	8.07	22.63	46.75
Mean height	m	20	11.6	17.6	29.1
Top height	m	20	13.6	23.5	32.6
Standing volume	$m^3\ ha^{-1}$	20	152	343	739
Canopy cover estimate	%	20	70	85	90
Diffuse Non Interceptance (DIFN)		20(*)	0.01	0.03	0.13
Canopy depth (main crop layer)	m	20	5.1	10.3	22.5
Leaf Area Index (LAI)	$m^{2*}m^{-2}$	20(*)	2.44	4.29	5.43
Leaf Area Density (LAD)	$m^{2*}m^{-3}$	20(*)	0.13	0.38	0.84
Leaf litter	$Mg\ ha^{-1}$	20 (*)	2.171	3.510	4.997
Soil					
Soil Carbon content (Ctot)	$g\ kg^{-1}$	20	87	286	512
Soil Nitrogen content (Ntot)	$g\ kg^{-1}$	20	5.04	13.00	19
Ratio C:N (C/N)	ratio	20	2.71	2.95	3.43
Soil Phosphorous content (Ptot)	$mg\ kg^{-1}$	19	6.04	6.78	7.46
Ratio C:P (C/P)	ratio	19	4.7	5.7	6.66
Soil K content (Ktot)	$mg\ kg^{-1}$	19	7.21	8.01	9
Soil Ca content (Catot)	$mg\ kg^{-1}$	19	8.1	9.3	10.24
Soil Mg content (Mgtot)	$mg\ kg^{-1}$	19	6.34	8.06	10.36
Soil pH (CaCl2) (pH)	pH unit	19	3.03	5.00	6.07
Meteorology					
Winter Index	°C	12	0	124	719
Summer Index	°C	12	545	1518	3263.3
Late Frost Index	°C	12	0	2.30	12.4
Annual precipitation (mm) (P)	mm	12	495.6	1108.85	3024.5
Evapotranspiration potential (ETP)	mm	12	414.4	614.65	927
Difference between P and ETP (P-ETP)	mm	12	9.8	545.90	2468.6
Evapotranpiration (ETR)	mm	12	203	421.50	580.2
Relative Evapotranspiration (RET)	%	12	26	70	100
Precipitation over the vegetative season (P1apr-30sep)	mm	12	155	474	1784
Maximum Temperature at 2 m height (Tmax)	°C	12	21.57	30.43	34.82
Minimum temperature at 2 m height (Tmin)	°C	12	-15.05	-10.7	-1.73
Deposition					
H+ deposition (DepH+)	meq^*m^{-2} per year	15	1.19	8.62	21.45
Total N deposition (DepNtot)	meq^*m^{-2} per year	15	29.78	64.92	129.04
Exceedance of critical load for N (Nexc)	meq^*m^{-2} per year	15	-42.08	-8.08	44.92
SO4—deposition (DepSO4--)	meq^*m^{-2} per year	15	32.21	50.24	74.2
Number of vascular species $^*100m^{-2}$	n	19	8.17	16.25	31.08

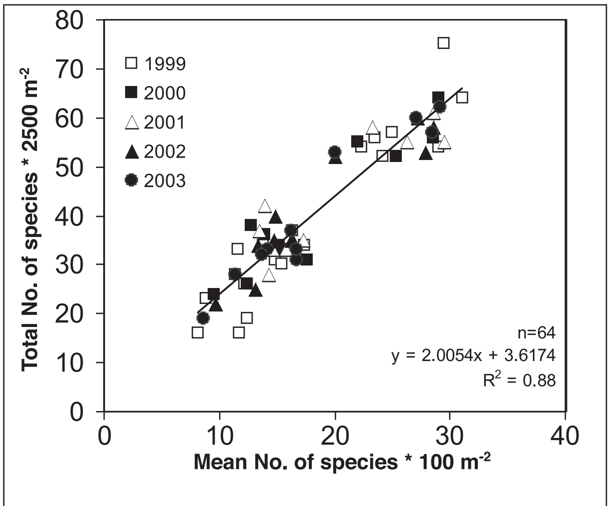


Figure 1 – Total number of species surveyed on the 2500 m^2 plot regressed against the estimated mean number of species obtained from 12 10*10 m quadrats (systematic sampling) within the same plot. Paired data for individual plots and years are reported. See Canullo *et al.* (this volume) for details.
*Numero di specie totali sul plot di 2500 m^2 in funzione del numero medio di specie ricavato da 12 quadrati di 10*10 m (unità campionarie selezionate in maniera sistematica) all'interno dello stesso plot. Vengono riportati dati appaiati per gli stessi plot ed anni. Vedi Canullo* et al. *(in questo volume) per i dettagli.*

(predictor categories) in order to select the most suited variables;

- Option 2: analyzing all the available databases (predictor categories) in order to reduce the dimensionality of the dataset and the collinearity among predictors (Vetaas 1997; Badgley and Fox 2000).

For the first options, the selected variables were used for Generalized Linear Models (GLM) (see below). In the second option, the scores computed from the PCA were used as new independent variable values for a multiple ordinary least square regression (OLSR) analysis.

Database STAND. The PCA for the stand variables showed high correlation between many variables (Table 2). Many of these relationships were due to the fact that many variables were calculated from the same, or similar, measures. Variables that were correlated to the same factor were also correlated between themselves. Four factors explained 84.83% of the total variance. The first factor explained the most part of the of the total variance of the system (48.45%) and mostly describe the forest mensurational aspects at the plot. The second factor explained 15.77% of the variance and contains information about canopy characteristic: cover, DIFN, and LAI. The third factor is about tree species: number of tree species in the PMP, number of species in the dominant (upper) layer, percent coverage of main tree species (MTS) in the dominant layer. The fourth factor explained a remaining part of information about leaf litter. Taking into account their correlation with the main factors, the nature of their information and the reliability of their measurements, the predictors selected for the subsequent analysis were: number of tree species in the dominant layer, dbh, LAI and litterfall.

Table 2 - Principal Component Analysis, stand data. Number in bold refer to correlation coefficient higher than 0.7 (assumed as conventional threshold) between the factor and the variable. The proportion of variance explained is reported.
Analisi delle componenti principali, dati sul soprassuolo. I numeri in grassetto si riferiscono a coefficienti di correlazione tra fattore e variabile > 0.7 (assunta come soglia convenzionale). Viene riportata la proporzione di varianza spiegata da ciascun componente.

	Factor STAND1	Factor STAND2	Factor STAND3	Factor STAND4
Stand age	**0.917**	0.069	0.041	-0.035
Tree density	**-0.844**	-0.018	0.012	0.455
Tree species in the PMP	-0.558	0.011	**0.636**	0.087
Tree species dominant/upper layer	-0.509	-0.059	**0.746**	0.104
MTS dominant/upper layer	0.321	0.190	**-0.706**	0.065
Mean dbh	**0.929**	0.059	-0.003	-0.291
Basal area (total)	**0.819**	0.159	0.024	0.343
Basal area (dominant/upper layer)	**0.730**	-0.099	0.083	0.540
Mean height	**0.930**	0.170	0.095	-0.242
Top height	**0.864**	0.149	0.330	-0.220
Standing volume	**0.942**	0.251	0.070	-0.011
Canopy cover estimate	-0.311	**0.711**	-0.213	0.168
DIFN	0.145	**-0.915**	-0.264	0.026
Canopy depth (main crop layer)	**0.779**	-0.103	0.434	0.232
LAI	-0.163	**0.921**	0.257	-0.052
LAD	**-0.724**	0.454	-0.270	-0.191
Leaf litter	-0.410	-0.276	0.250	**-0.580**
Prop. explained variance	*48.45%*	*15.77%*	*12.34%*	*8.27%*

Database SOIL. Three factors explained the 84.17% of the total variance (Table 3). The first factor (related to C and N content) explained the 46.25% of the variance; the second (Ca, Mg and pH) explained the 21.05% of variance. P content was alone on the third factor (16.87% of variance explained). C/N, P and pH have been selected to represent the SOIL database.

Database METEO and database SITE. The database METEO contained simple variable and calculated indexes (details about the indexes are in Klap *et al.* 1997; Costantini and Amoriello 2000; Amoriello *et al.* 2003). The PCA results are in Table 4. Overall, three factors explained 86.8% of the total variance. The first two factors explained more then 76% of the information; the third one was related to the Late Frost Index (LFI), that accounts for the 10% of the total variance of the system and is uncorrelated with the other variables. Winter index, summer index, max tem-

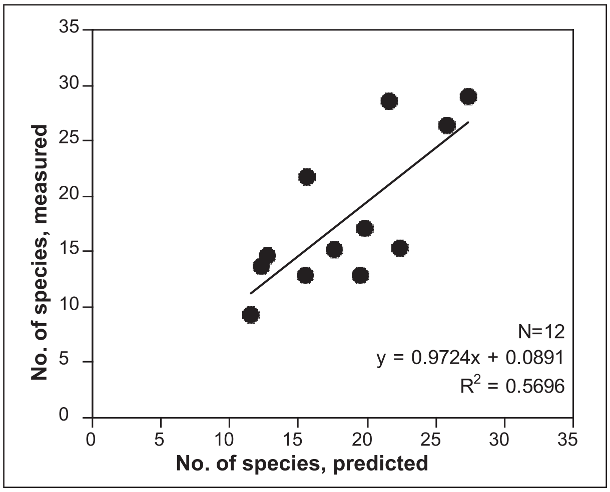
Table 3 - Principal Component Analysis, soil data. Number in bold refer to correlation coefficient higher than 0.7 (assumed as conventional threshold) between the factor and the variable. The proportion of variance explained is reported.
Analisi delle componenti principali, dati relativi al suolo. I numeri in grassetto si riferiscono a coefficienti di correlazione tra fattore e variabile > 0.7 (assunta come soglia convenzionale). Viene riportata la proporzione di varianza spiegata da ciascun componente.

	Factor SOIL1	Factor SOIL2	Factor SOIL3
Ctot	**-0.902**	-0.098	0.413
Ntot	**-0.716**	-0.062	0.633
C/N	**-0.863**	-0.107	-0.078
Ptot	0.146	-0.048	**0.949**
C/P	**-0.972**	-0.070	-0.139
Ktot	**0.712**	0.496	0.272
Catot	-0.238	**0.917**	0.137
Mgtot	0.210	**0.605**	-0.188
pH	0.333	**0.840**	-0.066
Prop. explained variance	0.463	0.211	0.169

Table 4 - Principal Component Analysis, meteo data. Number in bold refer to correlation coefficient higher than 0.7 (assumed as conventional threshold) between the factor and the variable. The proportion of variance explained is reported.
Analisi delle componenti principali, dati meteo. I numeri in grassetto si riferiscono a coefficienti di correlazione tra fattore e variabile > 0.7 (assunta come soglia convenzionale). Viene riportata la proporzione di varianza spiegata da ciascun componente.

	Factor METEO1	Factor METEO2	Factor METEO3
Winter Index	**0.881**	0.097	-0.046
Summer Index	**-0.934**	-0.232	0.055
LFI	0.224	0.127	**-0.837**
P	0.036	**0.945**	-0.211
ETP	**-0.926**	-0.239	0.132
P-ETP	0.131	**0.917**	-0.254
ETR	0.231	**0.715**	0.479
RET	**0.666**	**0.632**	0.313
P1apr-30sep	0.337	**0.894**	0.091
Tmax	**-0.859**	-0.179	0.037
Tmin	**-0.909**	-0.073	0.106
Prop. explained variance	0.432	0.329	0.107

Figure 2 - Measured number of species regressed against prediction of the model based on the outcomes of the StepOLSR.
Numero medio di specie misurate in funzione del numero medio di specie predette dal modello basato sui risultati di StepOLSR.



perature (T_{max}), min temperature (T_{min}) and potential evapotranspiration (ETP) were correlated along the first component, which could be considered as a sort of a latent temperature index. The second factor was more related to the precipitation: it includes variables as precipitation (P), P-ETP, ETR and precipitation between April and September. The selected variables were: LFI, precipitation and maximum temperature. These variables were processed together with the database SITE (latitude, longitude, elevation). This has been done in order (i) to find integrated relationships between meteorological and geographical aspects and (ii) have useful scores for Option 2. The PCA showed that altitude and late frost index were correlated on the first component and were both inversely correlated with maximum temperature. On the second component there are latitude and longitude (this is an artefact due to the shape of Italy itself, see Ferretti *et al.* this volume, Figure 2). On the third component, independent from the other variables, there was the precipitation.

Database DEPOSITION

This database is very simple and it has been analyzed by PCA only to have the scores for the Option 2. There was a relationship between H^+ and SO_4^{-} deposition (Dep H^+ and Dep SO_4^{-}), while $DepN_{tot}$ is independent.

Data analysis

Two different analyses were carried out. One used the values averaged over the period 1999-2003. These data were assumed to be representative of the "mean" status of the plots and therefore more suited for an analysis that takes into account long-term factors (*e.g.*, geographical factors, soil, mean meteorological status). The other analysis considered plot-wise annual data to explore relationships between annual variation of number of species and variation in environmental factors that are expected to change also in the short-term (*e.g.* annual variation in precipitation amount).

Mean species richness 1999-2003

Multivariate and univariate analyses have been carried out. For the multivariate analysis Generalized Linear Models (GLM) (Green *et al.* 1994; McCullagh *et al.* 1989) and Ordinary Least Square Regression (OLSR) (Draper *et al.* 1981; Frank *et al.* 1983) have been used. This is because the two approaches can cover different analytical applications of the same dataset. In particular, GLM was used on the basis of the *variables* selected by the PCA. On the other hand, OLSR have been applied on *scores* generated by PCA on the original datasets (see methods). Two kinds of multiple regressions were used: one that used all the latent variables (OLSR); and another that used a step selection of the variables (StepOLSR). In this case, since we were working with PCs (which are independent by definition), only the forward procedure was

Table 5 – Results of the two regression analyses.
Risultati delle due analisi di regressione.

Regression	Multiple R	Multiple R^2	Adjusted R^2	DF	F	p
OLSR	0.825	0.681	0.458	10	3.057162	0.0537
Forward step selection (StepOLS)	0.797	0.635	0.523	13	5.667936	0.0072

used. The aim of the analyses was to identify possible significant factors associated with species richness, thus enabling the generation of a predictive model of mean number of vascular species for the plots under study.

Univariate Spearman rank order correlation analysis between species richness and environmental variables have been carried out for all plots (n=19) and for the beech plots only (n=7). This has been done because – due to limited number of plots - it has resulted not possible to carry out a multivariate analysis for subset of plot types. It was considered important, however, to investigate whether differences exist between correlates of species diversity in different plot types.

Annual variation in species richness

By means of univariate statistics, plot-level analysis was used to study whether relationships exist between the model residuals (measured annual values - modelled number of species) and those predictors expected to change on a temporal basis: precipitation, LFI, T_{max}, deposition of total nitrogen ($DepN_{tot}$) and tree defoliation (whose changes may create different light condition for the understorey, see Ferretti *et al.* 1999).

Results and discussion

Mean vascular species richness 1999-2003

Multivariate analysis

The results of the GLM (different parameterizations: Poisson error distribution, log link; normal error distribution, identity link; response variable log transformed) were inconclusive and the amount of deviance explained in terms of D^2_{adj} was always < 11% (for example, Ohlemüller *et al.* 2004 found values between 28.2 and 54.1%).

The scores obtained from PCA were used as variables in OLSR. Two steps were performed. First, correlation between PC of each database (SOIL, SITE, STAND, METEO and DEPOSITION) and the response variable were investigated. Second, databases showing significant relationships between at least one PC and the number of species were used for regression analysis. With our data, only SOIL (three components) and STAND databases (four components) showed significant correlation with species richness, so only their scores were used for the regression analysis. Two kinds of multiple regressions were carried out: one that used all the PCs (7) (OLSR); and another that used a forward step selection (StepOLSR). Table 5 reports the results obtained with the two multivariate regressions. StepOLSR gives a little worse fit, but a far better significant model (Table 5, Figure 2): four significant components have been selected: SOIL1 (that include C_{tot}, N_{tot}, C/N, K_{tot}, C/P), SOIL3 (P_{tot}), STAND3 (number of tree species in the plot, percent coverage of MTS in upper layer, number of tree species in the dominant/upper layer) and STAND4 (leaf litter) (see Tables 2 and 3) for relationships between actual and latent variables). Table 6 reports the coefficient for the StepOLSR and the related model. Looking at β value, the 4 PCs have more or less the same importance. It is worth noting, however, that two of them, STAND4 and SOIL3, have a negative coefficient. It means that the relationships between *real* variables and the number of species are as follows:

- direct relationship: K_{tot}, number of tree species in the plot, number of tree species in the dominant/upper layer, leaf litter. Species richness is relatively high where there is higher content of K in the soil, higher number of trees species in the dominant layer and higher litterfall.
- inverse relationship: C_{tot}, N_{tot}, C/N, C/P, P_{tot}, percent coverage of MTS in upper layer. Species richness is relatively low where there are high values for C, N, C/N, C/P and P in the soil and high coverage of the main tree species in the upper layer.

Table 6 – StepOLSR, model coefficients.
Coefficienti del modello derivato da StepOLSR.

	coefficient	t	p	C.I. 95.00%	C.I. 95.00%	β
Intercept	19.0389	17.0585	0	16.6277	21.4501	
STAND3	1.86768	2.42423	0.03066	0.20328	3.53208	0.4125
STAND4	-2.7523	-2.4117	0.03139	-5.2178	-0.2868	-0.4644
SOIL1	4.21549	3.42703	0.0045	1.55808	6.8729	0.5950
SOIL3	-3.3962	-2.6496	0.02003	-6.1654	-0.6271	-0.5056

Table 7 – Spearman rank order correlation coefficients (and relevant p values) between number of species and stand, soil, meteo and deposition data for all plots and beech plots only. Significant correlations (P<0.05) are in bold.
Coefficienti di correlazione per ranghi di Spearman (e relativi valori di p) tra numero di specie e variabili del soprassuolo, del suolo, meteo e deposizione sia per tutti i plot che per i plot di faggio solamente. Le correlazioni significative (P<0.05) sono in grassetto.

Independent variable	*all plots*			*beech plots*		
	n	*R*	*p*	*n*	*R*	*p*
CV dbh	19	0.08	0.75	7	0.07	0.88
HC	19	0.26	0.28	7	-0.14	0.76
Stand age	19	-0.28	0.24	7	0.31	0.50
Tree density	19	0.00	1.00	7	-0.57	0.18
Tree species in the PMP	**19**	**0.48**	**0.04**	7	0.19	0.69
Tree species dominant/upper layer	19	0.39	0.10	7	-0.29	0.53
MTS dominant / upper layer	19	-0.19	0.44	7	0.35	0.44
Mean dbh	19	-0.05	0.84	7	0.57	0.18
Basal area (total)	19	-0.02	0.95	7	0.54	0.22
Basal area (dominant / upper layer)	19	0.02	0.94	7	0.29	0.53
Mean height	19	0.00	0.99	7	0.71	0.07
Top height	19	0.13	0.59	**7**	**0.86**	**0.01**
Standing volume	19	-0.07	0.79	**7**	**0.82**	**0.02**
Canopy cover estimate	19	-0.32	0.19	7	-0.42	0.35
DIFN	16	0.00	1.00	6	-0.25	0.64
Canopy depth (main crop layer)	19	-0.18	0.45	7	0.60	0.15
LAI	19	0.02	0.94	7	0.14	0.76
LAD	16	0.10	0.71	6	-0.35	0.49
Leaf litter	19	0.40	0.09	7	0.32	0.48
Latitude	19	-0.10	0.68	7	-0.71	0.07
Longitude	19	0.38	0.11	7	**0.89**	**0.01**
Elevation	19	-0.28	0.24	7	-0.45	0.31
Ctot	19	-0.21	0.40	7	0.57	0.18
Ntot	19	-0.14	0.55	**7**	**0.86**	**0.01**
C/N	19	-0.19	0.43	7	0.15	0.75
P tot	18	-0.20	0.42	6	0.77	0.07
C/P	18	-0.30	0.22	6	-0.26	0.62
K tot	18	0.36	0.14	6	-0.37	0.47
Ca tot	18	0.08	0.76	6	0.31	0.54
Mg tot	18	0.27	0.29	6	-0.20	0.70
pH	19	0.33	0.16	7	0.41	0.36
DepH+	14	0.09	0.75	6	-0.26	0.62
DepNtot	14	-0.28	0.33	**6**	**-0.83**	**0.04**
Nexc	14	-0.10	0.73	**6**	**-0.94**	**0.00**
DepSO4--	14	0.13	0.66	6	0.20	0.70
P	10	0.08	0.83	4	-0.20	0.80
Tmax	11	0.17	0.62	4	0.89	0.11

Univariate analysis

Table 7 reports the Spearman correlation coefficients between number of vascular species and several variables on all plots and for beech plots only, respectively. When all plots were considered, the only significant correlation was with the number of tree species in the plots: the higher the number of tree species in the plot, the higher the mean number of vascular plant species (Table 7). Very different results were obtained when only beech plots were considered. High correlation coefficients could be observed for many variables (mean tree height, latitude, soil P and T_{max}), and significant correlations (P<0.05) were found for a smaller, still considerable, number of variables. Vascular species diversity correlated positively with longitude (and – at a lesser extent - with latitude: beech plots are located from NW to SW Italy), top height, standing volume and soil N. On the other hand, negative correlations were found with N deposition and exceedance of critical level of N. The case of N is interesting: on one side, the number of vascular species increased with soil N content, a situation that occurred in beech plots located in southern Italy; this is also consistent with the relatively high coefficient observed for latitude (0.71, P=0.07). On the other side, the number of species decreased as the N deposition, and the exceedance of N critical level in particular, increased: this situation occurred in most cases for the beech plots in northern Italy characterized by the lowest N content in the soil (Figure 3). Figure 3 may suggest that these results can be regarded as an artefact due to a correlation with a latent, superimposed geographical pattern (*e.g.* the number of vascular species in beech plots occurred to be high in Southern Italy ones, where soil N and deposition are different from those in northern Italy, but the two results are unrelated). However, it is worth noting that soil (and soil C/N) resulted to be a significant predictor also in the multivariate approach. In this direction, the potential effect of N on species diversity need to be explored further to understand whether it can be explained in terms of eutrophication or acidification, or both. A number of evidences have been reported on possible effects of N deposition on species diversity (*e.g.* Nordin *et al.* 2004; Thimonier *et al.* 1992, 1994; Van Dobben *et al.* 1999; Diekmann *et al.* 1999). In this respect, it would be necessary to concentrate on groups of species that may be particularly sensitive to changes in soil condition due to atmospheric inputs.

Annual variation in vascular species richness

In the previous section, factors were averaged between years and examined to predict mean vascular species diversity. However, it is interesting to consider

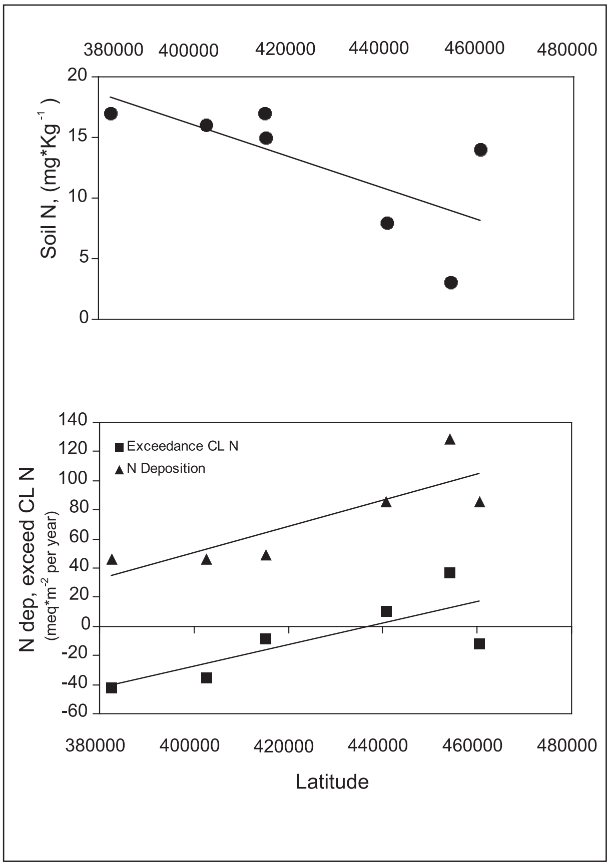


Figure 3 - Trend in latitude of soil N (top), deposition of total N and estimated exceedance of critical load for N (bottom) for the beech plots.
Tendenze in relazione alla latitudine dell'N nel suolo (in alto), della deposizione totale di N e della eccedenza stimata del carico critico di N (in basso) per i plot di faggio.

the role of annual fluctuations for those variables expected to have short-term variation (*e.g.*, precipitation, temperature,...). To assess possible correlates of the annual variation of the number of species (1999-2003 period), the residuals of the stepOLSR model were regressed versus $DepN_{tot}$, LFI, annual precipitation, T_{max}, tree defoliation. Results must be examined taking into account the limited number of annual observations available (maximum 5 years) and the relatively small variation in species richness occurring over the years: in most cases, the year-to-year variation is within the confidence limit of the estimate (see Canullo *et al.* this volume). As reported in Table 8, significant (P<0.05) correlation between number of species residuals and environmental variables occurred only in two cases. At the plot CAL1, number of species decreases in years with high DepNtot and low defoliation; at the plot LOM1 there is a direct correlation between residuals and LFI: anyway this correlation may be an artefact due to the particularly small number of available datapoints (3).

Conclusions

Biodiversity is a top issue on the environmental agenda and a considerable emphasis is placed in the need of proper forest management to maintain the diversity of our forests. It is therefore important to understand what are the main factors associated to vascular species richness, a possible useful biodiversity indicator. Different multivariate and univariate analyses were carried out on the basis of the data collected on 19 PMP of the CONECOFOR programme in Italy. Within our dataset (based on selected intensive monitoring plots in Italy), soil (mainly C/N, pH and P) and stand variables (number of tree species in the dominant storey, number of tree species in the plot, LAI, litterfall amount) resulted as significant predictors of the mean number of vascular species at the plots. Significant univariate relationships were found with the number of tree species in the plot (all plots), top height, volume, longitude and N status of the plots (beech plots). In particular, negative relationships were found with the exceedance of critical loads of N, which occurred mostly on N-limited soils in Northern Italy.

As far as annual changes are concerned, only preliminary results are available: significant correlations were obtained only for one plot, CAL1, where the number of species decreased with increasing level of deposition and decreasing defoliation.

It is always important to stress that the above

Table 8 – Spearman rank order correlation between model residuals (annual values of number of species – model values) and environmental factors. Significant correlations (P<0.05) are in bold.
Coefficienti di correlazione per ranghi di Spearman tra I residui del modello stepOLSR (valori annuali misurati-valori medi modellati) e vari fattori ambientali. Le correlazioni significative(P<0.05) sono in grassetto.

PMP	n	N deposition	Late Frost Index	P (mm)	Tmax	Defoliation
01ABR1	4	-0.707	-0.723	-0.271	-0.309	0.709
03CAL1	4	**-0.996**	-0.609	-0.034	-0.753	**0.929**
04CAM1	5	-0.202	-	-	-	-
05EMI1	5	0.494	-	0.595	-0.752	-0.484
09LAZ1	5	0.107	-0.502	-0.051	-0.043	-0.793
10LOM1	3	-0.614	**0.998**	-	0.657	0.184
16TOS1	3	0.183	-	0.405	-0.426	0.808
19VAL1	5	-	-0.132	-0.065	-0.610	0.520

results are relevant to the examined plots only and cannot be extrapolated to other ones. In addition, the outcomes of both multivariate and univariate analyses need to be explored further: in this context, the extension of the available time series appears particularly important.

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We are grateful to all the colleagues involved in the CONECOFOR programme. In particular, Bruno Petriccione (National Forest Service, CONECOFOR co-ordinator) provided strong support to the work of the I&C Task Force. We are in debt with Alessandro Chiarucci and Giovanni Bacaro (University of Siena) for their continuous help and stimulating discussion. Last, but not least, the authors would like to thank R. Leardi (University of Genoa) for the Matlab® routine (varcum2).

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Biodiversity status and changes in the permanent monitoring plots of the CONECOFOR programme – Achievements, problems, perspectives

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Abstract – Biodiversity-related investigations have been carried out in the CONECOFOR permanent plots since 1996. Forest structure, vascular species, epiphytic lichens, dead wood, invertebrates, landscape and vegetation naturalness have been investigated and a correlative study has been undertaken to identify possible predictors of species richness. For the time being, both significant increase and reduction in species richness was observed, according to the plot. New species of invertebrates have been reported and field methods in epiphytic lichens and deadwood assessment have been tested. Stand structure and soil properties have been identified as significant predictors of vascular plant species richness. For beech plots, N seems to play a significant role. Data quality issues problems and insufficient length of monitoring time window have been reported as major limitations. In future, new data from the repetition of previous survey and from new plots will help the analysis and the interpretation. .

Key words: *biodiversity, forest ecosystem, Italy.*

Riassunto – Stato e tendenze della biodiversità nelle aree permanenti del programma CONECOFOR – Risultati, problemi e prospettive. Dal 1996 sono in corso indagini collegate alla biodiversità nelle aree della rete CONECOFOR. Struttura, specie vascolari, licheni epifiti, invertebrati, legno morto, paesaggio e naturalità della vegetazione sono state investigate, ed uno studio correlativo ha cercato di identificare possibili predittori della ricchezza specifica. Ad oggi, a seconda dei plot, sono state rilevate sia diminuzioni che aumenti significativi del numero di specie di piante vascolari. Sono state descritte nuove specie di invertebrati e sono stati sperimentati nuovi metodi per quanto riguarda il legno morto ed i licheni epifiti. La struttura forestale e le caratteristiche del suolo si sono dimostrati predittori significativi del numero di specie di piante vascolari. Per i plot di faggio, l'azoto sembra giocare un ruolo significativo. Alcuni problemi con la qualità dei dati e l'insufficiente lunghezza del periodo esaminato costituiscono le principali limitazioni emerse. In futuro, la disponibilità di nuovi dati derivanti dalla ripetizione di vecchie indagini e da nuove aree permanenti aiuterà una migliore analisi ed interpretazione.

Parole chiave: *biodiversità, ecosistemi forestali, Italia.*

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Introduction

The various papers of this report examined different aspects of biodiversity as it is assessed in the plots of the Italian forest intensive monitoring network CONECOFOR: forest structure, vascular species diversity, epiphytic lichens, dead wood, invertebrates (Fabbio *et al.*, this volume; Canullo *et al.*, this volume; Giordani *et al.*, this volume; Travaglini *et al.*, this volume; Mason *et al.*, this volume). Additional investigations were carried out about landscape and naturalness of vegetation (Ingegnoli, this volume; Petriccione, this volume) and about factors influencing the diversity of vascular species (Ferretti *et al.*, this volume). The value of these data and results should be considered in relation to the objectives of the Convention on Biological Diversity (CBD), which wishes "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level..." (Decision VI/26, Strategic Plan for the CBD). Among the seven focal areas identified by the CBD, the data collected by the CONECOFOR programme are directly relevant to focal area 1 ("Status and trends of the components of biological diversity") and 3 ("Threats to biodiversity") (Table 1). Actually, given the nature of the plots (forest plots located in areas where direct disturbances and/or land-use changes are absent or very limited, also in the surroundings), data obtained from the CONECOFOR plots are particularly relevant to investigate the effects of climate

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Table 1 – The focal areas of the 2010 biodiversity target of the CBD.
Aree focali dell'obiettivo biodiversità 2010 della CBD.

	Focal Areas of the CBD
1	Reducing the rate of loss of the components of biodiversity, including: (i) biomes, habitats and ecosystems; (ii) species and populations; and (iii) genetic diversity;
2	Promoting sustainable use of biodiversity;
3	Addressing the major threats to biodiversity, including those arising from invasive alien species, climate change, pollution, and habitat change;
4	Maintaining ecosystem integrity, and the provision of goods and services provided by biodiversity in ecosystems, in support of human well-being;
5	Protecting traditional knowledge, innovations and practices;
6	Ensuring the fair and equitable sharing of benefits arising out of the use of genetic resources;
7	Mobilizing financial and technical resources, especially for developing countries, in particular least developed countries and small island developing States among them, and countries with economies in transition, for implementing the Convention and the Strategic Plan.

and air pollution on biodiversity, two drivers that are of concern at global level.

As a tradition in the Integrated and Combined (I&C) series of reports (see Ferretti 2000; Ferretti *et al.* 2003), this final paper wishes (i) to provide a summary of the main achievements, (ii) to identify problematic issues and (iii) to suggest a perspective for future biodiversity-related monitoring within the CONECOFOR programme.

Achievements

Baseline data on key biodiversity indicators

A first result obtained is the collection of data that may serve as baseline to detect changes over time. This is particularly true for vascular species diversity and forest structure, *e.g.* two key components of forest biodiversity. Data reported by Canullo *et al.* (this volume) identify limited statistically significant changes in the mean number of vascular species over the monitoring period, although 5 years is a short-term to identify changes (Figure 1, top). When data are plotted with reference to the first monitoring year (1999) (Figure 1, bottom), the complex nature of changes in species richness is obvious, with very few plots showing a distinct and consistent pattern and the majority displaying year-by-year fluctuations. Data in Figure 1 show clearly the need for a continuous monitoring in order to document the progress towards the 2010 objective.

A second important result is that new species of invertebrates have been identified (Mason *et al.*, this volume). These species were new for science and/or new for Italy. Again, these data on key species will be helpful for a better understanding of species richness at the CONECOFOR plots.

Testing of assessment methods and diversity indices

The range of investigations carried out at the CONECOFOR plots allows testing a number of field methods in terms of indicators considered, sampling design (spatial allocation and density of measure-

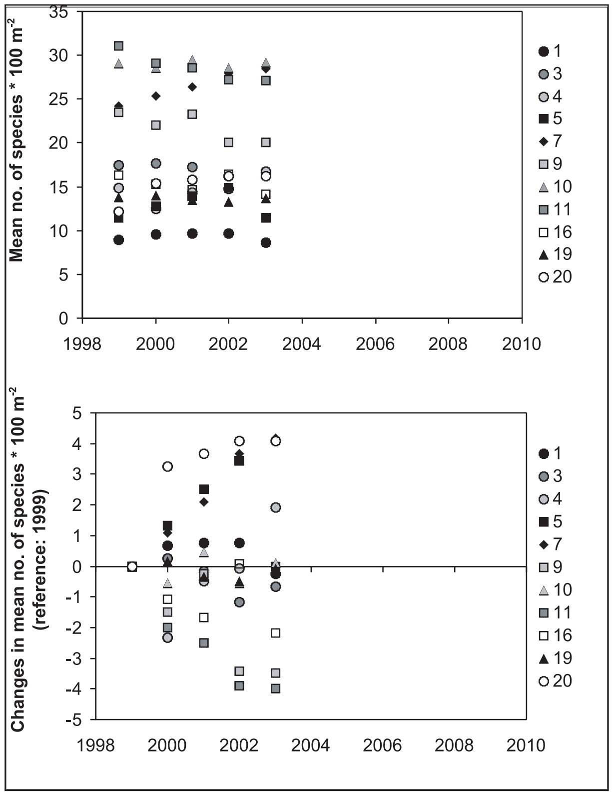

Figure 1 – Mean number of species$*100m^{-2}$ at the CONECOFOR plots over the period 1999-2003. Top: plot-wise annual values. Bottom: annual deviations from 1999 data. Legend, symbols: circles=beech plots; quadrates=oak-dominated plots; triangles=spruce-dominated plots; rhomb=mixed broad-leaved plot. Legend, numbers: plot identification number, see Canullo *et al.*(this volume). (Drawn on the basis of data by Canullo *et al.*, this volume).
Numero di medio di specie per $100m^{-2}$ ai plot CONECOFOR nel periodo 1999-2003. In alto: valori medi annuali per plot. In basso: deviazioni annuali dal dato del 1999 assunto come riferimento. Legenda, simboli: cerchi=plot di faggio; quadrati=plot a dominanza di querce; triangoli=plot a dominanza di abete rosso; rombi=plot di latifoglie miste. Legenda, numeri: numero identificativo del plot, cfr. Canullo et al., *questo volume. (Disegnato sulla base di Canullo* et al., *questo volume).*

ments) and nature (bias and precision) of the resulting estimates. While a comprehensive assessment of these aspects has been carried out only for dead wood (see TRAVAGLINI *et al.*, this volume), the data and information collected will allow in-depth analysis also for other investigations, in particular for ground vegetation, epiphytic lichens and invertebrates.

The performance and significance of several forest structure diversity indices have been investigated in detail (see FABBIO *et al.*, this volume). A number of statistically significant relationships were found between diversity indices (Shannon, Pielou, Cox, Holdridge complexity index) that can be calculated in relation to diameter at breast height (dbh), tree height, and the spatial (horizontal and vertical) distribution of the trees. These results are of value when thinking about the relationships existing between forest structure and diversity (see below) and the need for having proxy data for biodiversity. For example, the identification of all the vascular species in the plot requires always qualified botanists; on the other hand, mensurational data about the tree compartment are easier to be collected: if a robust relationship is found between *e.g.* number of tree species in the dominant layer or tree height and species richness, this offers the basis for a model-based estimate for those sites where the actual figure about number of vascular species is not available.

Insight in factors affecting vascular species diversity

While many investigations have been carried out in the past about biodiversity components at different scale, the added value of the data obtained by the CONECOFOR programme is that diversity data are collected together with a number of site and environmental variables (*e.g.*, age, stand structure, soil, meteorology, deposition) at the same plots. This enabled a first statistical analysis of correlates of vascular species diversity (FERRETTI *et al.*, this volume). Results showed that soil (mostly C/N ratio and P content) and stand (mostly diversity of the dominant layer and leaf litter) are significant predictors of the mean number of vascular species observed at the plots. When only beech plots are considered, significant positive correlations were found with standing volume and top height (a proxy for site fertility), geographical locations (species richness increases from north to south and west to east) and soil N content. On the other hand, excess of N deposition has a negative significant correlation with the number of species. This suggests that, while the number of species is higher in naturally N-rich, fertile soils, an excess of N deposition with respect to the critical loads of the site may cause a decrease in species richness.

Problems

Data quality

Data quality is a central issue in monitoring programmes and it has been stressed as a major concern also within the CONECOFOR programme. Data quality of species richness (a key indicator adopted in this report) has been documented by a Quality Assurance programme (CANULLO *et al.*, this volume) and the same applies for other investigations. Yet, data completeness is still a major challenge, especially for meteorological data which are subjected to the possible fault of equipments. Since many calculations of meteorological indexes need high data completeness, any improvement in this direction will be beneficial.

Number of sites and allocation of measurements

This point has been made several times (FERRETTI *et al.* 2000; FERRETTI *et al.* 2003): there are gaps in data coverage that limit the potential for data evaluation. Continuous data on species richness are available for a subset of plots (11 out of the original 20) and even less plots are covered by investigations such as epiphytic lichens (7), dead wood (5), invertebrates (12), landscape (10) and naturalness analysis (12). At a lesser extent, this is also true for data about predictors such as deposition (15 plots out of the 20 original ones) and meteorological data (12), which are particularly important to interpret and understand annual fluctuation. The combined effect of the gaps in predictors and gaps in response is that a straightforward data analysis can be achieved for a limited number of plots only. This effect is exacerbated by the differences existing between plots, that introduce a further limit to the statistical analysis.

More time is needed

While the data collected up to date were useful under many respects, the time series is still too short to enable a trend analysis. For the time being, it is difficult to separate the nature of a time trend (random fluctuation *vs.* directional signal). For the same reason (too few degrees of freedom) is difficult to identify what factors are involved in year-by-year changes. There is a strong need for continuing the monitoring over the next years.

Perspectives

Research on indicators should continue

Several questions about indicators remains to be investigated in details. For example, one of the reviewers of this report (see *ad hoc* referees committee) identified some key questions: what indicators are best suited for effective monitoring? How the various indicators can be used as a warning system in a sustainable management framework? Which one can be suited for large scale monitoring of biodiversity? In addition, other indicators can be considered for future assessment: for example, the Winkelmass index (see Von Gadow *et al.* 1998 and Von Gadow 1999, quoted in Corona *et al.* 2005) has been recently tested also in Italy (Corona *et al.* 2005) and it has been proven to be easy to implement.

Continuous time trend analysis in view of the 2010 objective

The investigations about trends in species richness will continue. A new I&C report is currently being prepared (Ferretti, 2005) which will investigate the biological, chemical and physical condition of the CONECOFOR plots over the period 1996-2005. In this framework, also species richness data will be processed further and it will help the detection of trends of concern.

New plots, new data

Although the core of the CONECOFOR dataset is represented by the "original" twenty plots installed in 1995, eleven new plots have been added at subsequent, later stages (see Ferretti *et al.*, this volume). These new plots have been installed into beech (3), mixed broadleaved (3), Norway spruce (2), holm oak (2) and larch (1) forests. Whenever data will become available for these plots, multivariate studies will benefit from increased degrees of freedom. At the same time, the repetition of the plot's mensuration survey (undertaken from late 2004 to early 2005) after 8 years since the first one will provide important new data about the development of forest structure and this will help in explaining changes also in the understorey and ground vegetation.

Conclusions

The data collected in the plots of the intensive forest monitoring network CONECOFOR enabled a first assessment of some aspects of biodiversity and their changes through time. Co-located data about site characteristics, soil, tree condition, meterology and atmospheric deposition allow a correlative study to find out possible predictors of species richness. Main results include: baseline data on species richness, identification of new species, methods and indicator testing, identification of soil and stand structure as significant predictors of vascular species richness. For beech plots, soil N and N deposition correlates with species richness as well. Although these data need confirmation, N deposition is again reported as a possible threat to biodiversity. Significant decrease in number of species was recorded at one plot only. Some gaps in the datasets and a still too short time window have prevented a more complete analysis. In the future years, continuation of diversity-related investigations on an annual basis and on a larger number of plots is considered essential to provide answers to the 2010 CBD objective.

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