FUNGI

[Silvano Onofri, Annarosa Bernicchia, Valeria Filipello Marchisio, Claudia Perini, Giuseppe Venturella, Laura Zucconi, Caterina Ripa]

Until a few decades ago, the fungi were included in the *Thallophyta* division of the *Plantae* kingdom, together with bacteria, lichens and algae. In fact, it was not until 1969 that WHITTAKER proposed a separate kingdom, the *Fungi*, distinct from the *Animalia*, *Monera*, *Plantae* and *Protista* kingdoms. Since then the boundaries of the *Fungi* kingdom have undergone various changes. Today, more thorough ultrastructural, biochemical and molecular studies have shown that the four phyla *Chytridiomycota*, *Zygomycota*, *Ascomycota* and *Basidiomycota* are also properly to be placed in the *Fungi* kingdom (Figures 4.24 and 4.25). To these must also be added the informal group of anamorphic fungi, which reproduce asexually. On the other hand, organisms such as the *Myxomycetes*, the *Hyphochytridiomycetes* and the *Oomycetes*, which were previously placed in the *Fungi* kingdom, are today placed, respectively, in the *Protista* kingdom (the first) and in the *Chromista* kingdom (the latter two) (KIRK *et al.*, 2001). Molecular biological studies on the sequences of rRNA of fungi in vesicular-arbuscular mycorrhizal symbiosis with the roots of plants have recently led to the proposal to place such fungi in a new *phylum Glomeromycota*, which covers four orders (*Glomerales*, *Diversisporales*, *Paraglomerales* and *Archaeosporales*), and is separated from the *phylum Zygomycota*, in which these species were previously placed. By means of phylogenetic analysis it has been shown that the *phylum Glomeromycota* probably shares a common ancestor with *Ascomycota* and *Basidiomycota* (SCHÜßLER *et al.*, 2001).

Fungi are considered to be the most ancient organisms to have left aquatic environments to colonize land environments, and they seem to be evolutionarily closer to animals than to plants. It is only in the last twenty years or so that studies by various researchers and mycologists have demonstrated how important the role of fungi is for life on earth (HAWKSWORTH, 1991) and it was only at the end of the 20th century that the interest of scientists in protecting fungi reawakened. For example, the European Council for the Conservation of Fungi (ECCF) – founded in Oslo in 1985 on the occasion of the IX Congress of European Mycologists and the *Journées Européennes du Cortinaire* (JEC) – highlighted, by way of meetings, studies and research projects, the fundamental contribution made by fungi to the conservation of nature and the environment (KOUNE, 1999). The conservation of fungi, as with other life-forms, can be achieved in two complementary ways, *in situ* and *ex situ*. Conservation *in situ* may be hampered by several factors: lack of information on whether or not a species is present at a particular site; the time required for, and the workload involved in, the production of lists of fungal species, together with distributional maps enabling the rarity of each species to be established; the lack of information on the precise ecological characteristics of species. Conservation *ex situ* may be achieved by means of mycology collections, even if, unfortunately, only 7% of known fungal species – and 1% of the estimated total of fungal species – are conserved in collections worldwide (HAWKSWORTH, l.c.).

Fig. 4.24 - *Amanita caesarea* (Scop. : Fr.) Pers., a well-known and valued Basidiomycetes (Photo by A. Cherubini).

Fig. 4.25 - *Boletus edulis* Bull. : Fr., a well-known and sought-after species (Photo AMER).

Global Mycodiversity

Despite their having been established within a kingdom in its own right, and although they form what is probably the second most numerous group of living organisms on earth (after that of the insects), fungi have not received the scientific (and institutional) attention that both their estimated numbers and their ecological importance in the biosphere merits. The scant attention paid to fungi in the debates on biodiversity is mainly due to a lack of awareness among biologists themselves of the importance of fungi to evolution, to ecosystems, to human progress and to Gaia (HAWKSWORTH, 1991). But it is also due to the not negligible difficulties which are intrinsic to mycological study.

To date, about 64,000 fungal species have been described, solely in respect of *Chytridiomycota*, *Zygomycota*, *Ascomycota* and *Basidiomycota*, the *phyla* which are properly included in the *Fungi* Kingdom; in addition there are currently about 16,000 species of anamorphic fungi (*Fungi Imperfecti*) which have been validly described – bringing the overall total to 80,000 species. Awaiting a global Checklist of fungal species considered nomenclaturally valid (this is the objective of the CABI/BPI which forms part of the IUBS/IUMS SPECIES 2000 project), the possibility that the total number of fungal species might reach 100,000, or even, indeed, 150,000, cannot be excluded (KIRK *et al.*, 2001).

The latest edition of *Ainsworth & Bisby's Dictionary of the Fungi* (KIRK *et al.*, l.c.) gives the total number of reported species as 80,060, which includes part of the *Protozoa* and the *Chromista*, with 960 and 889 species respectively, comprising 2.3% of the total (Table 4.14); as regards *Fungi*, the current total of micoflora is 78,211 species, of which 29,914 belong to the *Basidiomycota* (20,391 of these to the *Basidiomycetes* class) and 32,739 belong to the *Ascomycota*.

One school of thought based its study estimating the global total of fungal species on the ratio between the number of plants known for a given locality and the number of fungi found in all the substrates in that locality (not just the fungi found on plants or plant residues). The use of this approach as a basis was a key element in arriving at the estimate of 1.5 million as the global total of fungal species (HAWKSWORTH, 1991, 2001). This study was repeated after a period of 10 years, using updated data, but still comparing the ratio between plants and fungi in different locations across the United Kingdom. Whereas in 1991 this ratio averaged 1:6, in 2001 it averaged between 1:5.4 (excluding microfungi) and 1:8.4 (including microfungi). A simple extrapolation of this latter ratio to the global level, using the estimate of 270,000 species of vascular plants, gives a figure of between approximately 1,5000,000 and 2,300,000 as the estimated total number of fungal species on earth (HAWKSWORTH, 2001).

	Genera	Species	Genera	Species
Protozoa				
Acrasiomycota			6	12
Myxomycota			80	879
Dictyosteliomycetes	4	46		
Myxomycetes	62	798		
Protosteliomycetes	14	35		
Plasmodiophoromycota			15	47
			162	960
Chromista				
Hyphochytriomycota			6	23
Labyrinthulomycota			13	48
Oomycota			92	808
			117	889
Fungi				
Ascomycota			3,409	32,739
Basidiomycota			1,353	29,914
Basidiomycetes	1,037	20,391		
Urediniomycetes	195	8,057		
Ustilaginomycetes	119	1,464		
Chytridiomycota			123	914
Zygomycota			181	1,090
Trichomycetes	55	218		
Zygomycetes	124	870		
Anamorphic fungi			2,887	15,945
				78,211
Total				**80,060**

Table 4.14 - Numbers of fungi currently known in the world (KIRK *et al.*, 2001).

The study of the Italian Mycodiversity

Mycology in Italy boasts a sound and glorious tradition, which can date back to PLINIUS THE OLD (23-79 A.D.) and whose most important representatives are P.A. MICHELI (1679-1737), G. DE NOTARIS (1805-1877), P.A. SACCARDO (1845-1920) and G. BRESADOLA (1847-1929) (ONOFRI *et al.*, 1999).

Many Authors edited local or regional floras which included many fungal species, like the *Flora Ticinensis* (Pavia, 1816-1826) by G.B. BALBIS and D. NOCCA, with 213 fungal species of Lombardia, the *Flora Veronensis* (Verona, 1822-1824) by C. POLLINI, with 400 fungal species of Northern Italy, the two *centuriae* of the *Funghi Siciliani* (Palermo, 1865 and 1879) by G. INZENGA, the *Fungi* *napolitani enumerati* (Portici, 1878) by O. COMES (241 species), the *Fungi Tridentini novi vel nondum delineati* (1881-1892) by G. BRESADOLA, the *Flora Veneta Cryptogamica* (Padova, 1885) by G. BIZZOZERO and the *Primo censimento dei funghi della Liguria* (Genova, 1886) by F. BAGLIETTO (LAZZARI, 1973).

Mention should be made of the work by F. CAVARA, both for his collection of published *exsiccata Fungi Longobardiae exsiccati* (Pavia, 1890-1896), and because he proposed and promoted the *Flora Italica Cryptogama* (1905-1943), edited by the Italian Society of Botany. This work consists of five sections: *Fungi*, *Algae*, *Lichenes*, *Bryophyta*, *Pteridophyta*. The section *Fungi* is the largest one and is divided into many issues, and had the contribution of seven great Mycologists. The issues *Gasterales* (1909) and *Hymeniales* (1915 and 1916) deal with the same taxonomic groups which have been considered in the recently published *Checklist dei funghi italiani* (Checklist of Italian Fungi), and were respectively edited by L. PETRI and P.A. SACCARDO. To cite it as an example, 2,331 species and 263 varieties of *Hymeniales* are listed.

SACCARDO gave an enormous contribution to the international descriptive Mycology, with his highest peak *Sylloge fungorum omnium hucusque cognitorum* (Padova, 1882-1931). Besides his consistent contribution to the *Flora Italica Cryptogama* he published , between 1873 and 1881, a substantial Mycological Flora of the Veneto, *Fungi veneti novi vel critici*, and, between 1877 and 1886, *Fungi italici autographice delineati*, including 1,500 fungal species, mostly microfungi, masterfully illustrated (LAZZARI, 1973).

After the flourishing activity of the period which goes from the end of the nineteenth century to the dawning of the twentieth century, Mycological studies in Italy directed their steps towards morphology, genetics and physiology; only in the last decades the floristic mycology is progressively living an encouraging revival.

Italian Mycodiversity

If we apply the minimum values estimated by HAWKSWORTH (1991, 2001) for the ratios between the number of species of vascular plants and the number of fungi, the total Italian mycoflora should theoretically amount to more than 300,000 species.

Many Italian mycologists felt that the distribution and diversity of fungal species in Italy needed to be established with precision and this led to the compiling of lists and the drawing up of regional and local distributional maps. Among these, the most significant are those realised for Sicilia by VENTURELLA (1991), for Alto Adige by BELLÙ (1992), for Toscana by PERINI *et al.* (1999) and for Liguria by ZOTTI & ORSINO (2001). In 2000 the Ministry for the Environment Land and Sea Protection set up and financed a project at the 'Università degli Studi della Tuscia' in Viterbo, the objective of which was the production of a national Checklist of the *Basidiomycota* (limited to the *Basidiomycetes* Class), the *Check-list dei funghi italiani, Parte I: Basidiomycota, Hymenomycetes* (ONOFRI, 2001). This survey of Italian fungal species was a first and most important step towards obtaining wide-ranging and thorough information on mycodiversity in Italy, though the parasitic *Basidiomycota* known as rusts and smuts, the *Ascomycota*, the *Zygomycota* and the anamorphic fungi (for which the sexual reproduction is not known) were left out. Numerous problems were encountered in realising the project, arising in the main from poor homogeneity of data at the national level and the almost complete lack of data for some regions. This situation can partly be explained by Italy's enormous geographical, climatic, geological, pedological (and therefore biogeographical) and biological variability, which together lead to the non-homogeneous distribution of fungi throughout the country. The variety and variability of climates and habitats are responsible for the extreme richness and diversification of Italian flora in general and its mycoflora is equally diversified (ONOFRI, 1994).

The number of taxa so far recorded in Italy for the *Basidiomycetes* class (*phylum Basidiomycota*) is 4,296 (of which 3,973 are species, 6 subspecies, 263 varieties and 54 forms). This figure comprises about 20% of the total number of species (20,391) known to date in the world for this class. This high percentage is certainly destined to rise still further, considering the extent of Italian national teritory which currently remains unexplored.

The mycodiversity of the *Basidiomycetes* in each of the Italian regions is shown in Figure 4.26.

Still higher is the percentage formed by the genera recognised for Italy, at 443 this comprises 43% of the genera known to date in the world for this class (1,037). Of these 443 genera recognised for Italy, the most numerous group, with 233 genera (52,6%), is that of the order (currently considered an artificial grouping and subdivided into varius orders) *Aphyllophorales*. This is followed by the *Agaricales* with 119 genera (27%). Few of the genera belong to the other orders. While no estimate is available for the number of *Aphyllophorales* genera and species worldwide, a global total of 347 genera and 9,387 species are reported in literature for *Agar-*

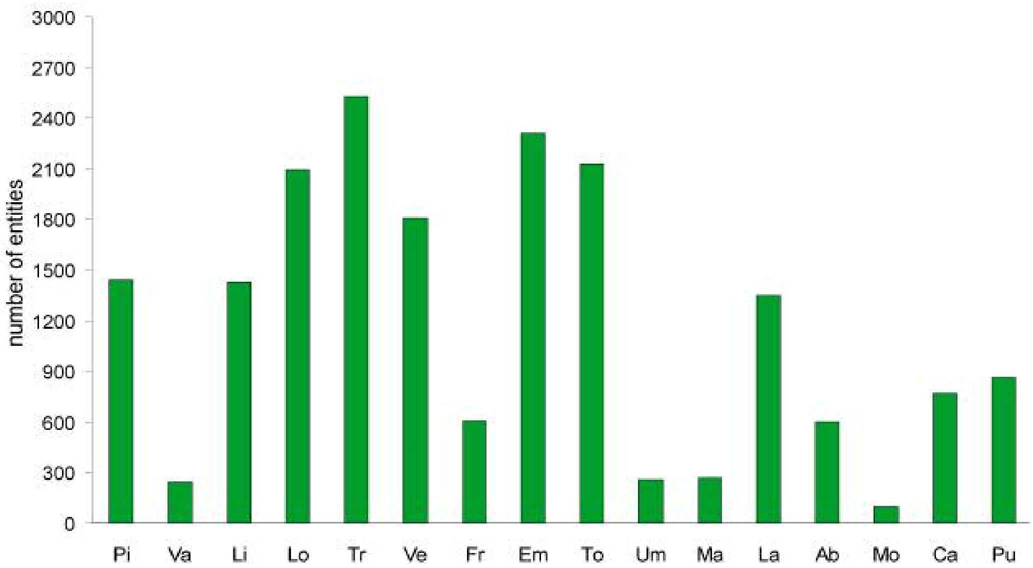

Fig. 4.26 - Number of Basidiomycetes per region.

icales (Kirk *et al.*, 2001); 40% of these current world totals for *Agaricales* genera are to be found in Italy.

As regards the distribution of species among the orders, the highest number of species and infraspecific *taxa*, 1,782, belong to *Agaricales* (41.5% of the Italian *taxa* surveyed). With a global total of 6,000 species, *Agaricales* is the group which is richest in species, not only among the mycoflora of Italy, but also the world. Thus, approximately 30% of the current numbers of known species of *Agaricales* in the world have been recorded in Italy. Following these are *Aphyllophorales*, with 1,047 *taxa* (24% of the Italian *taxa* surveyed), and *Cortinariales*, with 817 *taxa* (19% of the Italian *taxa* surveyed). This number of *taxa* for *Cortinariales* is very high, seeing that it represents 60% of the global total (1,360 species) for the order. This confirms what has already been observed at the European level where, for the *Cortinariales* order, the highest number of species as a proportion of the global total for the group have been recorded (Koune, 1999) - indicating that the order is comprised primarily of European species.

The great diversity and wide distribution of genera and species of fungi in Italy are the consequence of the climatic and edaphic features of the country, as well as of unique biotic factors. It is the environmental factors which determine the distribution of these genera and species in space and time (Perini *et al.*, 1993). In fact, it needs to be stressed that the recognition of fungi is strictly linked to the presence of fruiting bodies, but, as is well known, a lack of fruiting bodies does not necessarily mean that mycelium is totally absent in an area.

According to a study carried out after the publication of *Flora Europaea* (Tutin *et al.*, 1964-1980), Italy is the European country with the highest number of plant species. It could be hypothesised that, to this high level of floristic diversity, corresponds an equally high level of fungal diversity. Unfortunately, not many studies have been performed in the countries of the Mediterranean area to describe in detail the actual amounts of mycoflora present. A first step towards a more thorough study of fungal diversity was taken by Zervakis *et al.* (1998) in Greece. This research led to the compilation of a Checklist of 811 fungal species of the *phylum Basidiomycota*, belonging to 10 orders and 214 genera. Figures such as these in themselves indicate just how provisional the Greek Checklist must be. In fact, this has been confirmed by the authors, who emphasise that the work is preliminary, owing to the fact that few data have been published and such data as there are refer almost exclusively to northern regions of the country. Comparing this Checklist for Greece to the Checklist for Italy, it was noted that tendencies regarding the distribution of genera and species, as far as the orders are concerned, mirrored the situation in Italy. This result is perfectly in accordance with the similarities that exist between the flora and the climates of the two countries, both of which belong to the Mediterranean belt.

Data for the Ascomycetes are also given in the current Checklist of Italian fungi. These result from a local study carried out by the Department of Environmental Sciences of the University of Tuscia, and are thus preliminary data only. The study, nevertheless, enabled a Thesaurus of 532 names of Ascomycetes and 380 synonyms to be compiled and this will prove a useful tool in future studies aimed at updating and broadening data regarding the *phylum Ascomycota*.

Endemic, alien and rare species in Italy

The information contained in the Checklist of Italian fungi also includes data on the ecology of species and whether they are endemic, alien or rare in Italy. On the basis of these preliminary data, 56 species with possible endemic characteristics have been recognised (Table 4.15; Figures 4.27 and 4.28), together with 12 alien species (Table 4.16), while there could be 87 species which are rare, endangered or critically endangered (Table 4.17; Figure 4.29) All information on endemicity, alien status and rarity of these species was obtained from bibliographic sources and/or from the personal evaluations of the revisers of the Checklist, who also indicated taxonomical critical status regarding 406 species of *Basidiomycetes*. However, since this information is based on data which are often incomplete or preliminary, it will need to be checked case by case.

Fig. 4.27 - *Antrodia macrospora* Bernicchia & De Dominicis, a possibly endemic species (Photo by C. Perini).

Fig. 4.28 - *Pleurotus nebrodensis* (Inzenga) Quél., a rare species (Photo by G. Venturella).

Fig. 4.29 - *Cortinarius praestans* (Cordier) Gillet, a possibly rare species in some Italian regions (Photo by C. Perini).

Albatrellus syringae (Parmasto) Pouzar
Aleurodiscus ilexicola Bernicchia & Ryvarden
Alnicola sphagneti (P.D. Orton) Romagn.
Amaurodon viridis (Alb. & Schwein. : Fr.) J. Schröt.
Amphinema diadema K.H. Larss. & Hjortstam
Antrodia alpina (Litsch.) Gilb. & Ryvarden
A. macrospora Bernicchia & De Dominicis
Ceriporia sulphuricolor Bernicchia & Niemelä
Cortinarius anthracinus (Fr.) Fr.
C. aurilicis Chevassut & Trescol
C. cavipes J. Favre
C. emunctus Fr.
C. favrei M.M. Moser
C. gentilis (Fr.) Fr.
C. helvelloides (Fr.) Fr.
C. ionochlorus Maire
C. ionophyllus M.M. Moser
C. ionosmus M.M. Moser, Nespiak & Schwöbel
C. pholideuns (Fr. : Fr.) Fr.
C. porphyropus (Alb. & Schwein.) Fr.
C. subtorvus Lamoure
Dendrothele incrustans (P.A. Lemke) P.A. Lemke
D. nivosa (Höhn. & Litsch.) P.A. Lemke
Dentipellis fragilis (Pers. : Fr.) Donk
Duportella malençonii (Boidin & Lanq.) Hjortstam
Echinodontium ryvardenii Bernicchia & Piga
Entoloma ritae Noorde. & Wölfel
Filobasidiella lutea P. Roberts
Fomitopsis labyrinthica Bernicchia & Ryvarden
Hebeloma ammophylum Bohus
H. bruchetii Bon
H. cistophilum Maire
H. kuehneri Bruchet
H. marinatulum (J. Favre) Bruchet
Hyphoderma orphanellum (Bourdot & Galzin) Donk
Inocybe arenicola (R. Heim) Bon
I. coelestium Kuyper
I. egenula J. Favre
I. geraniodora J. Favre
I. glabrescens Velen.
I. guttulifera Kühner
I. heimii Bon
I. leptophylla G.F. Atk.
I. leucoloma Kühner
I. monochroa J. Favre
I. napipes J.E. Lange
I. ochroalba Bruyl.
I. oreina J. Favre
I. pseudohiulca Kühner
I. salicis Kühner
I. taxocystis (J. Favre) Singer
I. tetragonospora Kühner
I. umbrinodisca Kühner
Piloporia sajanensis (Parmasto) Niemelä
Pleurotus nebrodensis (Inzenga) Quél.
Russula citrinochlora Singer

Table 4.15 - The 56 possibly endemic species belonging to the class *Basidiomycetes*.

Table 4.16 - The 12 alien species and varieties belonging to the class *Basidiomycetes*.

Boletus caucasicus (Singer) Singer
B. dryophilus Thiers
B. frostii J.L. Russell
B. mamorensis Redeuilh
B. speciosus Frost
Conocybe intrusa (Peck) Singer
Cortinarius albocinctus M.M. Moser
C. herculeus Malençon
Entoloma vezzenaense Noordel. & Hauskn.
Favolaschia calocera R. Heim
Suillus amabilis (Peck) Singer
Tricholoma tridentinum Singer var. *cedretorum* Bon

Table 4.17 - The 87 possibly rare species and varieties, at least in some zones of Italy. Some of them should be considered threatened and/or endangered in Italy.

Aleurodiscus botryosus Burt
A. cerussatus (Bres.) Höhn. & Litsch.
A. dextrinoideocerussatus G. Moreno, M.N. Blanco & Manjon
Alnicola sphagneti (P.D. Orton) Romagn.
A. tantilla (J. Favre) Romagn.
Amphinema diadema K.H. Larss. & Hjortstam
Amyloathelia amylacea (Bourdot & Galzin) Hjortstam & Ryvarden
Amylocorticium subincarnatum (Peck) Pouzar
A. subsulphureum (P. Karst.) Pouzar
Antrodia radiculosa (Peck) Gilb. & Ryvarden
Botryobasidium botryoideum (Overh.) Parmasto
B. candicans J. Erikss.
B. conspersum J. Erikss.
Brevicellicium exile (H.S. Jacks.) K.H. Larss. & Hjortstam
Bulbillomyces farinosus (Bres.) Jülick
Ceraceomyces borealis (Romell) J. Erikss. & Ryvarden
C. sulphurinus (P. Karst.) J. Erikss. & Ryvarden
Cerinomyces crustulinus (Bourdot & Galzin) Martin
Ceriporia excelsa (S. Lundell) Parmasto
Ceriporiopsis pannocincta (Romell) Gilb. & Ryvarden
Clavulicium delectabile (H.S. Jacks.) Hjortstam
C. macounii (Burt) J. Erikss. & Boidin
Cortinarius aurantiomarginatus Jul. Schäff.
C. badiovinaceus M.M. Moser
C. bibulus Quél.
C. caesiocinctus Kühner
C. calopus P. Karst.
C. canabarba M.M. Moser
C. colus Fr.
C. croceoconus Fr.
C. fuscoperonatus Kühner
C. gentilis (Fr.) Fr.
C. helobius Romagn.
C. hillieri Rob. Henry
C. ionosmus M.M. Moser, Nespiak & Schwöbel
C. latobalteatus (Schaeff. apud M.M. Moser) M.M. Moser
C. leochrous Schaeff.
C. magicus Eichhirn
C. orellanoides Rob. Henry
C. papulosus Fr.
C. paracephalixus Bohus
C. parvannulatus Kühner
C. patibilis Brandud & Melot
C. pluvius (Fr. : Fr.) Fr.
C. porphyropus (Alb. & Schwein.) Fr.
C. praestans (Cordier) Gillet
C. psammocephalus (Bull.) Fr.
C. pulchripes J. Favre
C. pygmaeus (Velen.) M.M. Moser
C. scaurotraganoides Rob. Henry
C. subporphyropus Pilát
C. terpsichores Melot var. *calosporus* Melot
C. uliginosus Berk.
Cristinia gallica (Pilát) Jülich
C. rhenana Grosse-Brauckm.
Crustoderma dryinum (Berk. & M.A. Curtis) Parmasto
Crustomyces expallens (Bres.) Hjortstam
C. subabruptum (Bourdot & Galzin) Jülich
Cyphellostereum laeve (Fr. : Fr.) D.A. Reid
Cystostereum murraii (Berk. & M.A. Curtis) Pouzar
Dentipellis fragilis (Pers. : Fr.) Donk
Erythricium hypnophilum (P. Karst.) J. Erikss. & Hjortstam
Fibricium rude (P. Karst.) Jülich
F. subceraceum (Hallenb.) Bernicchia
Fomitopsis cajanderi (P. Karst.) Kotl. & Pouzar
Gloecystidiellum karstenii (Bourdot & Galzin) Donk
Hebeloma funariophilum M.M. Moser
H. pyrophilum G. Moreno & M.M. Moser
Hyphoderma litschaueri (Burt) J. Erikss. & Å. Strid
Hypochnicium polonense (Bres.) Å. Strid
Inocybe albomarginata Velen.
I. albovelutipes Stangl
I. amblyspora Kühner
I. fuscescentipes Kühner
I. geraniodora J. Favre
I. glabrescens Velen.
I. huijsmannii Kuyper
I. leptophylla G.F. Atk.
I. oreina J. Favre
I. piceae Stangl & Schwöbel
I. tricolor Kühner
Inonotus dryophilus (Berk.) Murrill
Mucronella flava Corner
Oxyporus corticola (Fr. : Fr.) Ryvarden
Phanerochaete aff. avellanea (Bres.) J.Erikss. & Ryvarden
Phlebia chrysocreas (Berk. & M.A. Curtis) Burds.
Pleurotus nebrodensis (Inzenga) Quél.

References to fungi in the Annexes to the 1979 Berne Convention ('Convention on the Conservation of Wildlife and Natural Environments in Europe') are currently somewhat generic.

In 1993 ING proposed a first list of species to be included in a European Red List. This list drew upon the national and regional lists of some European countries, but it did not include data regarding the countries of the Mediterranean area - Albania, France, Greece, Italy, Portugal and Spain. ING (l.c.) listed 278 macrofungi threatened of extinction or extinct and divided the threatened species into 4 groups, identified as A, B, C and D. The group A included those species which had experienced significant regression, rapid decline in the numbers of population and/or many extinctions at the national level. The group B included species in an evident state of decline and some species in the process of becoming extinct at a national level. The group C included species belonging to fungal populations which had a wide distribution area, but were sparsley distributed within this area, characterised by limited number of cases of extinction. The group D included fungal species showing decreases at a local level and some extinctions, but mainly located at the limits of their geographical distribution area.

In 1997, VENTURELLA *et al.* proposed a provisional list of 23 species of macrofungi which are endangered in Italy (Table 4.18), and assigned all 23 to what was then the IUCN's 'category K'. This category was subsequently changed to DD - Data Deficient, which covers 'taxa which it is supposed are to be included in one of the endangered categories', but for which there is still insufficient information available to justify their being assigned to one of the other IUCN categories. According to the current state of knowledge, endangered species status is con-

Amanita eliae Quél.
Antrodiella onychoides (Egeland) Niemelä
Battarrea phalloides Dicks.: Pers.
Boletus junquilleus (Quél.) Boud.
Cortinarius herculeus Malençon
Cortinarius orellanus (Fr.) Fr.
Dendrothele incrustans (P.A. Lemke) P.A. Lemke
Entoloma madidum (Fr.) Gillet
Gyrodontium sacchari (Spreng.) Hjortstam
Hebeloma hiemale Bres.
Hebeloma remyi Bruchet
Hygrocybe calyptriformis (Berk. & Broome) Fayod
Hygrocybe spadicea (Scop.: Fr.) P. Karst.
Inocybe tricolor Kühner
Junghuhnia semisupiniformis (Murr.) Ryvarden
Leucopaxillus lepistoides (Maire) Singer
Lycoperdon mammeiforme Pers.
Melanophyllum eyrei (Massal.) Singer
Panaeolus dunensis Bon & Courtec.
Rhodotus palmatus (Bull. Fr.) Maire
Russula seperina Dupain
Torrendia pulchella Bres.
Trametes ljubarskyi Pilát

Table 4.18 - Endangered macrofungi in Italy.

Fig. 4.30 - *Trametes versicolor* (L. : Fr.) Pilát (Photo by S. Onofri).

Fig. 4.31 - *Ganoderma lucidum* (Curtis : Fr.) P. Karst. (Photo by S. Onofri).

Fig. 4.32 - *Suillus granulatus* (L. : Fr.) Roussel (Photo by S. Onofri).

Fig. 4.33 - *Gyroporus castaneus* (Bull. : Fr.) Quél. (Photo by S. Onofri).

firmed only for *Inocybe tricolor*. After having integrated existing data and those resulting from research currently in progress, a Red List of Italian fungi species and their habitats will emerge.

Conservation problems

The mycoflora of Italy is extremely diversified in species, varieties and forms. The groupings considered consist mainly of species with sporophores of significant dimensions, and the greater part of the data collected on Italian national territory refers to such species. The reason for this is partly because it is easier to find such fungi and identify them taxonomically, but it is also because there are often economic and commercial interests attached to such fungi. The data that are available provide a 'snapshot' of the current state of knowledge on the mycodiversity of Italy. However, these data are influenced to some degree by the non-homogenous distribution of mycologists throughout Italy and this highlights the need for in-depth research in those regions which have been little explored to date. The availability of up-to-date lists of the Italian fungi species, of their distribution maps, of their ecological data as well as of Red Lists of Fungi will make it possible to assess the overall naturalistic value of the habitats. Fungi are frequently a most sensible component of the biocoenoses in terms of environmental changes. For example, the disappearance of micorrhyzal fungal species in forestal environments, caused by changes of acidity or increase of toxic soil cations, can reveal a severe decay of the wood, as a direct outcome of the damage for the same fungus. Yet, this use of the mycological knowledge is based upon the existence of lots of verified data on the occurrence and role of species living in healthy environments; we need to collect these data quite soon. In fact, it has been proposed to use the data on natural communities of fungi for the biomonitoring of atmospheric pollution and heavy metal contamination (ONOFRI & ZUCCONI, 1999).

Although there are bibliographic data about the heavy metal accumulation performed by several fungi, both mycorrhyzal and non-mycorrhyzal, the possibility that certain species could serve as effective indicators is not taken into account by the Authors (MICHELOT *et al.*, 1998). On the contrary, the analysis of the decrease of mycodiversity in relation with environmental pollutions seems to be more realistic and applicative. This decrease reveals itself 5 to 10 years before the decline of the forest communities; this sensitivity gives the fungal communities the outlook of an important applicative role.

Some European researchers suggested to use the mycorrhyzation index (*i.e.* the ratio between the percentage of mycorrhyzal fungi and all the macrofungi) as indicator of the pollution of woods; this ratio is in fact much lower in the polluted areas (FELLNER, 1993). Yet, it seems this index does not work for the Mediterranean area, where the number of mycorrhizal species is significantly correlated to other more environmental parameters, such as height, number of plant species and tree coverage (LAGANÀ *et al.*, 1999).

The current climate change, which is partly due to the human activities, affects the fungal communities both indirectly, by changing the plant environment, and directly, by making easier the substitution of native species with more thermophilous ones. Monitoring the changes of the distribution areas of fungal species and the transgression of alien species, provides data which could also be a valid reference for the study and monitoring of the effects of climate change, as VAN HERK *et al.* (2002) proposed for lichens.

It is anyway plain that the habitat destruction is the primary cause of the decline of fungal species, therefore the conservation of rare or endangered species necessarily passes through the protection of their typical habitats. This obvious remark often clashes with the poor knowledge of the actual habitat of these species. Here the Checklist, which quotes also the habitats where the species are found, becomes an indispensable conservation tool.

The setting up of mycological reserves is a valid initiative for the conservation of fungal species, above all because it allows to preserve the habitats where these species live (COURTECUISSE, 2001).

We must also remember the cultivation of fungi, like in the case of *Pleurotus nebrodensis* (Inzenga) in Sicilia, which leads to the conservation of an edible, much looked for, rare and endangered species, by means of the *ex situ* conservation but, most of all, by reducing the collecting pressure (VENTURELLA & FERRI, 2001; ZERVAKIS & VENTURELLA, 2002).

Often the spontaneous fungi are a source of income and frequently they are part of the cultural tradition of some folks. In these cases a sustainable use of the fungi as a resource must be planned, both by searching an option to the collection, as for *P. nebrodensis*, and by regulating the collection itself. Anyway, while respecting customs, traditions and economic activities, we must remind that:

collecting the sporophores of any single species affects its own reproduction;

the simple human pressure of the collectors has a negative influence on all the fungal species occurring in the habitat, including the ones whose collection is forbidden. The allowed amount of collection must be therefore assessed for each case, for each species and for each zone, keeping into account the effects at a short, medium and long term. For this purpose it can be supposed the identifying of integral protection areas as sites for conservation and comparison.

Fig. 4.34 - *Amanita vaginata* (Bull. : Fr.) Vittad. (Photo AMER).

Fig. 4.35 - *Amanita phalloides* (Fr.) Link (Photo AMER).

Bibliography

BELLÙ F., 1992 – *Mapping and cartography of macrofungi in Alto Adige*. Giornale Botanico Italiano, 126: 707-803.

COURTECUISSE R., 2001 – *Current trends and perspectives for the global conservation on fungi*. In: MOORE D., NAUTA M.M., EVANS S. E., ROTHEROE M., (eds.), *Fungal Conservation. Issues and Solutions*. Cambridge University Press, UK, pp. 7-18.

EUROPEAN COUNCIL FOR THE CONSERVATION OF FUNGI (ECCF), KOUNE J.P., 2001 – *Datasheets of threatened mushrooms of Europe, candidates for listing in Appendix I of the Convention*. Strasbourg.

FELLNER R., 1993 – *Air pollution and mycorrhizal fungi in central Europe*. In: PEGLER D.N., BODDY L., ING B, KIRK P.M., (eds.), *Fungi of Europe: Investigation Recording and Conservation*, Royal Botanical Garden, Kew, U.K., pp. 239-250.

HAWKSWORTH D.L., 1991 – *The fungal dimension of biodiversity: magnitude, significance and conservation*. Mycological Research, 95: 641-655.

HAWKSWORTH D.L., 2001 – *The magnitude of fungal diversity: the 1.5 million species estimate revised*. Mycological Research, 105: 1422-1432.

HERK C.M. VAN, APTROOT A., VAN DOBBEN H.F., 2002 – *Long-term monitoring in the Netherlands suggests that lichens respond to global warming*. Lichenologist, 34: 141-154.

ING B., 1993 – *Towards a red list of endangered Eurpean macrofungi*. In: PEGLER D.N., BODDY L., ING B., KIRK P.M., (eds.) *Fungi of Europe: Investigation Recording and Conservation*, pp. 231-237. Royal Botanical Garden, Kew, U.K.

KIRK P.M., CANNON P.F., DAVID J.C, STALPERS J.A., 2001 – *Ainsworth & Bisby's Dictionary of the Fungi*. Ninth Edition. CABI Bioscience, CAB International, Wallingford, U.K.

KOUNE J.P., 1999 – *Étude sur les champignons menacés en Europe*. Strasbourg.

LAZZARI G., 1973 – *Storia della Micologia Italiana*. Arti Grafiche Saturnia, Trento.

LAGANÀ A., LOPPI S., DE DOMINICIS V., 1999 – *Relationship between environmental factors and the proportions of fungal trophic groups in forest ecosystems of the central Mediterranean area.* Forest Ecology and Management, 124: 145-151.

MICHELOT D., SIOBUD E., DORÉ J.-C., VIEL C., POIRIER F., 1998 – *Update on metal content profiles in mushrooms – Toxicological implications and tentative approach to the mechanisms of bioaccumulation.* Toxicon, 36: 1997-2012.

ONOFRI S., 1994 – *Il programma di censimento e cartografia delle specie fungine in Italia.* Micologia Italiana, 2: 23-26.

ONOFRI S. (coordinatore), 2001 – *Check-list delle specie fungine italiane. Parte I.* Basidiomycota, Hymenomycetes. Ministero dell'Ambiente, Servizio Conservazione della Natura.

ONOFRI S., GRANITI A., ZUCCONI L., 1999 – *Italians in the History of Mycology.* Mycotaxon Ltd., Ithaca, NY.

ONOFRI S., ZUCCONI L., 1999 – *Funghi e metalli pesanti, bioindicazione, bioaccumulo e biorisanamento.* In: PICCINI C., SALVATI S. (eds.), Atti del workshop *Biomonitoraggio della qualità dell'aria sul territorio nazionale*, pp. 155-170. Roma, 26-27 novembre 1998.

PERINI C., BARLUZZI C., GOVI G., 1993 – *Evoluzione del progetto di mappatura dei macromiceti in Italia.* Micologia Italiana, 3: 37-44.

PERINI C., NARDUCCI R., BARLUZZI C., LAGANÀ A., SALEMI E., 1999 – *I funghi in Toscana. Allegato 1. Elenco delle specie censite in Toscana.* In: TOFACCHI L., MANNINI M., *I funghi in Toscana. Mappatura e censimento dei macromiceti epigei*, pp. 73-98. ARSIA Regione Toscana e Associazione Gruppi Micologici Toscani.

SCHÜßLER A., SCHWARZOTT D., WALKER C., 2001 – *A new fungal phylum, the* Glomeromycota*: phylogeny and evolution.* Mycological Research, 105: 1413-1421.

TUTIN T.G., HEYWOOD V.H., BURGES N.A., VALENTINE D.H., WALTERS S.M., WEBB D.A., 1964-1980 – *Flora Europaea.* Voll. 1-5. Cambridge University Press, Cambridge.

VENTURELLA G., 1991 – *A checklist of Sicilian fungi.* Bocconea, 2: 5-221.

VENTURELLA G., PERINI C., BARLUZZI C., PACIONI G., BERNICCHIA A., PADOVAN F., QUADRACCIA L., ONOFRI. S., 1997 – *Towards a Red Data List of fungi for Italy.* Bocconea, 5: 867-872.

VENTURELLA G., FERRI F., 2001 – *Progetto FUNGIS. Progetto di Sviluppo per la funghicoltura in Sicilia.* Palermo, pp. 118.

WHITTAKER R.H., 1969 – *New concepts of kingdoms of organisms.* Science, 163: 150-160.

ZERVAKIS G., DIMOU D., BALIS C., 1998 – *A Check-list of the Greek macrofungi including hosts and biogeographic distribution: I.* Basidiomycotina. Mycotaxon, 66: 273-336.

ZERVAKIS G., VENTURELLA G., 2002 – *Mushroom breeding and cultivation enhances* ex situ *conservation of Mediterranean* Pleurotus *taxa.* In: ENGELS J.M.M., RAMANATHA RAO V., BROWN A.H.D., JACKSON M.T. (eds.), *Managing Plant Genetic Diversity*, pp. 351-358. CABI Publishing, CAB International, U.K.

ZOTTI M., ORSINO F., 2001 – *The check-list of Ligurian macrofungi.* Flora Mediterranea, 11: 115-294.

LICHENS

[Pier Luigi Nimis, Stefano Martellos]

Lichens (Plate 4.1) are mushrooms (Ascomycetes, more rarely Basidiomycetes) living symbiotically with a large number of photosynthetic organisms (cyanobacteria and/or green algae). From a taxonomic point of view, they belong to the Kingdom *Fungi*; that's why they are often called 'lichenized fungi'. On a planetary level the species described so far are approximately 16,000 (HAWKSWORTH, 1991). Lichens can grow on a wide variety of substrates: rocks, barks, wood, soil, leaves. They are the last representatives of plant life in the polar regions and resistance to the most extreme climates is possible only by means of the lichenic symbiosis: the single mushroom or alga would never survive autonomously. Lichens are excellent biological indicators, too: they are extremely sensitive to different types of atmospheric pollution and are able to accumulate trace metals; some species act as indicators of long-term ecological continuity within forests. Lichens also play a relevant role in the biodeterioration of stone monuments - a deeply felt problem in our country. Most people link the word 'lichen' to arctic and boreal ecosystems, where lichens are frequently the dominant landscape elements. Thus it could come as a surprise that Italy, with more than 2,300 species – 14.4% of the world's lichen flora – is one of the European countries with the highest lichen diversity.

Lichenology in Italy: an historical outline

In Italy the studies on lichenized fungi boast a tradition dating back to the founder of lichenology as a science: P.A. MICHELI (1679-1737), who put forward for the first time in his *Nova Plantarum Genera* of 1729 a classification system for lichens. In the midst of the 19th century, for a short though intense period, Italy came to be the seat of the main European lichenological school. The dominant figures of the 'golden period' of Italian lichenology (NIMIS & BARTOLI, 1992) were G. DE NOTARIS (1805-1877), V. TREVISAN (1818-1897), A. MASSALONGO (1824-1860), M. ANZI (1812-1883) and F. BAGLIETTO (1826-1916). Especially the latter two produced some of the best floristic studies ever conducted in Italy (Liguria, Sardegna, Toscana, western and central Alps). The 'golden period' only lasted a few years, from 1846 to 1880, after which a rapid decline culminated in the near extinction of the Italian lichenological school at the start of 1900's. The last years of the century were dominated by the figure of A. JATTA (1852-1912), who undertook the systematic exploration of southern Italy and who published the first and only lichenological flora of Italy, at the beginning of the new century (JATTA, 1909-11). Certainly significant as a work of synthesis, it needed subsequent improvement and integration on the part of a new generation of lichenologists. Unfortunately the Italian lichenological school was about to fade away and nowadays JATTA'S flora still stands as a sad memorial to the 'golden period' of Italian lichenology.

In the first half of the 20th century only a handful of names represent Italian lichenology: C. SBARBARO (1888-1967), M. CENGIA-SAMBO (1888-1939) and R. TOMASELLI (1920-1982). After the Second World War the study of lichens came to be one of the liveliest and most interesting branches of Botany at international level. In 1987 a few Italian researchers decided to set up the Italian Lichenological Society (SLI), which had unexpected success, rapidly growing to over 300 members. Nowadays Italian lichenology can be said to have experienced a true revival and the number of floristic and ecological publications, both fundamental and applied (bioindication and biodeterioration of monuments), is on the continuous rise.

Lichen diversity in Italy

The first modern list of Italian lichens was the annotated checklist by NIMIS (1993), reporting 2,145 infrageneric taxa together with their regional distribution, as derived from a literature search focused on the period from 1800 up to 1992. The checklist has evolved into a complex database, accessible online (*ITALIC*) since 1999. The stored data, however, have not been updated with respect to the intense lichenologic researches that have been conducted in Italy over the last ten years, nor with respect to systematics progress at international level. The following figures refer back to the last update by NIMIS and TRETIACH (1999) as well as to unpublished data not yet included in *ITALIC*. By the end of 2002 the total number of known species in Italy reached 2,323 taxa. Crustose lichens, with their 69.2%, represent the vast majority of those present in Italy, followed by the foliose (13.8%), fruticose (10.9%), squamulose (5%) and leprose (1.1%). As for the photosynthetic partners, 79% of all Italian lichens are involved in symbiosis with *Chlorococcales* green algae, 9% with green algae of the genus *Trentepohlia* and 12% with *Cyanobacteria*. The figure of approximately 2,300-2,400 species probably constitutes a proper assessment of the country's lichen diversity. Many

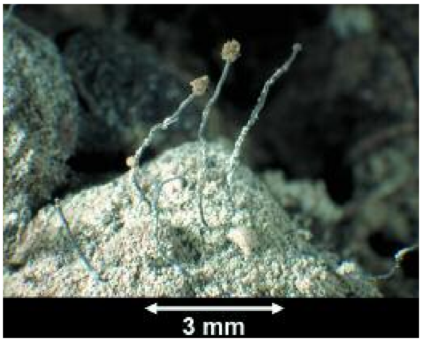

Tavola 4.1*a*

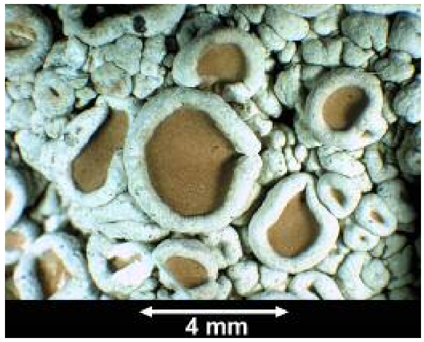

Tavola 4.1*b*

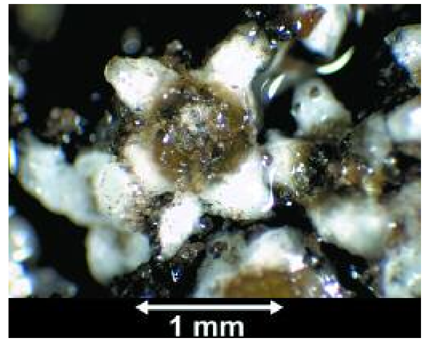

Tavola 4.1*c*

Tavola 4.1*d*

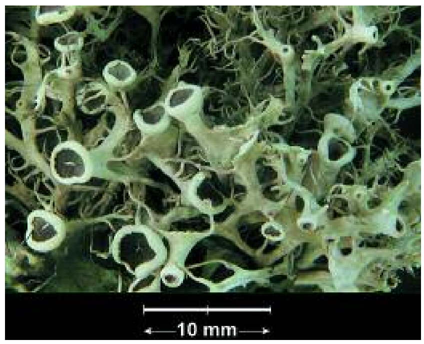

Tavola 4.1*e*

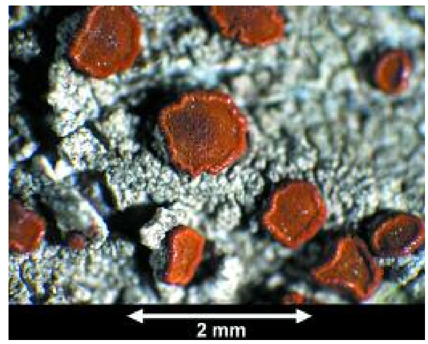

Tavola 4.1*f*

Plate 4.1 - *a. Chaenotheca gracilenta*, a representative of the 'pin-lichens' (*Caliciales*), often employed as indicators of prolonged ecological continuità of forest; *b. Ochrolechia balcanica*, a typical crusty lichen of the beech forests of central-northern Italy; *c. Solorinella asteriscus*, an extremely rare terricolous lichen with steppic-continental affinity restricted to few alpine valleys with dry climate; *d. Xanthoria fallax*, a common foliose lichen growing on isolated trees in environments rather affected by human activities; *e. Anaptychia ciliaris*, an epiphyte lichen still common in the Apennines, yet rapidly declining in northern Italy; *f. Caloplaca ferruginea*, a crusty lichen rather common over the old oaks in unpolluted environments.

species described during the last century and not critically revised will be added on the list of synonyms, but numerous species will also be discovered in Italy that are present in the surrounding countries. Italy's high lichen biodiversity comes as a result of it extending across two biomes, the temperate and the mediterranean, with the respective orobiomes and with a great variety of lithic substrates and different climate types.

Lichen exploration of the country has not been homogeneous: Trentino-Alto Adige, Lombardia, Piemonte and Sardegna are the better studied regions, with more than 1,000 species, the regions along the Adriatic side being the less studied. Figure 4.36 shows the rapid progress of lichen exploration of Italy from 1992 to 1999. Northern Italy is one of the most thoroughly explored areas of the world to date, whereas much remains to be done for Central and especially for Southern Italy.

The phytogeographic structure of Italian lichen flora was analyzed by NIMIS and TRETIACH (1995). Lichens, as opposed to other organisms, have rather wide distribution areas, frequently spanning over more than one continent. Thus it is hard to identify phytogeographic elements defined on the basis of their total distribution, also because many parts of the globe are yet to be explored. On the other hand, a subdivision based upon latitude and longitude extension is more feasible: thermal requirements being essentially reflected in the former case, hydrological requirements in the latter. According to NIMIS and TRETIACH (1995) Italian flora is composed of the following main phytoclimatic elements:

a) a temperate element with no affinity for suboceanic climate types, well represented over the whole country (38% of the total),
b) an element with subtropical affinities, tied to (sub)oceanic climate types, more frequent along Tyrrhenian coasts and on the islands (approx. 20% of the total),
c) a northern element, confined on the higher mountains, with a tendency to deplete itself out from the Alps to the southern mountains (approx. 25%),
d) a group of species with distribution areas restricted

to Southern European mountains, especially to the Alps (7%),

e) a group of species extending from the Canary Islands to the Mediterranean and at times to the Atlantic coasts of Europe, in Italy mainly exhibiting Tyrrhenian lowland and upland distribution areas (7%),

f) another small group of widely distributed species in arid environments of various continents, in Italy more common over the drier areas of the South and in the alpine valleys with a subcontinental climate (2%).

The lack of a specific Mediterranean element, in contrast to the vascular flora, could come as a surprise. The Mediterranean-Macaronesic (e) is the one coming closer, but it is hard to keep it distinct from the Mediterranean-Atlantic or general suboceanic types.

The general picture well reflects the climatic diversity of the country, with climates ranging from the cold alpine to the hot suboceanic; temperate to hot, moderately humid climate is clearly predominant, with truly arid climate types being poorly represented, in spite of a droughty summer season present in a few southern areas.

Territorial distribution of the phytoclimatic groups is not uniform throughout. Prevalence of the northern element in the regions of the north is obvious, less so is the east-to-west gradient running the length of the peninsula: the Tyrrhenian regions, open to the humid western currents, are home to a large percentage of species of the subtropical-suboceanic type, far less frequent along the Adriatic side. Lichens, whose metabolism strongly depends on atmospheric humidity, mirror quite well the climatic differences along the two sides of the peninsula. An example of 'Tyrrhenian' distribution is shown in Figure 4.37.

Lichen vegetation in Italy

If Italian lichen flora is rather well studied, not the same can be said for the vegetation aspects. Lichens give rise to rather easily distinguishable communities, frequently bearing forth interesting ecological or phytoclimatic data. Vegetation studies on the Italian territory however are quite spare.

Terricolous communities: Prevalently terricolous or muscicolous lichens constitute 16% of Italian flora. On acid soils northern species prevail: 26.1% of the arctic-alpine species grows on acid substrates, 15.9% on basic substrates. Southern temperate species and those widely distributed over semi-desert areas rather grow more abundantly on calcareous substrate, where they respectively add up to 10.8% and 26.3% of the total (acidophiles amount respectively to 4.3% and 5.3%). In Italy terricolous communities are usually fragmented and frequently dominated by crustose or squamulose lichens, thus only quite rarely attaining the splendour they take on in arctic tundras. Terricolous lichens grow slowly and hence are quite sensitive to disturbance. Terricolous lichen vegetation is still rather well preserved along the alpine belt of the Alps, whereas well developed communities are only a rarity along the Apennines and Mediterranean Italy, due to the heavy stamping brought about by grazing and anthropic pressure, especially along the coasts.

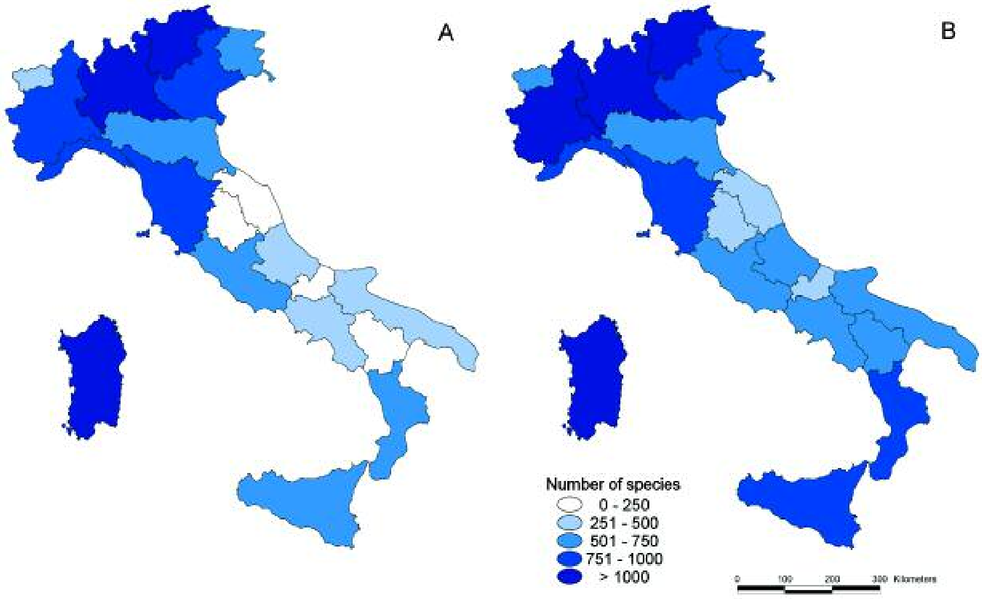

Fig. 4.36 - Improvements in the lichenological exploring in Italy from 1992 (A) to 1999 (B).

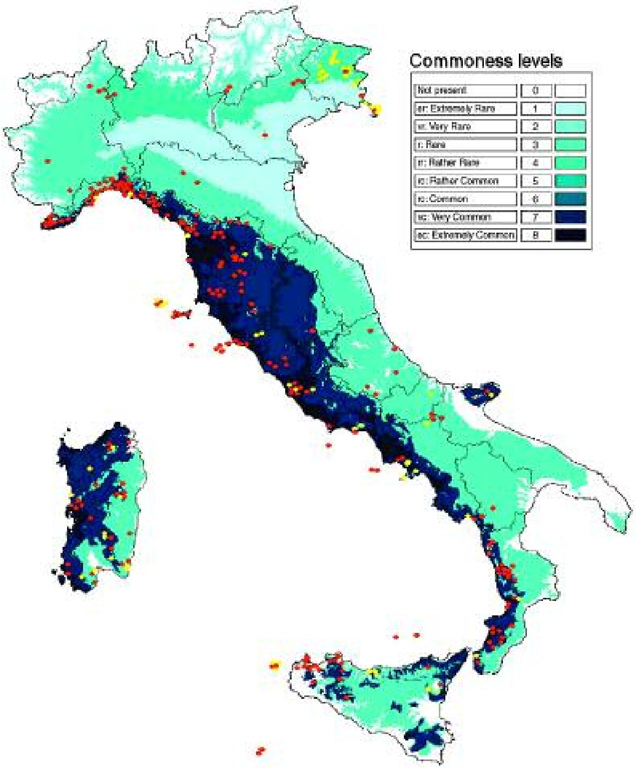

Fig. 4.37 - Distribution map of a typical 'Thyrrenian' lichen: *Parmotrema chinense* (Osbeck) Hale & Ahti. Red dots are bibliographical data, yellow dots are herbarium specimens of the Herbarium of (TSB), the different shades of blue specify the frequency of the lichen in the Italian bioclimatic regions, automatically calculated by the database *ITALIC*. Similar maps are available on the Web for all the Italian species and can be updated in real time.

Epiphytic communities: Prevalently epiphytic species constitute just about a third of Italian lichen flora (33.4%). Phytogeographic differentiation according to the substrate occurs also in this case; lichens on neutral-basic tree bark amount to just 5.3% of all epiphytic ones and the majority possess southern type distribution areas. On acid bark instead, 37% of all boreal and mountain species grows, as well as 40% of temperate species projecting to the boreal zone, while strictly southern species are of minor occurrence. Epiphytic vegetation is extremely varied: many communities connected to forests with long-term ecological continuity are subject to marked regression, whereas others connected to human activities have been the object of numerous air quality monitoring studies.

Saxicolous communities: Lichens establishing colonies on lithic substrates represent a clear cut majority of Italian flora (50.6% of the total, 31.1% on siliceous rocks, 19.5% on calcareous rocks). Also in this case on acid substrates northern species prevail, southern species on basic ones: 42.9% arctic and alpine lichens of Italian flora colonize siliceous rocks, just 13.2% calcareous rocks; on the contrary, 52% of submediterranean species is calcicolous and only 18.6% silicicolous; the same stands true for temperate species with southern distribution (45.2% on calcareous rocks, 11.8% on siliceous rocks). Saxicolous vegetation is unquestionably the least studied, not only in Italy, in so far as it is home to numerous small sized crustose species, frequently belonging to critical groups. However it takes on considerable significance in the bioalteration of stone monuments (Figure 4.38).

Many lichen species all over Europe are suffering marked decline. Lichen vegetation on the Alps and the Apennines however is still in good condition and does not appear to have been particularly damaged by the acid rains that have destroyed the lichen flora of other European countries, especially in Eastern Europe. There are three categories of more endangered species (Nimis, 1992):

1) Epiphytic suboceanic lichens, peaking in abundance in semi natural type of forest vegetation. They are the most sensitive to atmospheric pollution, to which the disappearance of optimum habitats must be added as a consequence of forest management activities.
2) Terricolous lichens of the Mediterranean zone. They end up as being greatly endangered by intense uncontrolled tourism, inland sheep farming and fires.
3) Coastal lichens: particularly endangered, as they are subject to growing tourist pressure on Italian coasts.

Fig. 4.38 - Chromatic change caused by a dense population of lichens on a stony monument (Photo by M. Tretiach).

LICHENS AS BIOINDICATORS

[Pier Luigi Nimis, Stefano Martellos]

Lichens are commonly employed to assess air quality: as bioindicators they supply informations on phytotoxic gas concentrations, as bioaccumulators they enable the exposure of trace metals deposition patterns (NIMIS *et al.*, 2002). Lichen based biomonitoring studies have been quite numerous in Italy (LOPPI, 1999; PIERVITTORI, 1999) and have shown how over vast zones (the Padano-Veneta plain, for instance) atmospheric pollution has greatly impoverished the original flora (Figure 1).

The problems posed by lichen growth on stone artworks have only recently begun to be addressed exhaustively (NIMIS *et al.*, 1992). Researches have inquired into many different aspects, among which the following are the most relevant: a) chemical/physical decay connected to the production of both acids and chelating compounds; b) comparison among single species effects in different environmental situations; c) ecological study of lichen vegetation to bring forward the causes leading to the onset of different colonization patterns; d) biocide application in order to control and/or eliminate lichen growth (NIMIS, 2001).

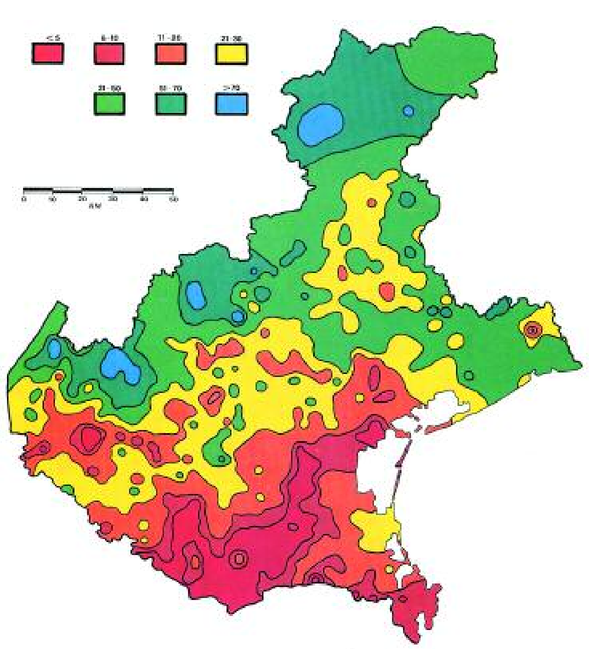

Fig. 1 - Map of lichen diversity in the entire Veneto region, as of the year 1989 (NIMIS *et al.*, 1991). Low values of diversity denote low air quality.

LOPPI S., 1999 – *Licheni come bioaccumulatori di elementi in tracce: stato dell'arte in Italia.* In: PICCINI C., SALVATI S. (eds.), *Proc. Workshop 'Biomonitoraggio della qualità dell'aria sul territorio Nazionale'*, ANPA, Roma: 123-143.

NIMIS P.L., MARTELLOS S., 2002 – *ITALIC - the information system on Italian lichens.* Bibliotheca Lichenologica, 82: 271-283.

NIMIS P.L., PINNA D., SALVADORI O., 1992 – *Licheni e Monumenti.* Clueb, Bologna. 164 pp.

PIERVITTORI R., 1999 – *Licheni come bioindicatori della qualità dell'aria: stato dell'arte in Italia.* In: PICCINI C., SALVATI S. (eds.), *Proc. Workshop 'Biomonitoraggio della qualità dell'aria sul territorio Nazionale'*, ANPA, Roma: 97-122.

NIMIS P.L., 2001 – *Artistic and Historical Monuments: Threatened Ecosystems.* In: Frontiers of Life, Part 2: Discovery and Spoliation of the Biosphere, sect. 2: Man and the Environment, Academic Press, S. Diego Ca, pp. 557-569.

Bibliography

JATTA, 1909-1911 – *Flora Italica Cryptogama, pars III. Lichenes*. Cappelli. Rocca di S. Casciano, 958 pp.

HAWKSWORTH D.L., 1991 – *The fungal dimension of biodiversity: magnitude, significance and conservation*. Mycological Research 95: 641–655.

NIMIS P.L., 1992 – *Lista rossa dei Licheni d'Italia*. In: Libro rosso delle Piante d'Italia. WWF. Roma: 501-556.

NIMIS P.L., 1993 – *The Lichens of Italy. An Annotated Catalogue*. Mus. Reg. Sc. Nat. Torino, Monogr. 12, 897 pp.

NIMIS P.L., 2000 – *Checklist of the Lichens of Italy 2.0.* University of Trieste, Dept. of Biology, IN2.0/2.

NIMIS P.L., 2001 – *Artistic and Historical Monuments: Threatened Ecosystems.* In: Frontiers of Life, Part 2.

NIMIS P.L., BARTOLI A., 1992 – *Il ruolo di G. de Notaris nella storia della Lichenologia.* In: A. GRANITI (ed.), La figura e l'Opera di de Notaris. Acc. Naz. Scienze, Pallanza: 123-133.

NIMIS P.L., MARTELLOS S., 2002 – *ITALIC - the information system on Italian lichens.* Bibliotheca Lichenologica, 82: 271-283.

NIMIS P.L., TRETIACH M., 1995 – *The lichens of Italy. A phytoclimatic outline* Cryptogamic Botany, 5: 199-208.

NIMIS P.L., TRETIACH M., 1999 – *Itinera Adriatica. Lichens from the eastern part of the Italian peninsula.* Studia Geobotanica, 18: 51-106.

NIMIS P.L., LAZZARIN A.G., GASPARO D., 1991 – *Lichens as bioindicators of SO_2 pollution in the Veneto Region (NE Italy).* Studia Geobotanica, 11: 3-76.

NIMIS P.L., SCHEIDEGGER CH., WOLSELEY P.A. (eds.), 2002 – *Monitoring with Lichens - Monitoring Lichens.* Kluwer, NATO Science Series 7, 408 pp.

FRESHWATER ALGAE

[Nadia Abdelahad, Giorgio Bazzichelli]

The modern word ‘alga’ comes from the Latin *alga*, the meaning of which was ‘aquatic plant’ in the broad sense. In LINNAEUS’s system (1754), algae figure as one of the four classes encompassed by the *Cryptogamia* division – *(Algae, Fungi, Musci, Filices)*. The term appears again in the taxonomic scheme of EICHLER (1883), as one of the three classes (*Algae*, *Fungi* and *Lichenes*) of the *Tallophyta* division. In 1903 – by which time it had been realised just how heterogeneous and complex the organisms referred to by the term, in fact, were – ‘*Algae*’ were divided among nine different divisions (ENGLER, 1903). Since then various systems of classification have been proposed for these organisms. A recent scheme (VAN DEN HOEK *et al*, 1995) still provides for ten or so different divisions. The main criteria for distinguishing among algae are: 1) photosynthetic pigment type on which basis the following are distinguished: ‘blue algae’ (*Cyanobacteria*), ‘red’ (*Rhodophyceae*), ‘golden’ (*Chrysophyceae*), ‘brown’ (*Phaeophyceae*) and ‘green’ (*Chlorophyceae*); 2) the cytoskeleton (flagellar roots and type of mytosis); 3) the presence or absence of endoplasmic reticulum membranes around the chloroplast; 4) the mode of reproduction. Algae differ enormously from each other, not only in respect of features such as those just mentioned (biochemical, ultrastructural *etc.*), but also as regards morphology, the organization and dimensions of the thallus which can vary from a few thousandths of a millimetre (as for example in phytoplanktonic algae) up to several tens of metres (as in the great brown algae of the cold seas).

Algae can colonise a huge variety of types of environment (seas, lakes, pools, peat-bogs, rivers, thermal springs, snow, soils, cliffs, *etc.*). Examples of characteristic species occurring in two of these environments (calcareous cliffs and alpine pools) are given in Plates 4.2 and 4.3.

Algae participate in many kinds of symbiosis, not only with fungi in lichens, but also with various animals and some plants. Algae are ecologically important as primary producers and as producers of oxygen in seas and lakes. Of particular interest are those algae which can bloom and those which produce toxins. Many algae species also attract economic interest, in the fields of alimentation, pharmaceuticals, cosmetics and, recently, even as a possible source of alternative energy.

Freshwater algae in Italy

Between the middle of the nineteenth century and today about one thousand studies have been published in Italy in the field of freshwater algology. The first studies of importance were those of DE NOTARIS (1867) and DELPONTE (1877) on the *Desmidiaceae* and the studies by FORTI on the diatoms [*e.g.* the diatomological studies of the Canavese lakes (FORTI, 1900-1901)]. Lacustrine environments have been studied most, followed by rivers, thermal springs, peat-bogs, pools, rice fields and cliffs. Comprehensive summaries of limnological research in Italy are contained in CORDELLA & PAGANELLI (1988) and in GUILIZZONI *et al.* (1992).

A complete list of freshwater algae in Italy does not yet exist. The first lists, limited to a few regions, appeared in the second half of the nineteenth century as part of catalogues dealing with all the cryptogams [ZANARDINI (1857), HOHENBÜHEL-HEUFLER (1871), PICCONE (1878), BIZZOZERO (1885) and others]. The data contained in these lists were subsequently used by DE TONI in compiling his monumental *Sylloge* (1889-1924). For the next century, no list of freshwater algae in Italy was published.

Recently, two lists of *Desmidiaceae* (*Chlorophyta*) have been published. The first, regarding Trentino-Alto Adige, contains 407 *taxa* belonging to 22 different genera (DELL’UOMO, 1991). The second, which regards the entire peninsula, contains 764 *taxa* belonging to 30 different genera (Table 4.19), and indicates the number of species and reports for each region (Table 4.20) (ABDELAHAD *et al.*, 2003).

	N. of *taxa*
Cosmarium	339
Staurastrum	149
Closterium	74
Euastrum	46
Actinotaenium	20
Xanthidium	19
Staurodesmus	18
Micrasterias	17
Pleurotaenium	11
Desmidium	9
Netrium	7
Penium	6
Spondylosium	6
Sphaerozosma	5
Cylindrocystis	4
Gonatozygon	4
Hyalotheca	4
Mesotaenium	4
Tetmemorus	4
Teilingia	3
Arthrodesmus	2
Docidium	2
Haplotaenium	2
Polytaenia	2
Roya	2
Bambusina	1
Euastridium	1
Genicularia	1
Heimansia	1
Spirotaenia	1
Total	**764**

Table 4.19 - Number of *taxa* of *Desmidiaceae* reported for Italy from 1837 to date.

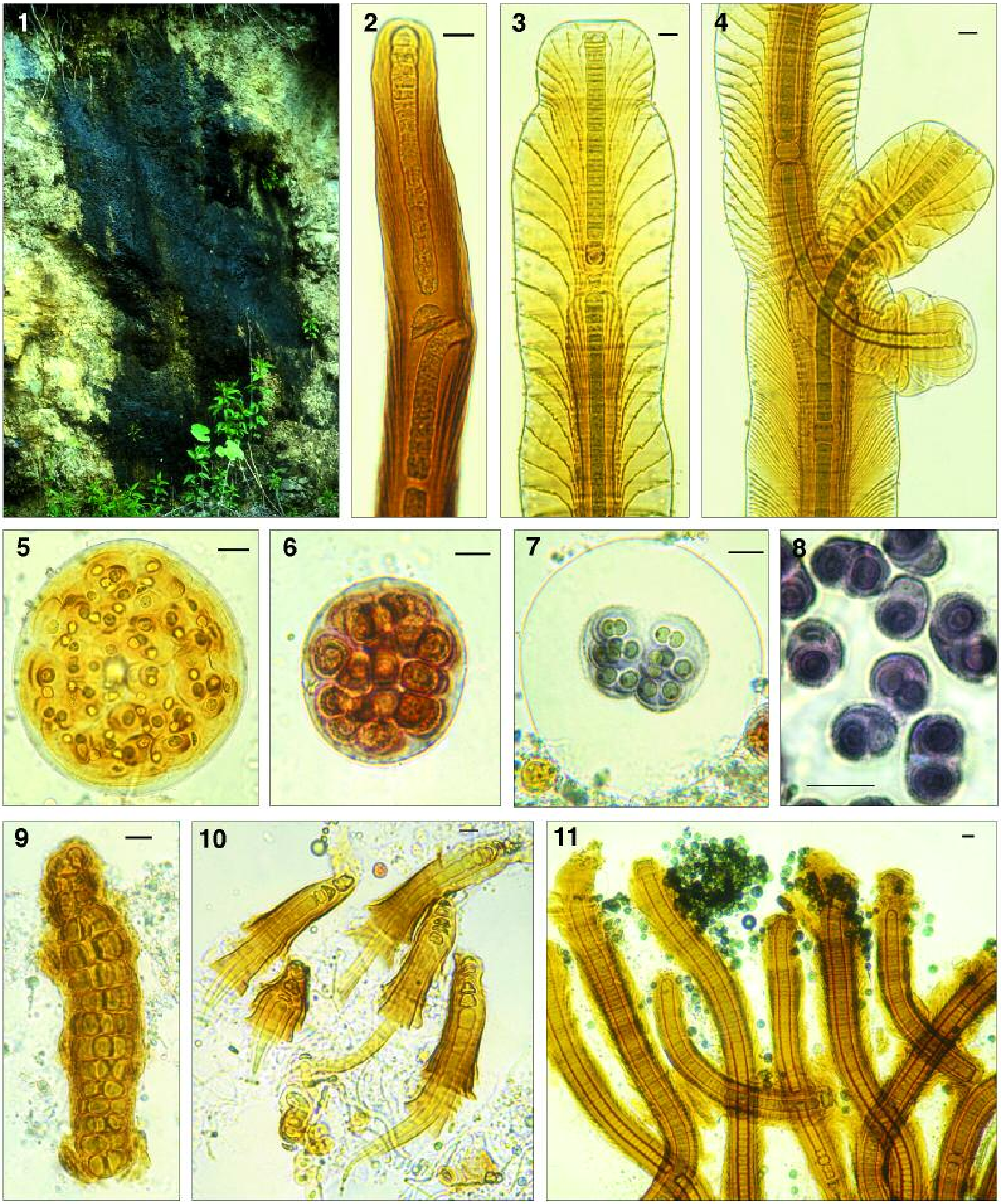

Plate 4.2 - Grotta dell'Inferniglio (Ienne, Lazio). 1. Patina of *Cyanobacteria* ('Tintenstriche' of German authors) on a calcareous cliff. 2-4. *Scytonema myochrous* (Dillw.) Ag. emend. Jaag in its ecoforms on dry (status *typicus*, fig. 2) and moist substrate (status *petalonema*, figg. 3-4). 5. *Gloeocapsa kuetzingiana* Näg. emend. Jaag. 6. *G. sanguinea* Näg. emend. Jaag (ecoform with red sheath). 7. *G. sanguinea* (ecoform with blue internal sheath). 8. *G. compacta* Kütz. emend. Golubic (status *perdurans*). 9. *Stigonema turfaceum* Cooke. 10. *Calothrix parietina* Thuret. 11. *Tolypothrix* sp. Bar = 20 μm.

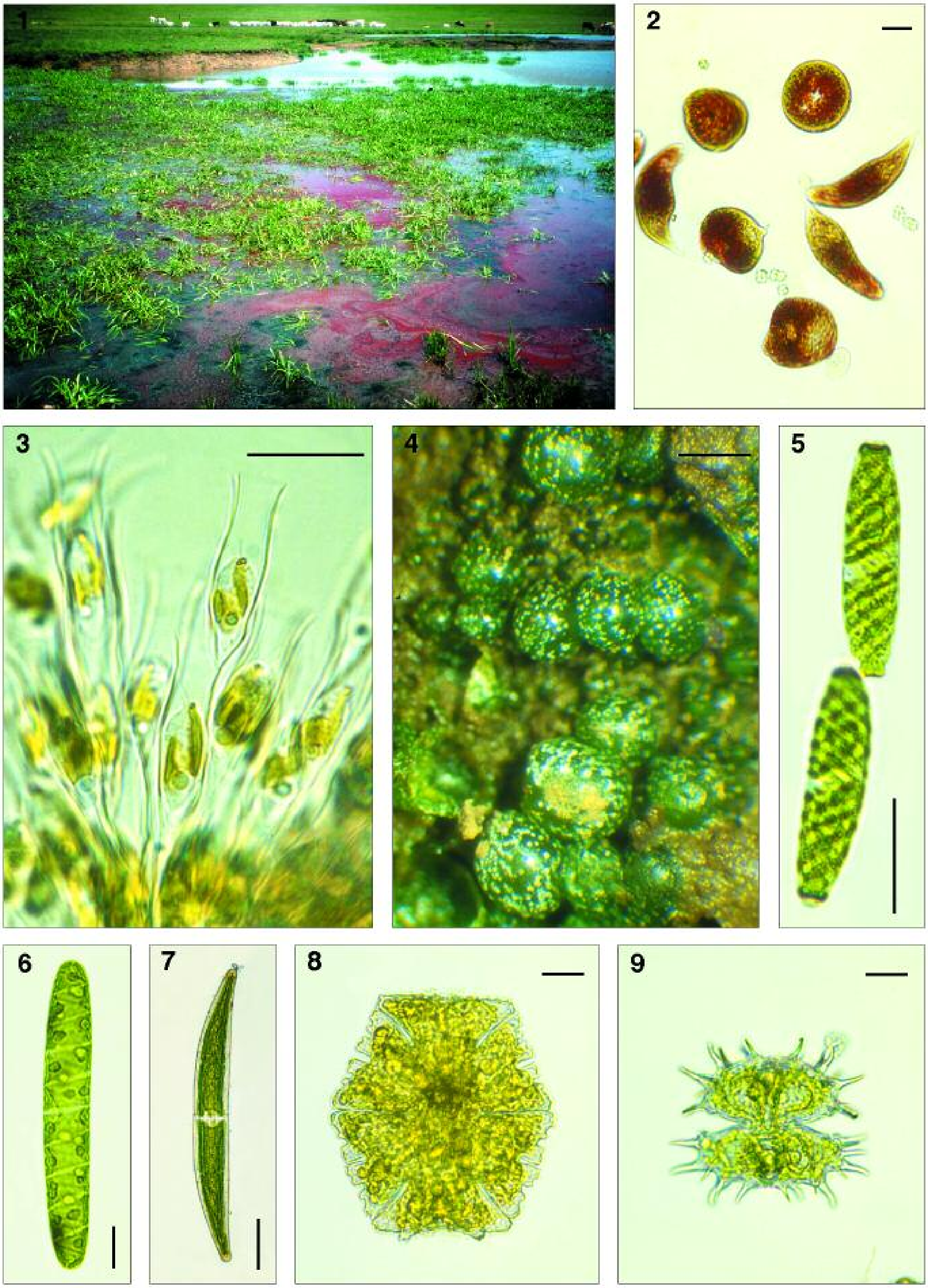

Plate 4.3 - Pantani di Forca Canapine (Monti Sibillini, 1588 m a.s.l.). 1. Summer look of a pond with water reddened by *Euglena sanguinea* Ehr. 2. Cysts and vegetative individuals of *E. sanguinea*. 3. *Dinobryon sertularia* Ehr. (Crisophyceae). 4. *Botrydium granulatum* Grev. (Xantophyceae). 5. *Polytaenia alpina* (Schmidle) Brook (Mesotaeniaceae). 6. *Spirotaenia condensata* Bréb. ex Ralfs (Mesotaeniaceae). 7. *Closterium intermedium* Ralfs (Desmidiaceae). 8. *Micrasterias americana* (Ehr.) ex Ralfs f. *lewisiana* West (Desmidiaceae). 9. *Xanthidium brebissonii* Ralfs (Desmidiaceae). 2-3, 5-6, 8-9 bar = 20 µm; 4 bar = 1 mm; 7 bar = 50 µm.

	N. of *taxa*	N. of records
Piemonte	439	1,043
Trentino - Alto Adige	414	1,171
Lombardia	240	656
Umbria	124	196
Lazio	122	244
Emilia-Romagna	90	103
Veneto	74	109
Toscana	42	47
Abruzzo	41	69
Campania	37	46
Basilicata	25	37
Marche	25	34
Liguria	19	22
Sardegna	19	20
Sicilia	12	38
Valle D'Aosta	2	2
Friuli - Venezia Giulia	1	1
Calabria		
Molise		
Puglia		
Totale segnalazioni		**3,838**

Table 4.20 - Numbers of *taxa* and records per region for the *Desmidiaceae* of Italy.

A first attempt at compiling a catalogue of the freshwater algae reported in Italy from the end of the nineteenth century up to the end of the 1950's was made by Mrs. Irma Miselli Pignatti. The catalogue, kindly made available to us by Prof. Sandro Pignatti, is currently also available in the form of an electronic database, upon request, from the authors. The catalogue contains the binomials of 2,295 species of algae reported in 48 studies, some of which regard Switzerland.

A second attempt at compiling a catalogue of Italian planktonic algae (restricted, however, just to those occurring in lacustrine environments) resulted from the combined efforts of three degree theses proposed and supervised by one of the authors (G. Bazzichelli) during the years 1974-77. For these theses more than 670 studies published between 1833 and 1977 were consulted. Across the three theses a total number of over 1,900 species were surveyed for the Italian lakes, distributed among the different classes of algae as shown in Figure 4.39. According to the provisional data provided by the theses, the total number of species reported for northern Italy (Piemonte, Lombardia, Valle d'Aosta, Trentino-Alto Adige, Friuli-Venezia Giulia, Liguria, Veneto, Emilia-Romagna) is over 1,600, while the total number of species reported for central and southern Italy taken together is over 500. These data must be considered incomplete by a large margin since, on the one hand they have not yet been updated, while on the other, they concern in the main only lacustrine environments, the specific objective of the three theses.

Lacking a complete floristic census, any judgement as to the overall floristic richness of freshweater algae in Italy is thus not possible at the moment. Neither is it possible, for the same reason, to estimate the biodiversity by comparing the number of Italian species belonging to the various genera to the global totals for these same genera. Moreover, the richness in species reported for any given region must be viewed in relation to the numbers and activites of specialists operating in that region. Indeed, the greater floristic richness reported for northern Italy may be the consequence of greater numbers of specialists working in this area (especially in the past) and not only of the presence there of a greater number and variety of wetland environments.

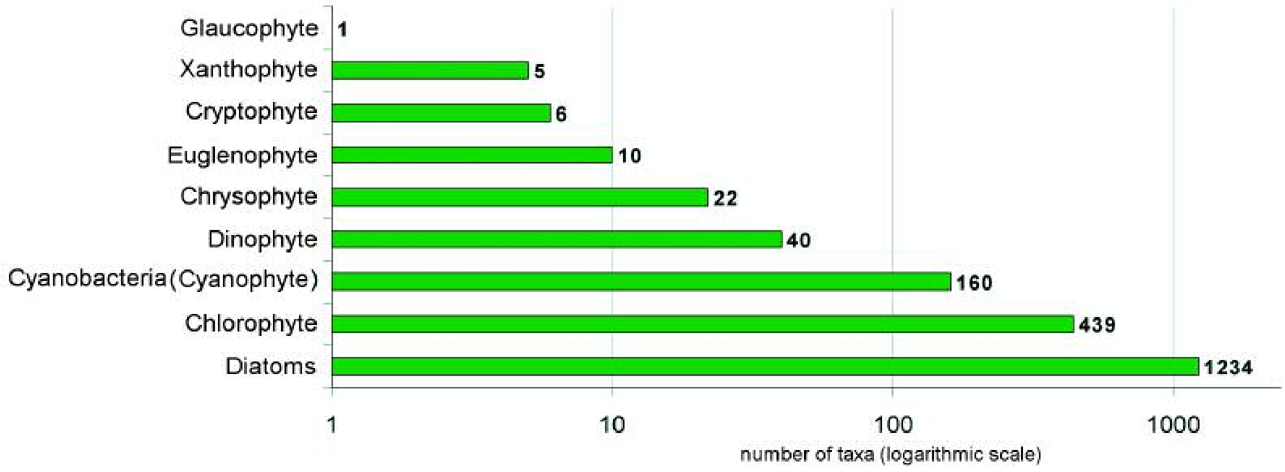

Fig. 4.39 - Number of algal *taxa* reported for the Italiani lakes from 1833 to 1977 (provisional data, unpublished).

FRESHWATER ALGAE AS BIOINDICATORS

[Nadia Abdelahad, Giorgio Bazzichelli]

For some years freshwater algae have been used as bioindicators of water quality of inland waters.

As regards lakes, phytoplanktonic algae have been used for two main purposes: 1) to obtain a typological classification of the lakes themselves, based on the type of phytoplankton present (this was done mainly in the past - APSTEIN, 1896; NAUMAN, 1927) [see also, for Italy, FORTI & TROTTER (1909) and MARCHESONI (1940)]; 2) to define the trophic state (HUTCHINSON, 1967) on the basis of specific phytoplanktonic indices (THUNMARK, 1945; NYGAARD, 1949).

As regards rivers, methods for controlling water quality based on the use of algae were first proposed in the 1950's (for a brief historical summary see PRYGIEL, COSTE & BUKOWSKA, 1999). Over the past decade this sector of research has been significantly developed throughout Europe - in contrast to the situation regarding lakes. Various biological indices have been adopted and applied in different European countries (see papers in PRYGIEL, WHITTON & BUKOWSKA, 1999), also at the request of public and private bodies responsible for control of the quality of surface water. In the main these indices are based on diatoms. Diatoms are unicellular algae, and are present with a large number of species in the plankton and benthos of inland waters. The value of diatoms as bioindicators comes, on the one hand, from their biodiversity and, on the other hand, from the way in which they associate in a relevée. Two indices which were proposed in Italy in the 1990's (DELL'UOMO, 1996) and which have recently been modified, have been tested on some central Apennine rivers. They appear to be well capable of measuring the extent of eutrophication and organic pollution in Italian waterways (DELL'UOMO, 1999).

The number of diatom species present in inland waters is in the order of some several thousands and new species are being described every year. Correct identification of these species, especially of those (few hundred) species that are used in calculating the indices, requires a good level of taxonomical competence. This presents no small problem when it comes to the training of staff responsible for checking water quality. This problem has been taken into consideration mostly in France (LECOINTE *et al.*, 1993) and Great Britain (KELLY, 1999).

DELL'UOMO A., 1999 – *Use of algae for monitoring rivers in Italy: current situation and perspectives.* In: PRYGIEL J., B.A. WHITTON, J. BUKOWSKA (eds.), *Use of algae for monitoring rivers III.* ISBN: 2-9502083-5-5, p. 17-25.

FORTI A., TROTTER A., 1909 – *Materiali per una monografia limnologica dei laghi craterici del M. Vulture. Parte seconda.* Ann. Bot., vol. VII (Suppl.): 31-111.

HUTCHINSON G.E., 1967 – *A treatise on Limnology, vol. II – Introduction to Lake Biology and the Limnoplankton.* John Wiley & Sons, Inc., 1115 pp.

KELLY M.G., 1999 – *Progress towards Quality Assurance of benthic diatom and phytoplankton analysis in the UK.* In: *Use of algae for monitoring rivers III.* ISBN: 2-9502083-5-5, p.208-215.

LECOINTE C., COSTE M., PRYGIEL J., 1993 - *"OMNIDIA" software for taxonomy, calculation of diatom indices and inventories management.* - Hydrobiologia 269/270 : 509-513.

MARCHESONI V., 1940 – *Osservazioni sul fitoplancton dei laghi craterici dell'Appennino centro-meridionale.* Nuovo Giorn. Bot. Ital. , n. s. 47: 229-233.

NAUMAN E., 1927 – *Über die Abhängigkeit des Phytoplanktontypus vom Gewässertypus.* Ark. för Bot., 21a, n. 11.

NYGAARD G., 1949 – *Hydrobiological studies of some danish ponds and lakes.* II. K. Danske Vidensk. Selsk. Biol. Skr., 7: 1-293.

PRYGIEL J., COSTE M., BUKOWSKA J., 1999 – *Review of the major diatoms-based techniques for the quality assessment of rivers.* State of the art in Europe. In: *Use of Algae for monitoring rivers III.* ISBN: 2-9502083-5-5, p. 224-238.

PRYGIEL J., WHITTON B.A., BUKOWSKA J., 1999 – *Use of Algae for monitoring rivers III.* ISBN: 2-9502083-5-5, 271 pp.

THUNMARK S., 1945 – *Zur Soziologie des Süsswasserplanktons. Eine methodologisch-ökologische Studie.* Fol. Limnol. Scand., 3.

The conservation of freshwater algae

The freshwater algae which are threatened with extinction are mainly those which colonise biotopes in which the water is characterised by particular physio-chemical conditions (peat-bogs, alpine pools, plain pools, marshes...). Since it is impossible to protect individual species of algae, their conservation is of necessity tied to the conservation of biotopes, which in this way become 'genetic reservoirs', literally, for numerous *taxa* of algae (MOLLENHAUER, 1998).

The most endangered species are, in the main, those belonging to *Desmidiaceae*, to *Chrysophyceae*, to some *Vaucheriaceae* and also to a few rare freshwater *Pheophyceae* and *Rhodophyceae*. For this reason the first Red Lists of freshwater algae, which appeared in Austria and Germany, regard *Desmidiaceae* (LENZENWEGER, 1986: 91 *taxa*; GUTOWSKI & MOLLENHAUER, 1996: 501 *taxa*) and *Vaucheriaceae* (MOLLENHAUER & CHRISTENSEN, 1996: 16 *taxa*).

No Red List for freshwater algae has to date been published in Italy. Nevertheless, it must be pointed out that of the 764 species of *Desmidiaceae* that have been reported for Italy (ABDELAHAD *et al.*, 2003), more than half must already be considered candidates for a Red List. Some of these species are shown in Plate 4.3 (5-9).

A realistic recommendation for conserving biotopes was made by MOLLENHAUER (1998). He proposed that an adequate number of aquatic biotopes should be selected in which algal vegetation was still well-conserved and that these should then be checked through the years by way of constant monitoring.

Bibliography

ABDELAHAD N., BAZZICHELLI G., D'ARCHINO R., 2003 – *Catalogo delle* Desmidiacee *(*Chlorophyta*,* Zygnematophyceae*) segnalate in Italia/A checklist of Desmids (Chlorophyta, Zygnematophyceae) reported in Italy.* Accademia Nazionale delle Scienze detta dei XL, Scritti e documenti, vol. XXIX: 1-102.

BIZZOZERO G., 1885 – *Flora Veneta Crittogamica. Parte II. Licheni, Alghe, Caracee, Muschi, Epatiche, Crittogame vascolari.* Padova.

CORDELLA P., PAGANELLI A., 1988 – *Un secolo di ricerca limnologica: sviluppo della scienza delle acque interne in Italia, situazione attuale e prospettive.* Società Botanica Italiana. Centenario, vol. II - 100 anni di ricerche botaniche in Italia (1888-1988): 821-835.

DELL'UOMO A., 1991 – *Catalogo delle Desmidiacee (*Zygophyceae*) del Trentino-Alto Adige.* St. Trent. Sc. Nat., Acta Biol., 68: 149-179.

DELPONTE G.B., 1873 – Specimen Desmidiacearum subalpinarum. Mem. R. Accad. Sci. Torino, ser. II, tomo XXVIII: 282 pp., 21 tav.

DE NOTARIS G., 1867 – *Elementi per lo studio delle Desmidiacee italiche.* R. Istituto de' Sordo-Muti. Genova 84 pp., 9 tav.

DE TONI G.B., 1889-1924 – *Sylloge algarum omnium huqusque cognitarum.* Patavii.

EICHLER A.W., 1883 – *Syllabus der Pflanzenfamilien.* Berlin.

ENGLER A., 1903 – *Syllabus der Pflanzenfamilien.* Berlin.

FORTI A., 1900-1901 – *Contribuzioni diatomologiche V-VI. VI. Diatomee bentoniche del Canavese raccolte in occasione dei rispettivi scandagli dal prof. G. De Agostini nell'autunno 1893.* Atti R. Ist. Veneto Sci. Lett. ed Arti, tomo LX, Parte seconda: 783-793.

GUILIZZONI P., TARTARI G., GIUSSANI G. Eds., 1992 – *Limnology in Italy.* Mem. Ist. Ital. Idrobiol., 50: 491 pp.

GUTOWSKI A., MOLLENHAUER D., 1996 – *Rote Liste der Zieralgen (*Desmidiales*)* Deutschlands Schr.-R. f. Vegetationskde., 28: 679-708

HOHENBÜHEL-HEUFLER L., 1871 – *Enumeratio Cryptogamarum Italiae Venetae.* Vienna.

LENZENWEGER R., 1986 – *Rote Liste gefährdeter Zieralgen (Desmidiales) Östereichs.* In: Rote Liste gefährdeter Pflanzen Östereichs. Grüne Reihe des Bundesministers für Gesundheit und Umweltschutz 5. Wien: 200-202.

LINNAEUS C., 1754 – *Genera Plantarum.* Holmiae.

MOLLENHAUER D., CHRISTENSEN T.A., 1996 – *Rote Liste der Schlauchalgen (*Vaucheriaceae*) Deutschlands.* Schr.-R. f. Vegetationskde., 28: 625-632.

MOLLENHAUER D., 1998 – *Gefährdungsursachen für Algen und höhere Wasserpflanzen sowie Möglichkeiten diese Pflanzen zu ehrhalten.* Schr.-R. f. Vegetationskde., 29: 205-217.

PICCONE A., 1878 – *Florula algologica della Sardegna.* Nuovo Giorn. Bot. Ital., 10: 289-367.

VAN DEN HOEK C., MANN D.G., JAHNS H.M., – *Algae. An introduction to phycology.* Cambridge University Press.

ZANARDINI G., 1857 – *Catalogo delle piante crittogame raccolte finora nelle province Venete.* Atti R. Ist. Veneto Sci. Lett. Arti, serie III, tomo III: 245-272.

MARINE ALGAE AND VASCULAR PLANTS

[Mario Cormaci, Giovanni Furnari, Giuseppe Giaccone]

The first floristic information on the phytobenthos of the Italian coasts was provided by studies carried out in the second half of the nineteenth century, by researchers such as C. AGARDH, J. AGARDH, ARDISSONE, KÜTZING, MENEGHINI, HAUCK, NACCARI, SCHIFFNER, ZANARDINI, MAZZA, DELLE CHIAJE, BERTHOLD, VALIANTE, FALKENBERG, TORNABENE, BORZÌ, PICCONE.The total set of species cited in the individual publications of these authors are also to be found in the monumental work *Sylloge algarum omnium huqusque cognitarum* by DE TONI (1889-1924), which was a compendium of the floristic knowledge on Italian algae up to that date. Between 1925 and 1962 only a few studies concerning the macrophytobenthos of the Italian coasts were published: SCHIFFNER & VATOVA (1937) on the algae of the Laguna di Venezia; LEVRING (1942) on some algae of the Adriatic Sea, of Sicilia and of the Golfo di Napoli; FUNK (1955) on some algae of the Stretto di Messina. However, from 1962 onwards, numerous studies have been carried out. These studies, undertaken by the current generation of Italian researchers, initially focussed only on Sicilia, and in particular on the northern and southern coasts of the island, with the exception of the one by PIGNATTI (1962). Then, from 1970 to today the eastern coasts of Sicilia and adjacent areas, the coasts of Toscana, Sardegna, the Ligurian Sea, the Adriatic Sea, the northern Ionian Sea and the island of Lampedusa have also been taken into consideration.

Nevertheless, despite this considerable number of floristic studies undertaken, knowledge of the benthic flora of the Italian coasts is still patchy and incomplete. In fact, while some areas have been particlularly well studied (*e.g.* the Golfo di Napoli, Sicilia and its minor islands, the northern Adriatic, the islands of Tremiti and the Golfo di Taranto), considerable areas have not yet been studied sufficiently (*e.g.* the Ligurian Sea, the coasts of Lazio, Calabria and Sardegna).

The diversity of marine benthic flora in Italy

According to the recent Catalogue of Macrophytobenthos, edited by FURNARI *et al.* (2003b)[1], the benthic flora of the Italian coasts consists of 924 *taxa*, confirmed at specific and infraspecific level, divided as shown in Table 4.21. To these are to be added 96 *taxa inquirenda,* 36 *taxa excludenda* and 7 *nomina nuda*. The compilation of this Catalogue involved the examination of 533 studies published between 1950 and 2000. The year 1950 was chosen as the cut-off date for studies to be taken into consideration in order to obtain an overall picture as close as possible to the present day situation and also a Flora comparable to the Checklists drawn up using the same methodology for *Fucophyceae*, *Chlorophyceae* and *Ceramiales* of the Mediterranean, published, respectively, by RIBERA *et al.* (1992), GALLARDO *et al.* (1993) and GÓMEZ GARRETA *et al.* (2001)].

Also indicated in the Tables is the floristic richness of stretches of Italian coast which fall within fishing sectors as defined by the FAO: sector 3 (Tyrrhenian Sea and adjacent basins); sector 4 (Adriatic) and sector 5 (Ionian). Sector 3 has the richest flora with 814 *taxa* (88.1% of the entire flora) followed by sector 5 with 741 *taxa* (88.2%) and then sector 4 - the poorest with 605 *taxa* (65.5%). 513 *taxa* (55.5%) were common to all three sectors, while 104 *taxa* (11.26%) were exclusive to sector 3; 43 *taxa* (4.65%) were exclusive to sector 4; and 55 *taxa* (5.95%) were exclusive to sector 5.

[1] Il Catalogo è stato realizzato nell'ambito della convenzione tra il Ministero dell'Ambiente e il Dipartimento di Botanica dell'Università di Catania.

	Italy	Sector 3	Sector 4	Sector 5	Specie common to all three sectors	Species exclusive		
						of sector 3	of sector 4	of sector 5
Cyanophyta	46	39	24	33	18	13	4	3
Rhodophyta	509	470	340	444	314	44	4	32
Chrysophyta	2	2		1		1		
Phaeophyta	208	169	124	148	93	26	21	15
Chlorophyta	154	130	113	110	84	20	14	5
Spermatophyta	5	4	4	5	4			
Totals	**924**	**814**	**605**	**741**	**513**	**104**	**43**	**55**

Table 4.21 - Macrophytobenthos of the Italian coasts: composition and consistency of the whole flora, of the flora of the FAO fishing sectors (sector 3: Thyrrenian Sea and adjacent basins; sector 4: Adriatic Sea; sector 5: Ionian Sea), of the species common to all three sectors and of the species exclusive of each sector (FURNARI *et al.*, 2003a).

Region	Cyanophyta	Rhodophyta	Chrysophyta	Phaeophyta	Chlorophyta	Spermatophyta	Totale
Veneto	17	190		64	77	4	**352**
Friuli Venezia Giulia	18	260		87	79	4	**448**
Liguria		83		16	18	2	**119**
Emilia-Romagna		12		3	26	1	**42**
Toscana	11	269	1	72	52	3	**408**
Marche	7	77		29	20		**133**
Lazio		82		11	9	1	**103**
Molise		36		9	8		**53**
Campania	5	347		113	91	3	**559**
Puglia	16	377		119	104	4	**620**
Calabria	5	202		88	42		**337**
Sicilia	50	501	1	171	132	5	**860**
Sardegna		279		97	69	3	**448**

Table 4.22 - Macrophytobenthos of the Italian coasts: floristic composition and consistency (including the taxa inquirenda) within each Region (FURNARI *et al.*, 2003b).

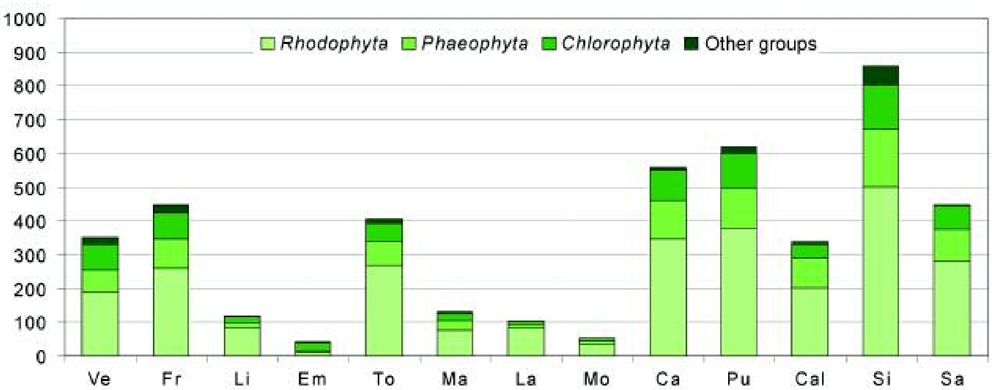

Fig. 4.40 - Macrophytobenthos of the Italian coasts: composition and consistency in the Italian regions (including *taxa inquirenda*).

The floristic richness of each of the Regions of Italy, expressed in total numbers of *taxa* is given in Table 4.22 and summarised graphically in the histogram of Figure 4.40, where the less numerous groups of *taxa* have been combined together under the heading 'other groups'.

A comparison made among the flora of the three sectors defined by the FAO, aimed at establishing the degree of floristic similarity (expressed in terms of Jaccard's index of similarity) showed that marked similarity exists between the Tyrrhenian flora (sector 3) and the Ionian flora (sector 5), whereas the Adriatic flora (sector 5) displays greater differences from each of the other two sectors (Figure 4.41). The Adriatic flora also differs from the others in that it has a lower total number of species (605). This is probably due to the fact that along the Adriatic coasts of Italy, rocky substrates, which host the greatest numbers of algae, extend for only short distances. Where they do occur they rarely stretch out beyond a depth of 30 metres and as a result there are few circalittoral species.

Since no Flora obtained using the same criteria as those used in obtaining the flora of Italy exists for other areas of the Mediterranean, it is not possible to evaluate fully to what extent the flora found in Italy is unique to the country. Nevertheless, as noted above, in recent years Checklists have been compiled for *Fucophyceae*, *Chlorophyceae*

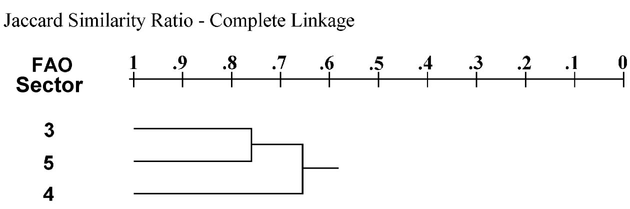

Fig. 4.41 - Dendrogram showing the floristic reciprocal similarities among the floras of the three FAO sectors (FURNARI *et al.*, 2003a).

and *Ceramiales* of the Mediterranean. As these Checklists were drawn up, like those of the Italian algal flora, on the basis of studies published from 1950 onwards, they were used to obtain a list of the *Fucophyceae*, *Chlorophyceae* and *Ceramiales* of six Mediterranean areas, delimited as follows: Italy (ITA), Spain (SPA), France (FRA), Greece-Turkey non-Italian Adriatic Coasts (GTR), Morocco-Algeria-Tunisia (MAT), Libya-Egypt-Levantine States (Syria, Lebanon, and Israel) (LEL).

It was therefore possible to make comparisons among the three components of the flora of the Italian coasts (ITA) and the flora of these other five areas of the Mediterranean. Figure 4.42 shows the number of species surveyed in the different areas: in the entire Mediterranean 260 *Ceramiales* (*Rhodophyta*), 243 *Fucophyceae* and 178 *Chlorophyceae* were surveyed making up a total of 681 species, which are divided up among the different areas in somewhat unequal proportions. Italy (ITA) and France (FRA) turned out to be the areas richest in species - for example FRA contains 82% of the *Ceramiales* present in the Mediterranean. The coasts of Libya, Egypt and the Levantine States (LEL), instead, turned out to be the poorest in species, with a *Fucophyceae* contingent which comprises only 30% of the species of the Mediterranean basin (probably because these have been the least studied).

There are rather few species which are common to all six areas (Table 4.23): 90 *Ceramiales* (34,6%), 54 *Fucophyceae* (22,2%) and 48 *Chlorophyceae* (27%). However, as can also be observed from Table 4.23, there are even fewer species which are exclusive to any one area alone. The species exclusive to Italian coasts (ITA, 12 *Ceramiales*, 22 *Fucophyceae* and 19 *Chlorophyceae*) are listed in Tables 4.24, 4.25 & 4.26, respectively.

Finally, on the basis of their respective flora, the six areas were compared in order to establish the degree of floristic similarity between each pair of areas, according to Jacard's index of similarity. The results are displayed in the dendogrammes of Figure 4.43. As regards *Ceramiales*, the floristic similarities among the six areas are, in general, con-

	Species common to all areas	Species exclusive					
		ITA	SPA	FRA	GTR	LEL	MAT
Ceramiales	90	12	3	5	2	4	1
Fucophyceae	54	21	4	11	2	3	3
Chlorophyceae	48	19	2	6	2	5	2
Total	**192**	**52**	**9**	**22**	**6**	**12**	**6**

Table 4.23 - Ceramiales, Fucophyceae and Chlorophyceae common to all areas and exclusive of each area. See text for the abbreviations (FURNARI *et al.*, 2003a).

*	*Antithamnionella elegans* (Berthold) J. H. Price et D. M. John v. *decussata* Cormaci et G. Furnari
*	*Ceramium incospicuum* Zanardini
	Ceramium strobiliforme G.W. Lawson et D.M. John
	Chondria pygmaea Garbary *et* Vandermeulen
*	*Crouania ischiana* (Funk) Boudouresque et M. Perret
	Laurencia caduciramulosa Masuda et Kawaguchi ([1])
	Laurencia glandulifera (Kützing) Kützing
*	*Osmundea maggsiana* Serio, Cormaci et G. Furnari
*	*Osmundea pelagiensis* G. Furnari
	Polysiphonia harveyi Bailey
	Polysiphonia orthocarpa Rosenvinge
*	*Polysiphonia perforans* Cormaci, G. Furnari, Pizzuto et Serio
	Taenioma perpusillum (J. Agardh) J. Agardh

([1]) Recently reported by FURNARI *et al.* (2001).

Table 4.24 - Ceramiales (*Rhodophyta*) exclusive to the Italian flora (the asterisk marks the endemic species).

Fig. 4.42 - Consistency of the *Ceramiales*, *Fucophyceae* and *Chlorophyceae* occuring in the Mediterranean and in each one of the six considered areas. See text for the abbreviations.

	Acrochaete geniculata (N.L. Gardner) O'Kelly
	Acrosiphonia arcta (Dillwyn) J. Agardh
	Blidingia ramifera (Bliding) Garbary et Barkhouse
	Blidingia subsalsa (Kjellman) Kornmann et Sahling ex Scagel *et al.*
*	*Bryopsidella ostreobiformis* Calderón-Sáenz et Schnetter
*	*Bryopsis dichotoma* De Notaris
	Capsosiphon fulvescens (C. Agardh) Setchell et N.L. Gardner
	Chaetomorpha gracilis Kützing
	Chaetomorpha litorea Harvey
*	*Derbesia corallicola* Funk
	Enteromorpha flexuosa (Wulfen) J. Agardh ssp. *biflagellata* (Bliding) Bliding
	Enteromorpha intestinalis (Linnaeus) Nees v. *asexualis* Bliding
	Enteromorpha ralfsii Harvey
	Entocladia perforans (Huber) Levring
	Microdictyon umbilicatum (Velley) Zanardini
	Monostroma grevillei (Thuret) Wittrock
	Rosenvingiella polyrhiza (Rosenvinge) P.C. Silva
*	*Ulva neapolitana* Bliding
	Ulva scandinavica Bliding

Table 4.25 - *Chlorophyceae* exclusive to the Italian flora (the asterisk marks the endemic species).

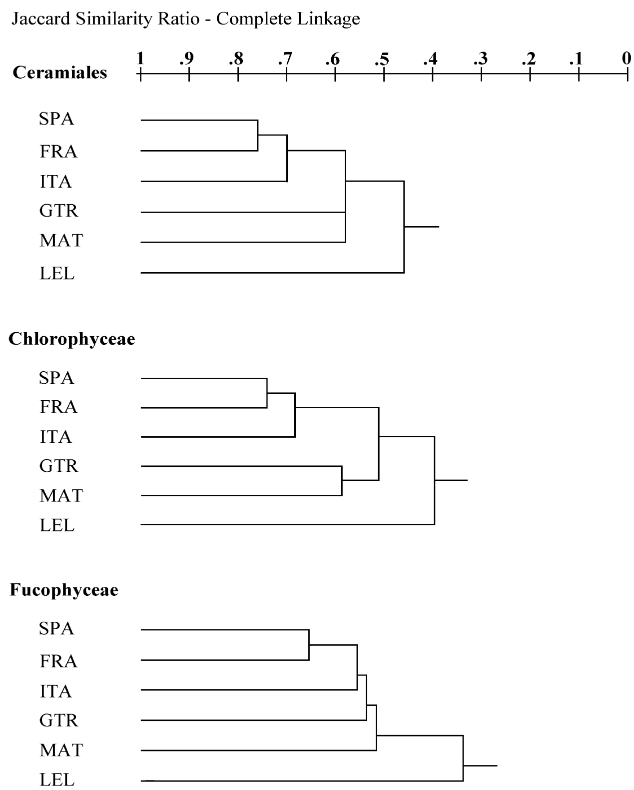

Fig. 4.43 - Dendrogram showing the floristic reciprocal similarities among *Ceramiales*, *Chlorophyceae* and *Fucophyceae* occurring in the six considered Mediterranean areas (Furnari *et al.*, 2003a).

	Cladosiphon chordariaeformis P. et H. Crouan
*	*Cystoseira hyblaea* Giaccone
	Desmarestia dresnayi J.V. Lamouroux *ex* Leman
	Ectocarpus fasciculatus Harvey v. *abbreviatus* (Kützing) Sauvageau
	Ectocarpus fasciculatus Harvey v. *pycnocarpus* (Rosenvinge) Cardinal
*	*Ectocarpus siliculosus* (Dillwyn) Lyngbye v. *subulatus* (Kützing) Gallardo
*	*Ectocarpus siliculosus* (Dillwyn) Lyngbye v. *venetus* (Kützing) Gallardo
	Elachista flaccida (Dillwyn) Fries
	Elachista fucicola (Velley) Areschoug
	Herponema velutinum (Greville) J. Agardh
*	*Leptonematella neapolitana* (Schussnig) Cormaci et G. Furnari
	Microcoryne ocellata Strömfelt
	Myriogloea sciurus (Harvey) Kuckuck ex Oltmanns
	Petalonia zosterifolia (Reinke) Kuntze
	Petrospongium berkeleyi (Greville) Nägeli
*	*Phaeostroma bertholdii* Kuckuck
	Scytosiphon dotyi M.J. Wynne
	Sphacelaria nana Nägeli ex Kützing
	Stilopsis lejolisii (Thuret) Kuckuck *ex* Hamel
	Streblonema parasiticum (Sauvageau) De Toni
*	*Taonia lacheana* Cormaci, G. Furnari et Pizzuto

Table 4.26 - *Fucophyceae* exclusive to the Italian flora (the asterisk marks the endemic species).

siderable - with the exception of the LEL area. The dendogramme for *Chlorophyceae* is quite similar to that for *Ceramiales*, with two distinct groups emerging in this case, too: SPA, FRA and ITA on one side, GTR and MAT on the other - while LEL is once again more isolated. As regards *Fucophyceae*, lower floristic similarity is apparent among the groups - reasonable similarities being observable only between SPA and FRA. Yet again, the LEL area displays fewer similarities. This low level of similarity resulting from the low number of species in each systematic group could in turn be the result not only of insufficient floristic knowledge about the area, but also of the geomorphological characteristics of the coasts (mainly sandy) and of paleoclimatic events which affected them, such as the sapropel crisis (Giaccone & Di Martino, 1997).

To conclude, the benthic flora of Italy is the richest in species among those areas of the Mediterranean considered - at least as regards *Fucophyceae* (brown algae) *Chlorophyceae* (green algae) and *Ceramiales* (red algae *p.p.*). This may, in part, be because the Italian flora is the one which has been most widely studied in recent years. Moreover,

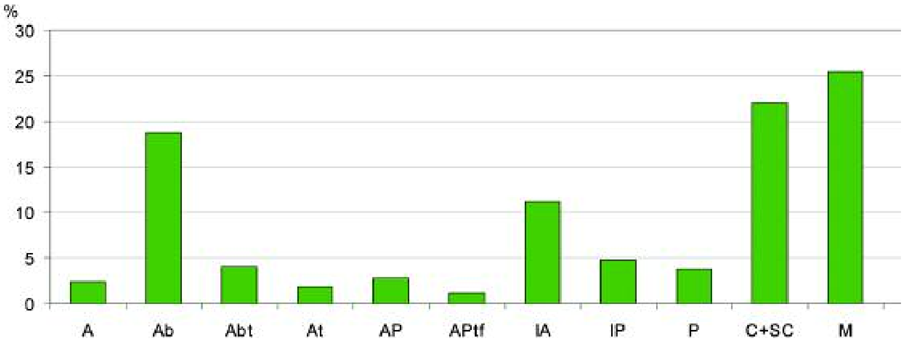

Fig. 4.44 - Chorological spectrum of the benthic flora of the Italian coasts.
A = Atlantic *s.l.*; Ab = Atlantic boreal;
Abt = Atlantic boreal-temperate;
At = Atlantic tropical;
AP = Atlantic-Pacific;
APtf = Atlantic-Pacific temperate cold;
IA = Indo-Atlantic; IP = Indo-Pacific;
P = Pantropical; C = Cosmopolitan;
SC = Subcosmopolitan;
M = Mediterranean.

from a chorological point of view the Italian flora exhibits high levels of the Mediterranean endemic chorotype (Figure 4.44) and this attests to the high naturalistic value of the marine zones of Italy. Nevertheless, the Italian flora do not display a particular uniqueness in absolute terms, even if (together with the flora of the more westerly of the six FAO areas - especially those of France and Spain, to which it displays marked similarity) it is clearly differentiated from the flora of the coasts of Libya, Egypt and the Levantine Countries. This, however, reflects the marked floristic difference which exists between the western and eastern parts of the Mediterranean basin (Giaccone & Di Martino, 2001). Finally it must be pointed out that the relatively high number of species which are exclusive to Italy is most likely due to the thorough studies which have recently been carried out along the Italian coasts, rather than to particular habitats or biogeographical factors.

Numerous species of the Italian flora can be considered 'critical': those which are endemic are shown in Tables 4.24, 4.25 & 4.26 and those which were proposed by UNEP (2000) for the selection of sites of natural interest for conservation are shown in Table 4.27 (Figures 4.45-4.58). This latter Table also shows some characteristic species of plant associations occurring in stable environments and which, when they form well-structured populations, are thus natural bioindicators of sites. In particular we note some species of *Cystoseira* (*Fucales*, *Fucophyceae*) which characterise the 'climax' associations on hard substrates at various depths [*C. amentacea* (in the infralittoral zone), *C. crinita* (in the upper-infralittoral zone), *C. sauvageauana* (in the middle-infralittoral zone), *C. spinosa* (in the lower-infralittoral zone), *C. zosteroides* and *C. dubia* (in the circalittoral zone, respectively in biotopes subject to currents and in calm biotopes where sedimentation occurs)] and the Spermatophyte *Posidonia oceanica* which characterises the 'climax' associations of mobile infralittoral substrates with large-grained sand. Exploratory investigations are therefore necessary to establish the distribution of these species along the Italian coasts, since they need to be monitored at those sites where they form well-structured populations in order that eventual degradation can be detected. Because these species are particularly sensitive to environmental variations, their conservation and the protection of the associations which they characteristise requires careful management of the coastal belt. The main impact factors and/or threats both for the critical species and for their habitats are: pattering, cementification, waste waters, in the meso-littoral zone; waste waters with draining pipes, wreckage discharging (reducing the clarity of coastal waters), acquicoltura systems with suspended cages, extreme herbivory and/or competition of invasive aliens in the infra-littoral zone; finally in the circalittoral zone, in addition to the ones listed for the infra-littoral zone, also drag-net fishing. All the above-mentioned impact factors and/or threats may cause the disappearance of critical species, therefore leading to profound changes in the structure of their plant communities and marked alterations both to the biodiversity and to the plant landscape with severe consequences for the connected biological resources.

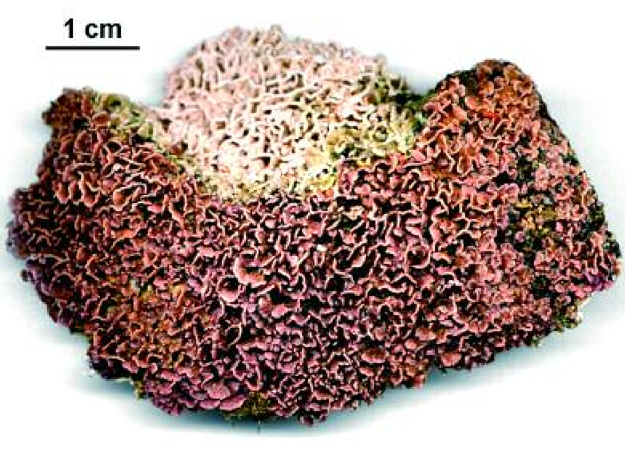

Fig. 4.45 - *Exsiccatum* specimen of *Lithophyllum byssoides* (Photo by M. Cormaci).

Rhodophyta
* ***Lithophyllum byssoides*** (Lamarck) Foslie **2** (reported as *Lithophyllum lichenoides*) Habitat: *Lithophylletum byssoidis* Giaccone 1993
* ***L. trochanter*** (Bory) H. Huvé *ex* Woelkerling **2** (reported as *Goniolithon byssoides*) Habitat: *Lithophylletum byssoidis* Subass. *Lithophylletosum trochanteris* Marino, Di Martino, Giaccone 1998
Nemalion helminthoides (Velley) Batters **4**
Rissoella verruculosa (A. Bertoloni) J. Agardh **4** Habitat: *Nemalio-Rissoelletum verruculosae* Boudouresque 1971
* ***Schimmelmannia schousboei*** (J. Agardh) J. Agardh **1** Habitat: *Rhodymenietum ardissonei* Pignatti 1962
Phaeophyta
* ***Cystoseira amentacea*** (C. Agardh) Bory **3** [including v. ***stricta*** Montagne and v. ***spicata*** (Ercegović) Giaccone] Habitat: *Cystoseiretum strictae* Molinier 1958
C. crinita Duby **3** Habitat: *Cystoseiretum crinitae* Molinier 1958
C. dubia Valiante **2** Habitat: *Cystoseiretum dubiae* Furnari *et al.* 1977
C. foeniculacea (Linnaeus) Greville v. ***latiramosa*** (Ercegović) Gómez Garreta *et al.* **3** Habitat: *Cystoseiretum spinosae* Giaccone 1973
C. foeniculacea (Linnaeus) Greville f. *tenuiramosa* (Ercegović) Gómez Garreta *et al.* 3 Habitat: *Cystoseiretum sauvageauanae* Giaccone 1994
* ***C. mediterranea*** Sauvageau **2** Habitat: *Cystoseiretum strictae* Molinier 1958
C. sauvageauana Hamel **2** Habitat: *Cystoseiretum sauvageauanae* Giaccone 1994
* ***C. sedoides*** (Desfontaines) C. Agardh **3** Habitat: *Cystoseiretum crinitae* Molinier 1958
* ***C. spinosa*** Sauvageau **3** Habitat: *Cystoseiretum spinosae* Giaccone 1973
C. tamariscifolia (Hudson) Papenfuss **1** Habitat: *Cystoseiretum strictae* Subass. *Cystoseiretosum tamariscifoliae* Giaccone 1972
C. usneoides (Linnaeus) M. Roberts **2** Habitat: *Cystoseiretum usneoidis* Giaccone 1972
* ***C. zosteroides*** C. Agardh **3** Habitat: *Cystoseiretum zosteroidis* Ciaccone 1973
Fucus virsoides J. Agardh **2** Habitat: *Fucetum virsoidis* Pignatti 1962
Laminaria ochroleuca De La Pylaie **2** Habitat: *Cystoseiretum usneoidis* Giaccone 1972
* ***L. rodriguezii*** Bornet 4 Habitat: *Cystoseiretum zosteroidis* Subass: *Laminarietosum rodriguezii* Giaccone 1973
Phyllariopsis purpurascens (C Agardh) E.C. Henry *et* South 4 Habitat: *Cystoseiretum usneoidis* Giaccone 1972
Spermatophyta
* ***Posidonia oceanica*** (Linnaeus) Delile **3** Habitat: *Posidonietum oceanicae* Molinier 1958
* ***Nanozostera noltii*** (Hornemann) Tomlinson *et* Posluzny **4** Habitat: *Nanozosteretum noltii* Harmsen 1936
* ***Zostera marina*** Linnaeus **1** Habitat: *Zosteretum marinae* (Van Goor 1921) Harmsen 1936

Table 4.27 - 'Critical' species of the macrophytobenthos of the Italian coasts. The habitats are identified by their phytosociological syntaxon. The asterisk marks the species to protect according to UNEP. The bold number after each species marks the conservation status according to the following scale: **1**= bad; **2**= poor; **3**= adequate; **4**= good; **5**= very good.

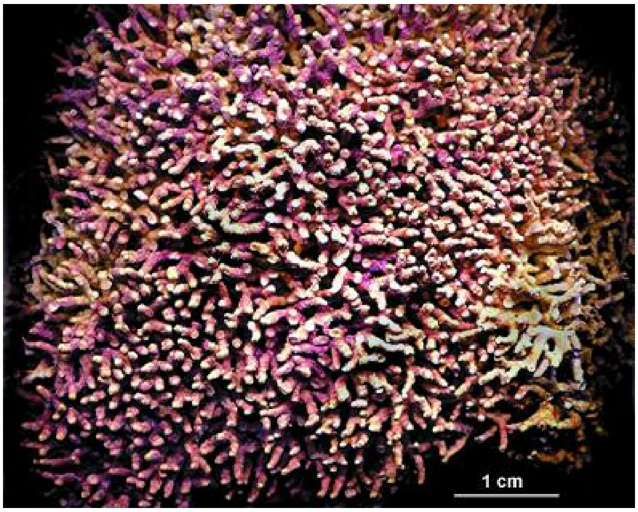

Fig. 4.46 - *Exsiccatum* specimen of *Lithophyllum trochanter* (Photo by M. Cormaci).

Fig. 4.47 - *Nemalion helminthoides* in its habitat (Photo by M. Cormaci).

Fig. 4.48 - *Exsiccatum* specimen of *Schimmelmannia schousboei* (Photo by M. Cormaci).

Fig. 4.49 - *Cystoseira amentacea* v. *stricta* in its habitat (Photo o by G. Giaccone).

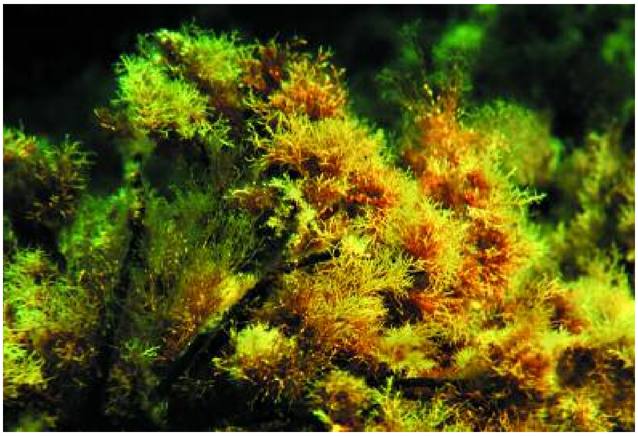

Fig. 4.50 - *Cystoseira crinita* in its habitat (Photo by G. Giaccone).

Fig. 4.51 - *Cystoseira dubia* in its habitat (Photo by B. Scammacca).

Fig. 4.52 - *Cystoseira foeniculacea* f. *tenuiramosa*: herbarium specimen conserved in glycerol (Photo by M. Cormaci).

Fig. 4.53 - *Cystoseira sauvageauana*: herbarium specimens conserved in glycerol. Left: specimen collected in Spring; right: specimen collected in Winter (Photo by M. Cormaci).

Fig. 4.54 - *Cystoseira sedoides* in its habitat (Photo by G. Giaccone).

Fig.4.56 - *Cystoseira zosteroides*: herbarium specimen conserved in glycerol (Photo by M. Cormaci).

Fig. 4.55 - *Cystoseira spinosa*: herbarium specimen conserved in glycerol. Left: specimen collected in Spring; right: specimen collected in Winter (Photo by M. Cormaci).

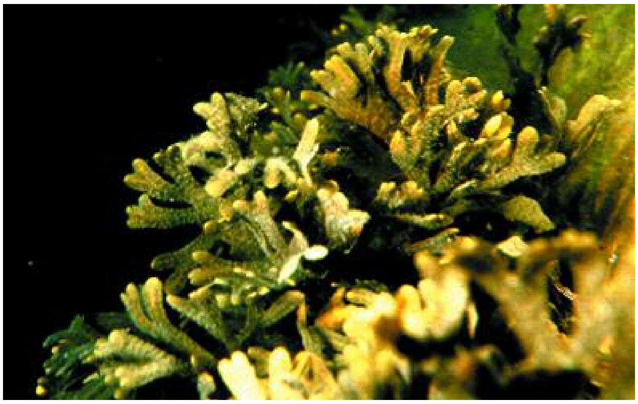

Fig. 4.57 - *Fucus virsoides* in its habitat (Photo by G. Giaccone).

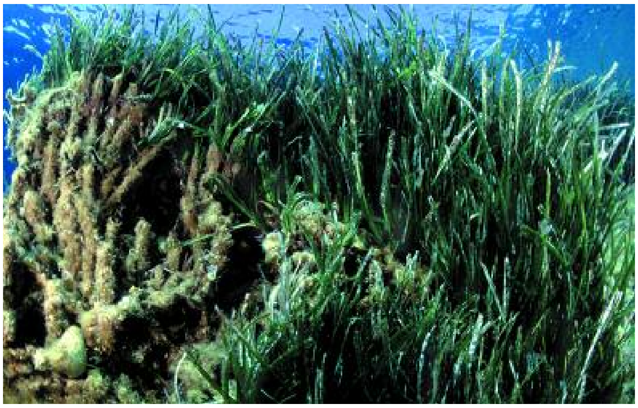

Fig. 4.58 - *Posidonia oceanica* in its habitat (Photo by V. Di Martino).

Bibliography

Cavaliere A., 1959 – *Ricerche sulla flora algologica dello Stretto di Messina.* Boll. Ist. Bot. Univ. Catania, 3: 79-88.

De Toni G. B., 1889-1924 – Sylloge algarum omnium huqusque cognitarum. Patavii.

Funk, 1955 – *Meeresalgen von Neapel.* Pubbl. Staz. Zool. Napoli, 25 (suppl.): 1-178.

Furnari G., Cormaci M., Serio D., 2001 – *The* Laurencia complex *(*Rhodophyta. Rhodomelaceae*) in the Mediterranean Sea: an overview.* Cryptog. Algol., 22: 331-373.

Furnari G., Cormaci M., Giaccone G., 2003a – *The benthic macroalgal flora of Italy: floristic and geobotanic considerations.* Bocconea, 16: 225-243.

Furnari G., Giaccone G., Cormaci M., Alongi G., Serio D., 2003b – *Biodiversità marina delle coste Italiane: catalogo del macrofitobenthos.* Biol. Mar. Medit., 10: 3-483.

Gallardo T., Gómez Garreta A., Ribera M.A., Cormaci M., Furnari G., Giaccone, G, Boudouresque C.F., 1993 – *Check-list of Mediterranean Seaweeds. II.* Chlorophyceae Wille s. l. Bot. Mar., 36: 399-421.

Giaccone G, Di Martino V., 1997 – *Syntaxonomic relationship of the mediterranean phytobenthos assemblages: paleoclimatic bases and evolutive tendencies.* Lagascalia, 19: 129-144.

Giaccone G., Di Martino V., 2001 – *Past, present and future of vegetational diversity and assemblages on Mediterranean Sea.* Actes du premier Symposium méditerranéen sur la végétation marine. RAC/SPA: Tunis: 34-59.

Gómez Garreta A., Gallardo T., Ribera M.A., Cormaci M., Furnari G., Giaccone G., Boudouresque C.F., 2001 – *Checklist of Mediterranean seaweeds.* III. Rhodophyceae *Rabenh.* 1. Ceramiales *Oltm.* Bot. Mar., 44: 425-460.

Levring T., 1942 – *Meeresalgen aus dem Adriatischen Meer, Sizilie und dem Golf von Neapel.* Kungl. Fysiogr. Soellsk. Foerhandl., 12: 25-41.

Pignatti S., 1962 – *Associazioni di alghe marine sulla costa Veneziana.* Atti Ist. Veneto Sci., Lett. Arti, Cl. Sci. Mat. Nat., 32: 1-134.

Ribera M.A., Gomez Garreta A., Gallardo T., Cormaci M., Furnari G., Giaccone G., 1992 – *Check-list of Mediterranean Seaweeds.* I. Fucophyceae *(Warming, 1884).* Bot. Mar., 35: 109-130.

Schiffner V., Vatova A., 1937 – *Le alghe della Laguna di Venezia.* Estratto dalla Monografia: La Laguna di Venezia, Venezia, vol. III, parte V, tomo IX: 174 pp.

UNEP (OCA)/MED WG, 2000 – *Rapport réunion d'experts pour la finalisation du formulaire standard des données (FSD) pour les inventaires nationaux de sites naturels d'intérêt pour la conservation.* Tunis, 167/4: 53 pp.