METHODOLOGIES AND PROCESSES FOR THE ANALYSIS, CONSERVATION AND MONITORING OF PLANT BIODIVERSITY

E. BIONDI, S. CASAVECCHIA, L. NANNI, L. PARADISI, S. PESARESI, M. PINZI

Dipartimento di Scienze Ambientali e delle Produzioni Vegetali (SAPROV)
Polythecnical University of Marche, Via Brecce Bianche I-60131 Ancona

ABSTRACT - The conservation of biodiversity asks for the conscious management of the ecosystems and the landscape and consequently involves a deep knowledge of the characterizing factors and the dynamic processes being at the basis of their origin and determining their spatial diffusion and the temporal transformation. Vegetation is a basic element of the landscape and owns a meaningful value of bio indication being sensitive to the variation of the ecological factors. The phyotosociological and geosinphytosociological analysis supplemented by the GIS methods allow to suggest management interventions for biodiversity conservation of species and environments and to plan the connections among sites having a different level of naturalness in order to improve the quality diffused in the territory. As a demonstrative example are presented some aspects regarding analysis, management and the monitoring of the sites of Community importance and special protection areas individuated through the Habitat Directive 92/43/CEE.

KEYWORDS - Biodiversity, geosinphytosociological analysis, GIS, management, monitoring, Sites of Community Importance.

INTRODUCTION

It is not easy to define what biodiversity is, for this reason Van der Maarel (1977) considers biodiversity as the "babel of the biosphere management". Biodiversity is surely the diversity, or better, the biologie variety which develops through different levels: genetics (flora and fauna), biocoenosis, ecosystem and landscape. Therefore the conservation of biodiversity requires a deep knowledge of all the levels and of the factors that characterise them. It is also important to understand the dynamic processes that are at the basis of this variety of ecosystems and landscapes and that determine their diffusion in space and transformation with time.

The vegetation is a fundamental component of the landscape, in that it forms a part of the ecosystems, of which it is an important structural and functional aspect. It is therefore important to be able to use the vegetation as a bioindicator in such a way that through its surveying it is possible to obtain useful indications of the qual-

ity of the ecosystems and of the value of the main ecological factors that characterise them.

Through the study of the serial successions and of the units of the plant landscape, the phytosociological and geophytosociological analyses allow the definition of predictive and dynamic models with great applicative interest (Rivas-Martinez, 1987; Géhu, 1988; Géhu & Rivas-Martinez, 1981; Biondi, 1996; Biondi, 2003). In particular, if they are correctly supported by computer-based and cartographic methodologies, including GIS methodologies, they allow the proposal of management solutions for the conservation of species and environment biodiversity, and the planning of the connections between sites with different natural features for the improvement of the quality throughout the territory (Blasi *et al.* 2000, Biondi & Nanni, 2005).

The Habitat Directive (92/43/CEE of 21 May, 1992) marked a decisive turning-point in the management perspectives of biodiversity in the European Union territories, in that it did not only reveal the plant and animal species in need of conservation (Annex II), but it also indirectly correlated them with the ecosystems in which they live and for which protection was proposed.

Here, we present the results of an investigation that has the aim of defining the most relevant methodology that should be followed in the realisation of a conservation programme for specific and coenotic plant biodiversity and for the plant landscape, which can be used for the analysis of the biodiversity, the organisation of the management plans and for the monitoring of the Sites of Community Importance (SCI) and of the Special Areas of Conservation (SAC) (Biondi *et al.*, in press). The research was carried out for the Marche Region (central Italy) through the collaboration of the Polithecnical University of Marche, the University of Camerino, the University of Urbino and the Marche Region for the study of the SCI and SAC of the regional territory.

Materials and Methods

With the aim of the study of SCI and SAC biodiversity, a specific methodology has been defined that can be used for the identification of the analyses to be conducted and for the steps through which the analyses will be carried out and the final results (the output) will be produced, (Figure 1). The method is organised according to a logical order: the columns represent the main groups under investigation that are integrated horizontally: the flora, the vegetation, the fauna and the methods for the data processing through a GIS. The products are indicated by the squares external to the columns.

Results and Discussion

Analysis of the flora biodiversity

The analysis of the floristic biodiversity allows the floristic patrimony of a territory to be known and the individuation of the species that are rare, endangered or of great phytogeographic interest for that territory. In particular, the Habitat Directive indicates that the orchid species are important for conservation.

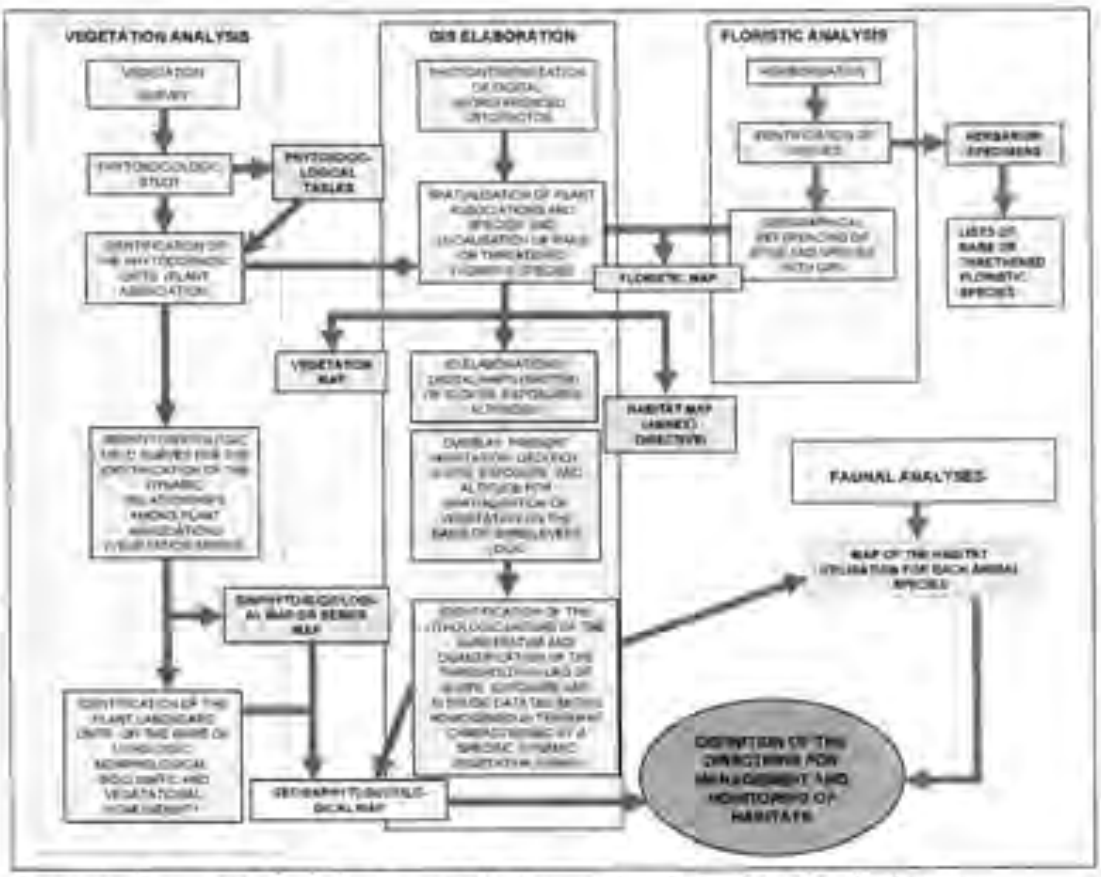

FIGURE 1 - The methodological scheme for the integrated analysis of the plant landscape.

Through the geographic localisation (with a Global Position System: GPS) of the sites where these species are found, they can be mapped, thus allowing distribution maps of the species of floristic interest to be prepared.

Future researches will regard the demographic study of the threatened populations, of the few endemic species of Marche and of the richer group of the Apennine endemic species and of species having here their distribution limit, in order to quantify the real status of the populations and evaluate the management actions more suitable for the conservation of every single species. The distribution of *Rhamnus alaternus*, species having a steno-Mediterranean distribution, is here reported such an example. In fact, this species founds in the Marche its north-western distribution limit, more precisely, in the area of Mount S. Bartolo, in the Pesaro-Urbino district.

The study of the demographic phenomena is correlated with the experimental analysis of the reproduction biology of every single species, of their auto-ecological behaviour and of the germoplasm conservation in a regional structure which is being built in the Botanical Garden of the Polytechnical University of Marche.

Analyses of the fauna biodiversity

Through the census of the animal species present in a territory, it is possible to prepare a number of maps. In the example here, a map of the nesting birds in a Special Area of Conservation (SAC in Italian is ZPS) in the Marche Region is shown.

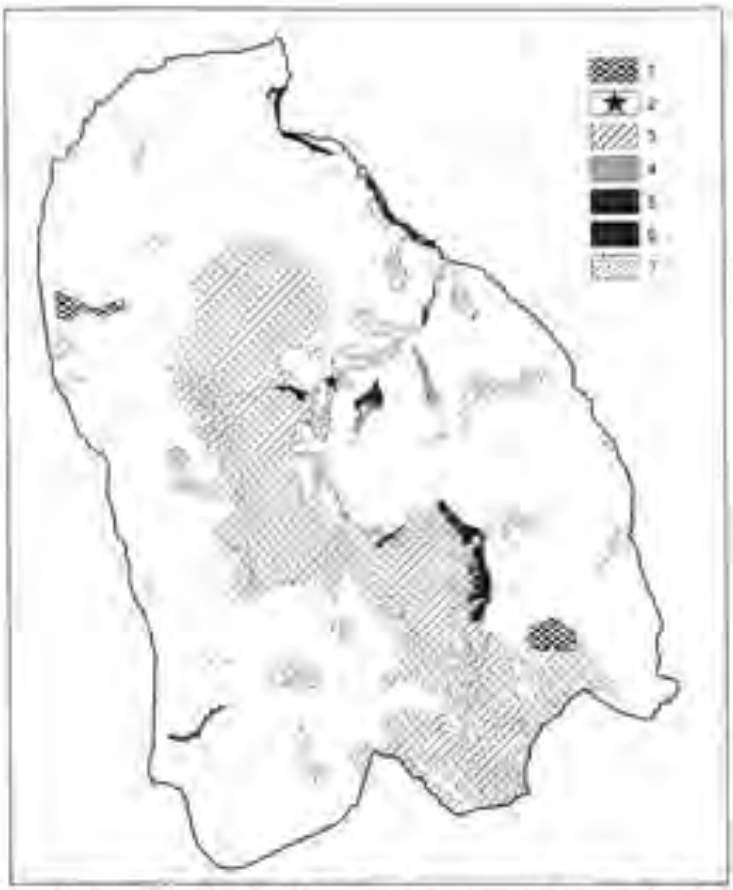

FIGURE 2 - The map of habitats of the SAC "M. Puro, Rogedano, Valleremita" in Marche Region.

1 *Juniperus communis* formations on heaths or calcareous grasslands (5130).

2 *Arborescent materral with *Laurus nobilis* (5230).

3 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites) (6210).

4 **Tilio-Acerion* forests of slopes, screes and ravines (9180).

5 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) (91E0).

6 *Apennine beech forests with Taxus and *Ilex* (9210).

7 *Quercus ilex* and *Quercus rotundifolia* forests (9340).

The interactions between all of these analyses result in a definition of the biological indications for the management and monitoring of the habitats, to which the urbanistic and socio-ecological analyses will be added.

Analyses of the vegetation biodiversity

The analyses of the vegetation are carried out following successive steps:

- field sampling of the vegetation types present in the area;
- elaboration of the phytosociological relevés through the tables;

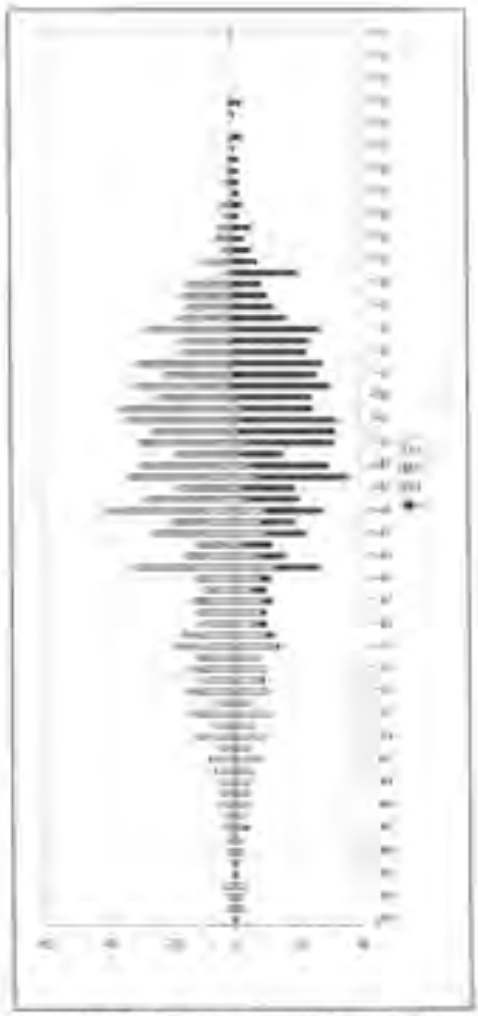

FIGURE 3 - The sex and age pyramids of a *Juniperus oxycedrus* population (from Baldoni *et al.*, 2004).

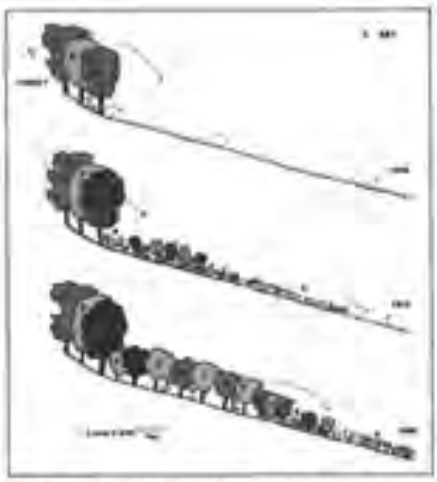

FIGURE 4 - Wood frontal advancing on abandoned fields and grasslands. O = *Ostrya carpinifolia*; Q = *Quercus pubescens*; S = *Spartium junceum*, C = field, P = grassland (from Biondi, 2003).

FIGURE 5 - Soil and vegetation evolution after the abandonment of the fields. F = *Fraxinus ornus*; O = *Ostrya carpinifolia*; Q = *Quercus pubescens*; S = *Spartium junceum* (from Biondi, 2003).

- recognition of the plant associations and interpretation of the ecological factors that determine and support them.

At the same time, this information is inserted in an archival system of the GIS data for the production of vegetation maps. The "plant association" attribute is assigned to each polygon that comes from the field phytosociological analyses. In this way, a computer-based vegetation map (that can be queried) is obtained with different details according to the scale.

Similarly, the habitats in the territory indicated by the Habitat Directive have been individuated. In FIGURE 2, the map of habitats for a Marche Region Special Area of Conservation (SAC) is shown. One of the most important habitat widespread in the Apennine and sub-Apennine SCIs (Sites of Community Importance), is the habitat of the secondary grasslands (Habitat 6210). These are: "Semi-natural grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (important orchid sites)". For their conservation, an active management is necessary that involves the cutting or its grazing for animals. At present, these habitats are in great danger of disappearing because they are of diminished economic interest. Due to some studies carried out in the same areas (Ballerini & Biondi, 2002; Ballerini *et al.*, 2002), the time for the recovery of the shrubs is known, and on the basis of this, the best management choice must be made.

Vegetation as a bioindicator

The vegetation has a great bioindicative value that must be used for the management choice. The summital secondary Apennine grasslands that are strongly invaded by juniper are shown here as an example. The demographic analyses conducted on these populations have revealed that the juniper populations (*Juniperus communis* and *J. oxycedrus*) are now in a senescent phase that will not

evolve further. This leads us to imagine various future scenarios that are not at present known. In FIGURE 3 the sex and age pyramids of a *Juniperus oxycedrus* population studied for the calcareous Umbria-Marche Apennines are shown (Baldoni *et al.*, 2004).

In contrast, if there is a repopulation with broom (*Spartium junceum*), the potential future formations can be established with certainty, because the vegetation series is known.

In recent studies it was observed that the invasion of the grassland by shrubs starts from the ecotonal space next to the wood. In a short time, the grassland disappears, it becomes a shrubbery. It was possible to elaborate different models of evolution such as wood frontal advancing and enucleation of broom shrubs (FIGURES 4-5) (Ballerini *et al.*, 2000, Biondi 2003).

Indeed, through the integrated analyses between the vegetation and the soil it is possible to precisely define the correlation between the soil and vegetation types, and therefore to individuate the potential vegetation series for that territory (Biondi *et al.*, 1999; Biondi *et al.*, 2002). Moreover, by adding in the time variable, it is possible to simulate the transformations in the landscape on the basis of the management choice that is made.

The analysis carried out, allows to define the interpretation dynamic and diachronic models utilisable for the direction of management decisions and for reaching a sustainable land development.

FIGURE 6 - An example of a plant landscape unit individuated in the Conero Natural Park. Virtual Tridimensional model of the cliff. In the forefront the calcareous-marly sector to which the indicated vegetation series are referred.

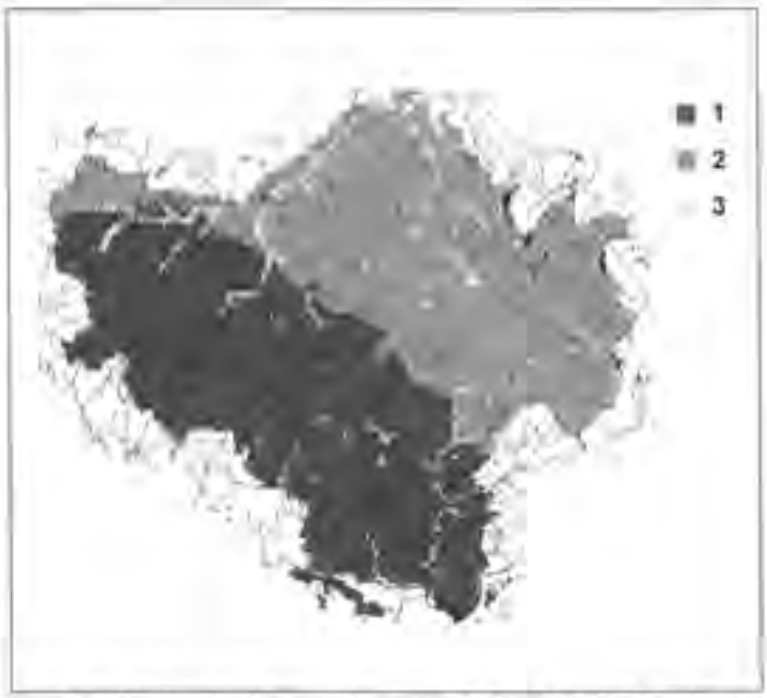

FIGURE 7 - An example of a plant landscape unit map made for a SAC in the Marche sub Apennines.

1 Plant landscape unit of the calcareous-marly substrata of the mesotemperate bioclimatic belt, of the hilly reliefs of the peri-Adriatic area of *Ostrya carpinifolia* and *Quercus pubescens*.

2 Plant landscape unit of the arenaceous-pelitic substrata, of the mesotemperate bioclimatic belt, of the hilly reliefs of the peri-Adriatic area of *Ostrya carpinifolia* and *Quercus pubescens*.

3 Plant landscape riparian unit (microgeosigmetum) of the alluvial substrata.

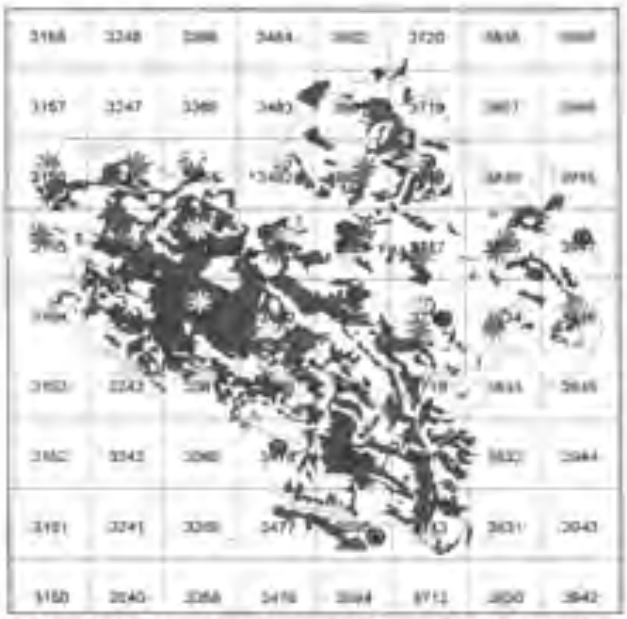

FIGURE 8 - Analysis of faunal biodiversity: presence of nesting birds in the SAC "Mombaroccio e Beato Sante" in Marche subappennine (by M. Pandolfi, University of Urbino).

Vegetation series and synphytosociological maps

The next stages of the analysis involve the recognition of the spatial or dynamic relationships that link the various phytocoenoses, and the individuation of the vegetation series. This allows the production of the synphytosociological map. GIS processing is fundamental for the individuation of the surfaces relevant to the various vegetation series, in that it allows the quantification of the threshold values of the slope, exposure and altitude data that delimit homogeneous *tesserae* characterised by a specific series of vegetation dynamics. Indeed, through the realisation of a three-dimensional digital model of the terrain and through the use of dedicated software (Vertical Mapper® 2.6), it is possible to produce maps of the exposure and slope. Superimposing the vegetation map on those of the slope, exposure and geology, it has been possible to establish the range of the spread of the associations and the vegetation series. The described methodology was applied to the protected area of the Conero Regional Natural Park in order to verify the distribution of the vegetation communities in relation to the geomorphological variations and to the lithological nature of the substrata. Thus, it has been possible to individuate the landscape systems and to attribute the potential vegetation series to the territories covered by replanted woods (FIGURES 6).

Plant landscape units and geosynphytosociological maps

For the realisation of the geosynphytosociological map, also named the plant landscape unit map, the plant landscape units are defined through an integrated reading of the plant coverage and of the characteristics of morphological, lithological and bioclimate homogeneity. In FIGURE 7, an example of a plant landscape map made for a SCI is shown, where it has been possible to recognise two landscape units by the emerging of pelitic-arenaceous rocks (light green) and calcareous-marl (dark green).

Habitat/fauna integrations

The information regarding the fauna, and in particular the birds included in the Bird Directive, can be integrated with the vegetation data. In the example shown in FIGURE 8, the integration involved the relation between the vegetation typologies and the feeding and nesting habitats of the birds included in the "Bird Directive".

CONCLUSIONS

The methodology used provides deep knowledge of the plant biodiversity of a territory under conservation measures. Indeed, the methodology used has a fundamental importance in the choice of planning and management of the habitats, in that the knowledge of the vegetation dynamics results in the definition of the evolution/regression history of the landscapes and in the foreseeing of future scenarios. The bioindication value of the vegetation allows the interpretation of the present anthropic pressures for the orientation of the management towards an ecocompatible development; moreover, the vegetation is the element that allows the individuation of the ecological niches of the fauna populations; therefore, through the definition of the potential correlations between the plant and animal communities, the entire biological component of the landscape is defined.

The series of integrated investigations allows the creation of models of the plant landscape that can be used for the interpretation of the ecological factors that underlie the mosaic that makes up the plant landscape.

The interpretation of the present vegetational potential in terms of the exact reconstruction of the vegetational dynamics allows for the correct management and continued monitoring of the biodiversity.

In applying the Habitat Directive, the integrative logical processing of the ecological data proposed defines the urbanistic and economic territorial analyses that follow, and that are indispensable for the definition of the management plans of SCI and SAC as well as of the biological connections between these zones.

Riassunto

La conservazione della biodiversità richiede la gestione consapevole degli ecosistemi e del paesaggio ed implica pertanto la conoscenza approfondita dei fattori che li caratterizzano e dei processi dinamici che sono alla base della loro origine e ne determinano la diffusione nello spazio e la trasformazione nel tempo. La vegetazione è una componente fondamentale del paesaggio ed assume una significativa valenza di bioindicazione in quanto sensibile alle variazioni dei fattori ecologici. Le analisi fitosociologiche e geosinfitosociologiche integrate con le metodologie GIS permettono di proporre soluzioni gestionali per la conservazione della biodiversità di specie e di ambienti e di progettare le connessioni tra siti a diverso grado di naturalità per migliorare la qualità diffusa nel territorio. A titolo dimostrativo vengono presentati aspetti riguardanti l'analisi, la gestione e il monitoraggio dei siti d'importanza comunitaria e delle zone di protezione speciale individuate in base alla Direttiva habitat 92/43/CEE.

References

Baldoni M., Biondi E. & Ferrante L., 2004 - *Demographic and spatial analysis of a population of Juniperus oxycedrus in an abandoned grassland.* Plant Biosystems, **138 (2):** 89-100.

Ballerini V. & Biondi E., 2002 - *Dinamica di popolazioni arbustive e preforestali nell'Appennino umbro-marchigiano (Italia centrale).* Fitosociologia **39 (1)** Suppl. 2: 175-183.

Ballerini V., Biondi E. & Calandra R., 2000 - *Structure and dynamic of a* Spartium junceum *L. population in the central Apennines (Italy).* Coll. Phytosoc., **XXVII:** 1071-1096.

Ballerini V., Neri D., Zucconi F. & Biondi E., 2002 - *Il modello architettonico di* Spartium junceum *L.* Fitosociologia **39 (1)** Suppl. 2: 163-173.

Biondi E., 1996 - *L'analisi fitosociologica nello studio integrato del paesaggio. In "Avances en Fitosociologia":* 13-22, Servicio Edit. Universidad del Pais Vaseo, Bilbao.

Biondi E., 2003 - *Processi di rinaturazione in seguito ad abbandono delle attività agro-silvo-pastorali ed implicazioni gestionali.* In: "Paesaggio culturale e biodiversità. Principi generali, metodi, proposte operative" Giardini e Paesaggio **7:** 47-80. Leo S. Olschki, Città di Castello.

Biondi E., Ballelli S., Allegrezza M., Taffetani F., Frattaroli A.R., Guitian J. & Zuccarello V., 1999 - *La vegetazione di Campo Imperatore (Gran Sasso d'Italia).* Braun-Blanquetia **16:** 53-115.

Biondi E., Casavecchia S. & Pesaresi S., 2005 - *Analisi del paesaggio vegetale e sua interpretazione in un'area costiera a forte instabilità idrogeologica.* Atti XIV Congresso Nazionale della Società Italiana di Ecologia (Siena 4-6 ottobre 2004) (in press).

BIONDI E., CASAVECCHIA S., PINZI M., BAGELLA S. & CALANDRA R., 2002 - *Excursion to the Conero regional natural park*. Fitosociologia **39 (1)** - Suppl. 3: 5-32.

BIONDI E. & NANNI L., 2005 - *Geosigmeti, unità di paesaggio e reti ecologiche*. In Atti del Terzo Congresso IAED (Roma 4-6 dicembre 2003) "Identificazione e cambiamenti nel paesaggio contemporaneo" Blasi C. & Paolella A. (a cura): 134-140.

BIONDI E., CASAVECCHIA S., FERRONI E., NANNI L., PARADISI L., PESARESI S., PINZI M. & ZABAGLIA C., 2005 - *Analisi e monitoraggio del paesaggio vegetale per la conservazione della biodiversità*. Atti XIV Congresso Nazionale della Società Italiana di Ecologia (Siena 4-6 ottobre 2004) (in press).

BLASI C., ACOSTA A., PAURA B., DI MARTINO T., GIORDANI D.M., DI MARZIO P., FORTINI P. & CARRANZA M., 2000 - *Classificazione e cartografia del paesaggio: i sistemi e i sottosistemi di paesaggio del Molise*. Inf. Bot. Ital. **32** Suppl.:15-20.

GÉHU J.M., 1988 - *L'analyse symphytosociologique et géosymphytosociologique de l'espace. Théorie et méthodologie*. Colloq. Phytosoc. **17:** 11-46.

GÉHU J.M. & RIVAS-MARTINEZ S., 1981 - *Notions fondamentales de phytosociologie*. Ber. Int. Simp. Int. Vereinigung Vegetationskunde: 533.

RIVAS-MARTÌNEZ S., 1987 - Nociones sobre Fitosociología, Biogeografia, Bioclimatología. In: Universidad de Alcalá de Hanares (Ed.), La vegetacion de España, pp. 19-45.

VAN DER MAAREL E., 1977 - Biodiversity from babel to biosphere management. Opulus Press.