PATTERNS OF BIODIVERSITY

UNDERSTANDING BIODIVERSITY FOR ITS CONSERVATION

[Carlo Blasi]

Understanding means elaborating models capable of explaining structure and function at various temporal, spatial and biological organisation scales.

The terms *ecology* and *biodiversity* are often used without realising how important it is to know the elements that make up ecosystems and the complex ecosystemic relationships that exist among populations in an ecosystem. In briefly outlining how the meaning of the term *ecology* has changed over time, we need to go back to the mid-nineteenth century when Ernest HAECKEL first coined the word "ecology" to represent the study of the relationships between different organisms and between organisms and their surroundings. Increased interest in the fields of biogeography and plant life led to the study of the interactions between the physical and biological environments. Ecological phenomena were interpreted in increasingly complex ways that focused on evaluating the relationships between single species and their surrounding environment. Hence, from the study of these relationships at individual level, the move was quickly made to study these relationships at community level, heightening the peculiarities in terms of competition and solidarity in order to reach a specific (not random) scheme of the distribution of the plant landscape. The next step was to study plant associations, zoocoenosis (the study of different animal species in a community) and synecology, (the ecology of communities rather than individual species). Towards the end of the nineteenth century, integrated studies began on evaluating biocoenosis (all plant, animal and other living organisms in a community), thus considering together all flora and fauna.

In the meantime, developments in genetics placed the emphasis on population studies and these had an extremely important role in the shift from the study of the individual to that of the community. In 1923, the British ecologist Arthur TANSLEY expanded on the concept of *ecosystem* (an abbreviation of the term *ecological system*) as "a distinct unit of interacting organisms and their surrounding environment." Biology was analysed on the theory of systems, and so biological sciences were increasingly integrated with physical sciences and human sciences. The ecosystem became the fundamental unit of ecology in that it expressed the synthesis of physical and biological values, and in recent years, *landscape* has also been inserted into the ecological and environmental context.

Having recognised that species, communities, landscapes and the natural environment are so closely connected, one can well say that ecology is the discipline that studies biodiversity in its various forms of biological organisation in a complex and systemic manner in space and time.

The attention paid to biodiversity, or perhaps it is more correct to speak of attention paid to biodiversity conservation, is closely correlated to the Convention on Biological Diversity undersigned in Rio de Janeiro in June 1992 during the United Nations Conference on Environment and Development (UNCED).

SUSTAINABLE DEVELOPMENT

In 1972, during the United Nations Conference on the Human Environment held in Stockholm (see chapter *Agreements on conservation and sustainable development*) attention was drawn to the need to preserve natural habitats to produce a sustained improvement in living conditions for all, and the need for international cooperation to achieve this. The emphasis was on solving problems, but without ignoring social, economic and development policy factors. The oil crises in 1973 and 1979 seemed to remind the world that natural resources should be used sparingly, and that it was indispensable to orientate science and technology towards ensuring the survival of life on Earth.

It was from here that growing attention was paid to "sustainable development", understood as the process capable of satisfying the needs of the present generation without compromising the indispensable natural resources to satisfy the needs of future generations.

According to this concept, knowledge of biodiversity becomes the essential element in monitoring, evaluation, planning, management, and therefore, in conservation. The biological system that most represents elevated biodiversity is the tropical forest: its biological richness surpasses any imagination. In 50 hectares of the peninsula of Malaysia, there are more tree species that those found in all of North America. These forests, which cover about 6% of the planet's land surface, host more than 70% of all the species on Earth. At present, scientists know only about 10% of the more than 120,000 plant species present in tropical forests, and in-depth studies have been conducted only on 1% of these.

The level of knowledge regarding what occurs in the various environmental systems of the planet is extremely limited; we know more about the surface of the moon than the many biological communities that are rapidly disappearing on Earth.

An issue that must be considered is the scarce commitment dedicated to the discovery of living organisms. We know only about 10% of these (some scientists believe this figure is more realistically around 1-2%) and even less do we know about their individual characteristics or interaction. Every nation should be committed to identifying, understanding, utilising and protecting the biodiversity that exists within its borders.

Unfortunately, the importance of biodiversity conservation in industrialised countries is not truly perceived in that direct contact has been lost with it. Suffice it to think of the 250,000 angiosperm species in the world that offer an extraordinary richness of flowers and fruits, though in reality, only a few dozen of them are commonly utilised as foodstuffs.

BIODIVERSITY IN FIGURES

In order to better describe the biodiversity status of a nation, it is also useful to analyse its quantitative aspect. It is astounding that with the seeds collected from the feathers of a single bird, Charles DARWIN was able to cultivate 82 plant species, that in the most urbanised part of Rome (inside the ring-road) there are about 1,300 plant species, that Italy's flora is made up of 7,500 flora species (see section *Vascular plants*), that Italian fauna encompasses more than 60,000 species (see chapter *Fauna*), that the flora in the Cilento Nature Park reaches almost 3,000 species, that in the small National Park of Circeo there are more than 1,500 plant species, and that along the coastal belt of the Pontina area there are stretches of forest vegetation with 7-8 species of the genus *Quercus*, while there are countries in Central Europe that have only two or three. How can one remain indifferent to all this?

The global pace of culture and environmental sensibility creates the need to learn about biodiversity. We live immersed in biodiversity but unfortunately, we do not have the necessary instruments to recognise it. Up to a few decades ago, "naturalistic" ignorance was the prerogative of the town-dweller; today it extends even to the rest of the population. It is not easy to connect what we eat to where it was produced; similarly, it is not easy to understand how to interpret the potential of nature based on observing the present situation. Industrialised nations do not accept the limitations imposed by the normal evolution of the environment. Our reaction to natural catastrophes is often an emotional one, without considering that in the majority of cases, it is often man who transforms autonomous processes of nature from a phenomenon into a disaster.

Diversity is a primary good for nature that regulates and influences its development: if man had not substituted the mixed forests of Central Europe with red fir forests, we would not have witnessed the death of forests so manifestly. The red fir is without doubt more useful than the maple, the ash and the oak tree in producing wood for building purposes, though no one had evaluated how sensitive it was to atmospheric pollution. Natural systems find their adaptation and stability capacity precisely in the richness of species and in the behavioural diversity of these species.

Traditional agriculture is based on this precise principle, always different in terms of production and activity: and this is the principle that present-day ecologists should refer to when elaborating efficient and functional territorial models and even ecological networks. A precise definition of "widespread naturalness" has not yet been formulated, though doubtless to say it is identified with a greatly diversified territorial model with all the various stages of natural succession within it: open areas, cultivated land, shrubland, and woodland.

Presently, the contribution made by scientific research in managing natural resources at a theoretical level is of vital importance, as is the ecosystem approach and the elaboration of an ecological territorial network. Moreover, the application of the Habitats Directive and the Convention on Biological Diversity (CBD) fosters new studies in evaluating conservation status and assessing incidence, both complex ecosystemic procedures that are needed to verify variations in sustainable use or new interventions in sites of the Natura 2000 Network.

A landscape approach in the study of biodiversity is in line with the objectives of the CBD, in that it has the advantage of linking environmental factors with anthropogenic ones (see chapter *Biodiversity and landscape*).

Landscape studies thus defined fully respond to the requisites of ecological research. The study and knowledge of landscape implies an analysis of its complexity, and the integration of knowledge on a spatial and temporal scale in order to reconstruct the processes that have led to the current situation and which define the dynamic models to apply to future scenarios.

Bibliography

BLASI C., 2003 – *Scoprire la biodiversità.* In: Paesaggi della biodiversità. Collana Immagini + Idee 01, pp. 8-27. Connecting cultures editions

BLASI C., PAOLELLA A., 1992 – *Progettazione ambientale. Cave, fiumi, strade, parchi, insediamenti.* Ed. NIS - Roma.

GIACOMINI V., 1980 – *Perché l'ecologia.* Ed. La Scuola, Brescia

HUDSON E.W. (ed.), 1991 – *Landscape linkages and biodiversity.* Island press. Washington.

PEARCE D., MORAN D., 1995 – *The economic value of biodiversity.* IUCN, Earthscan, Londra.

From the detection of causes to the identification of hotspots

[Fausto Manes, Francesca Capogna]

In 1988, the English ecologist Norman Myers defined the concept of hotspots in order to identify those land ecoregions of high priority conservation. Biodiversity hotspots are those areas where exceptional concentrations of endemic species are undergoing exceptional loss of habitat. As many as 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth. Eleven hotspots have lost at least 90% of their original natural vegetation and among these three have lost 95% (Myers *et al.,* 2000).

A hotspots revision released in 2005 identified 9 new hotspots, bringing the number of global biodiversity hotspots to 34 (2.3 percent of the Earth's surface) (Mittermeier *et al.*, 2005). Predominant are tropical forests, appearing in 18 of these hotspots, and Mediterranean-type zones in five. Eleven are either completely or principally made up of islands, while 16 are found in the tropics (Figure 1).

The identification and designation of each hotspot is based on three key factors that also determine the importance of each area: number of endemics, and the ratio of endemic species/area for both plants and vertebrates, and habitat loss. Table 1 lists the eight "hottest hotspots" which appear at least three times in the top ten listings for each factor. The leaders are Madagascar, the Philippines, and Sundaland, followed by Brazil's Atlantic Forest and the Caribbean. Two additional hotspots, the Tropical Andes and the Mediterranean Basin, should be considered as hyper-hot candidates for conservation support in the light of their exceptional totals of endemic plants: 20,000 and 13,000, respectively.

In particular, the Mediterranean Basin is the largest of the five Mediterranean-type ecosystems; 2,362,000 sq. km (original extent of primary vegetation) of hotspots overlook the Mediterranean which include parts of Spain, France, Italy, the Balkans, Greece, Turkey, Syria, Lebanon, Tunisia, Algeria, Morocco and a hundred or so scattered islands. Of the original coverage of primary vegetation, only 110,000 sq. km (4.7%) remain, the lowest percentage found among all the hotspots of the planet. In these areas there are 25,000 species of vascular plants, 13,000 of which (52%) are endemic species (Table 2).

This hotspot (Mediterranean Basin) is subdivided into a further 10 mini hotspots (Figure 2) that cover 15% of the total area and comprise 37% of all the endemics of this area. This characteristic makes this hotspot of priority importance for biodiversity conservation. The Mediterranean maquis, characterised by sclerophyllous shrubs (*Juniperus*, *Myrtus*, *Olea*, *Phillyrea*, *Pistacia*, and *Quercus*) covers more than half the region. *Arbutus*, *Ceratonia*, *Chamaerops* and *Laurus* are important components of Mediterranean vegetation and represent the relict species of the original forest present more than two million years ago. Shrubs such as *Artemisia*, *Astragalus* and *Ephedra*, and trees such as *Acer*,

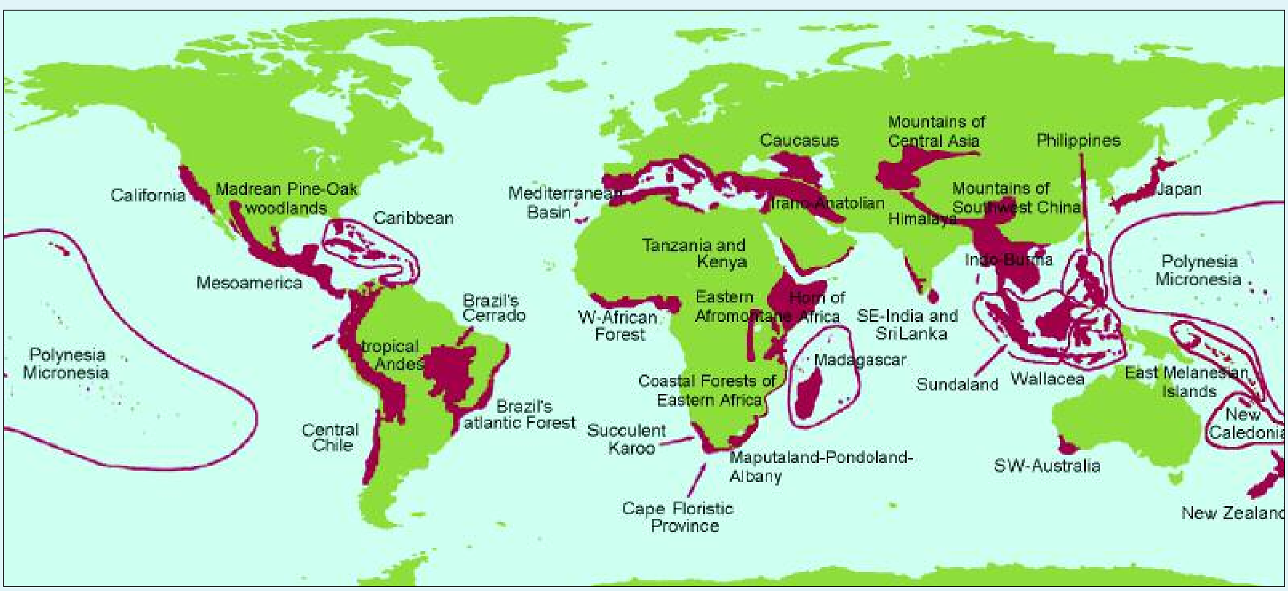


Fig. 1 - The 34 "hotspots" or land ecoregions with high priority conservation (Myers *et al.*, 2000; updated).

HOTSPOT	Endemic plants	Endemic plants/area (n° of species per 100 Km^2)	Primary vegetation still present (%)	Score for the designation
Madagascar	9,704	16.4	9.9	5
Philippines	5,832	64.7	3.0	5
Sundaland	15,000	12.0	7.8	5
Atlantic Forest of Brasil	8,000	8.7	7.5	4
Caribbeans	7,000	23.5	11.3	4
Indo-Burma	7,000	7.0	4.9	3
Sri Lanka	2,180	17.5	6.8	3
Mountains of the 'Eastern Arc' and Coastal Forest of Tanzania	1,500	75	6.7	3

Table 1 – The 8 ecoregions with the highest conservation priority ('Hottest Hotspots').

Betula, *Cercis*, *Fagus* and *Ulmus* replaced them during the Pleistocene, coming from Europe and Asia, and are still present in Mediterranean flora. Other species worthy of note are *Cedrus* sp. pl., present in Cyprus, in Morocco and in Algeria and the native palm of the Mediterranean, *Phoenix theophrasti*, still found in remote sites in Turkey and Greece.

MYERS N., MITTERMEIER R.A., MITTERMEIER C.G., DA FONSECA G.A.B, KENT J., 2000 – *Biodiversity hotspots for conservation priorities.* Nature, 403: 853-858.

MITTERMEIER R.A., ROBLES Gil P., HOFFMAN M., PILGRIM J., BROOKS T., GOETTSCH MITTERMEIER C., LAMOREUX J., DA FONSECA G.A.B., 2005 - *Hotspots Revisited: Earth's Biologically Richest and Most Threatened Terrestrial Ecoregions.* Conservation International.

Original expanse of primary vegetation (Km^2)	2,362,000
Remaining primary vegetation (Km^2) (% of original expanse)	110,000 (4.7)
Protected areas (Km^2) (hotspot %)	42,123 (38.3)
Plant species	25.000
Endemic plants (% of global plants, 300,000)	13,000 (4.3%)
Species/area ratio per 100 Km^2 of hotspots	11.8

Table 2 - Principal characteristics of vegetation present inside the hotspot of the Mediterranean Basin (MYERS *et al.*, 2000).

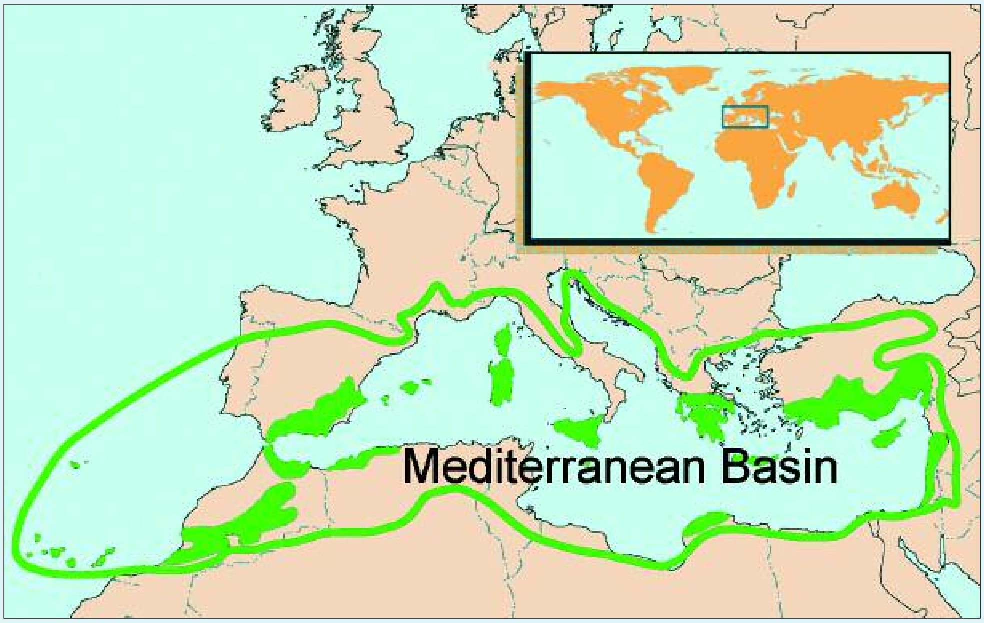


Fig. 2 - The hotspots of the Mediterranean Basin.

BIODIVERSITY AND BIOGEOGRAPHY

[Carlo Blasi, Goffredo Filibeck, Augusto Vigna Taglianti]

The distribution of living organisms depends on two kinds of factors. The first are ecological factors, that is, the environmental characteristics that allow a given species to live in a given site, and the interactions among organisms that may affect the chances of a species to live in a certain area. The second are biogeographical factors, that is, the degree of likelihood that a species has to reach a habitat suited to it. In other words, the limits of an organism's range does not depend only on environmental conditions, but also on the presence both past and present, of barriers and geographical connections capable of influencing the dispersal of species.

Consequently, even species richness in a given territory should be explained from an ecological as well as a biogeographical viewpoint. Thus, the great flora and fauna diversity present in Italy is due, on the one hand, to the diversity of habitats in this country, which encompasses a great complexity of lithologic, topographic, and climatic typologies in a restricted space; and on the other hand, it is due to an extremely complex paleogeographic and paleoclimatic history, which has provided Italy with flora and fauna species of very different origins.

Therefore, this section intends to briefly outline the main historical events that have influenced the current animal and plant population, as well as the consequences that these events have left in the present distribution model of the flora and fauna in Italy.

An attentive biogeographical interpretation from a historical and ecologic point of view, can provide a clearer picture of the being and becoming of this biological diversity, describe the distribution and highlight the geographical areas with the greatest species richness.

Biogeography and species richness

The geographic position of Italy

The Mediterranean basin covers portions of three continents, Europe, Asia and Africa. Europe lies to the north, and the three large peninsulas, the Iberian Peninsula, Italy and the Balkan Peninsula, extend into the Mediterranean-climate zone. The Mediterranean basin extends into western Asia, covering the western and southern portions of the peninsula of Anatolia, and includes the Mediterrean-climate Levant at the estern end of the Mediterranean bounded on the east and south by the Syrian and Negev deserts. The northern portion of the Maghreb region of northwestern Africa has a Mediterranean climate, and in the eastern Mediterranean the Sahara extends to the southern shore of the Mediterranean.

The complexity of its geographic position influences the co-presence of numerous and distinct bioclimatic and ecosystem realities which justifies its elevated biodiversity. Above all, its past history from a paleogeographic and paleoclimatic point of view, with the transformations of the Tetide Basin, the various orogenetic phases, the formation of the Mediterranean, the movement of continental plates, the immense evaporation of the Mediterranean during the Messinian and the glaciations during the Pleistocene, have played an enormously important role in shaping the plant and animal population in the Mediterranean area.

In its turn, Italy is in a central position in the Mediterranean area and the Tyrrhenian basin, which is its geometric centre, is surrounded by the peninsula and by the major islands. Undoubtedly, this position has facilitated and continues to facilitate the colonisation of species from the surrounding lands, in particular, from the west, south, and east. Italy is delimited in the north by the Alpine Arc, which separates and at the same time connects it to central Europe, thus affecting the flora and fauna with the introduction of northern and eastern components.

Species richness

Species richness, often simply defined as "biodiversity," is the immediate and most utilised indicator to evaluate species or taxonomic diversity in an area.

The number of species that occur in Italy is remarkably high: without considering prokaryotes, protists, algae and fungi, vascular plants alone (pteridophytes, gymnosperms, and angiosperms) number 6,711 (see section

Vascular plants), to which 1,130 bryophytes (see section *Bryophytes*) should be added; the currently known animal species (metazoans) within the political confines of Italy are about 55,600 (MINELLI, 1996).

The 55,600 Italian fauna species are divided up into several taxonomic groups with percentages that generally correspond to the general scheme of the temperate belt of the Palaearctic region. Vertebrates represent slightly more than 2% of Italian fauna, while the absolutely predominant category is made of arthropods (82%), which include crustaceans, arachnids, myriapods, and above all, insects, which alone account for more than 37,000 species, that is, 67% of Italian animals.

When considering how the total number of species acknowledged for Italy is divided up into the different environments (land, freshwater and marine), one can see that some 47,536 species (according to STOCH, 2000), more than 86% of all total fauna, belong to continental environments (with about 42,000 land and 5,600 freshwater), versus "only" 8,000 species that are strictly marine. However, very few animal groups make up this enormous land diversity (pulmonate gastropods, vertebrates, and arthropods, in which insects are the dominant group, make up about 80% of the species). On the contrary, marine fauna, which in any case has a much lower biodiversity in terms of species, is characterised by a very high biodiversity at the "phylogenetic" level, with the presence of almost all the different structural levels. Many groups, and often entire phyla, are in fact exclusively or almost all marine, such as the porifers, cnidarians, ctenophores, nemertines, annelid polychaetes, with pycnogonids among arthropods, bryozoans, echinoderms, tunicates and cephalochordates.

Italy in the European context

Compared to other European countries, the flora and fauna richness of Italy is very high. The 6,711 vascular plants identified for Italian Flora (see section *Vascular plants*), taking away about 700 naturalised exotic plants, make up half of the 12,500 species estimated for all of Europe, which makes Italy the country with the greatest number of plant species of the continent (WORLD CONSERVATION MONITORING CENTRE, 1992; CRISTOFOLINI, 1998). Suffice it to consider that the Lazio region in Italy contains more species than the United Kingdom, whose surface area is roughly that of Italy (cfr.: STACE, 1991; ANZALONE, 1996). As far as fauna is concerned, if we limit ourselves to comparing some animal groups of which there are reliable checklists, one can see, for example, that the number of orthopterans present in Italy (333 species) is about triple the number of those found in Poland (102), ten times that of Great Britain (30) and Norway, and more than 150 times that of Iceland, while the number of lepidoptera, one of the better known groups, exceeds 5,000 species in Italy, which is more than double those in Great Britain (2,400). As for coleoptera, another well known group of insects and of great biogeographical importance (the order represents 1/4 of all the animal species); there are about 12,000 species in Italy compared to 6,000 in Poland, 3,700 in Great Britain, 3,375 in Norway and 239 in Iceland (MINELLI, 1996). Italy is one of the European countries with the greatest documented diversity for a very large number of invertebrate groups.

These observations fully reflect the latitudinal gradient that is the pattern of species richness, in which the diversity decreases as the latitude increases (ASHTON, 2001). As Italy is at low latitudes in the European context, it has decidedly more species richness than central or northern European countries.

Italy in the Mediterranean context

When comparing the fauna diversity of Italy to those of other countries in the Mediterranean area, one can observe how the species richness of various animal groups (nesting birds, mammals, reptiles, amphibians, neuroptera, rhopalocera and tipulids) of the Italian peninsula, Sardinia, Sicily and Corsica is rather low compared to the Iberian islands, north-western Africa, the Balkans and Anatolia. This level is comparable to those of the first two regions, though much lower than those situated in the eastern Mediterranean area (OESTERBROEK, 1994). In any case, these figures are greatly influenced by the different surface area taken into examination: if one calculates the number of species per unit of surface area, then Italy has higher levels.

Similar observations can partly be made for flora diversity: the flora in Turkey (about 8,500 species: DAVIS, 1965-1985) is richer than that of Italy, though the species/surface area ratio is greater in Italy.

These results can logically be interpreted by the fact that, notwithstanding the smaller surface area, Mediterranean Italy comprises a great variety of habitats, which are representative of the entire Mediterranean ecosystem diversity.

HISTORICAL ASPECTS OF FAUNA AND FLORA

Historical aspects of fauna

Italy, though relatively young, was subjected to a very complex paleogeographic and paleoecological history starting from the Oligocene that greatly affected the composition and distribution of its fauna. The principal events can be summed up as follows:

1. During the Miocene (from about 23 to 6 million years ago) (Figure 2.1a) the break-up of some Euroasian microplates; some of them moved southwards colliding with North Africa, others with the newly formed Apennine chain and others still remained isolated (Sardinian-Corsican plate). The faunal affinity between Italian and North-African districts or between the Sardinian-Corsican massif and western Europe can be attributed to these vicariance events (GIUSTI and MANGANELLI, 1984; LA GRECA, 1990).
2. The Mediterranean was separated from the Atlantic during the Messinian which caused the entire sea to evaporate (known as the Messinian Salinity Crisis) about 6 million years ago (Figure 2.1b). In reality, agreement about the actual extent of this evaporation has yet to be reached, though certainly there were connections between regions previously and subsequently separated by the sea, for example between North Africa and Sicily, and between Sicily and the forming Apennines, and between the Apennines and the Balkans. This led to extensive faunal exchanges (GIUSTI and MANGANELLI, l.c.; STEININGER *et al.*, 1985; AZZAROLI, 1990; ESTABROOK, 2001).
3. The reopening of the Strait of Gibraltar, connecting the Mediterranean to the Atlantic Ocean, created the current geographical arrangement of the Mediterranean area, and in particular that of the Italian peninsula in the Pliocene (from 5 to 2 million years ago); the shift in climate from warm-humid to Mediterranean (Figure 2.2a); the onset of the first great ice age (Biber), when high-mountain environments first appeared (LA GRECA, 2002).
4. The lowering of the sea level (due to the greater quantity of water imprisoned in the polar glaciers) during the Pleistocene (1 million years ago), which connected areas then separated by sea, allowing further faunal exchanges to occur (Figure 2.2b). The glacial cycles, and the consequent connections among the present islands have come about principally in the last million years, in that the cold periods lasted hundreds of thousands of years, while the interglacial periods lasted tens of thousands of years (DAVIS, 1983; FOLLIERI and MAGRI, 1997). The geography of the coasts as they are today goes back only 13,000 years ago, that is, the end of the last glaciation, during which time the sea level was at least one hundred metres lower. During other glacial events of the Quaternary, the sea level was even lower; which makes the current sea level an "exceptional" and transitory situation (ROHLING *et al.*, 1998). On the other hand, the presence of glaciers acted as a disjunction factor between populations. The glaciations also influenced populations in paleoecological terms, because of the shifting and changes to the extent of various habitats.

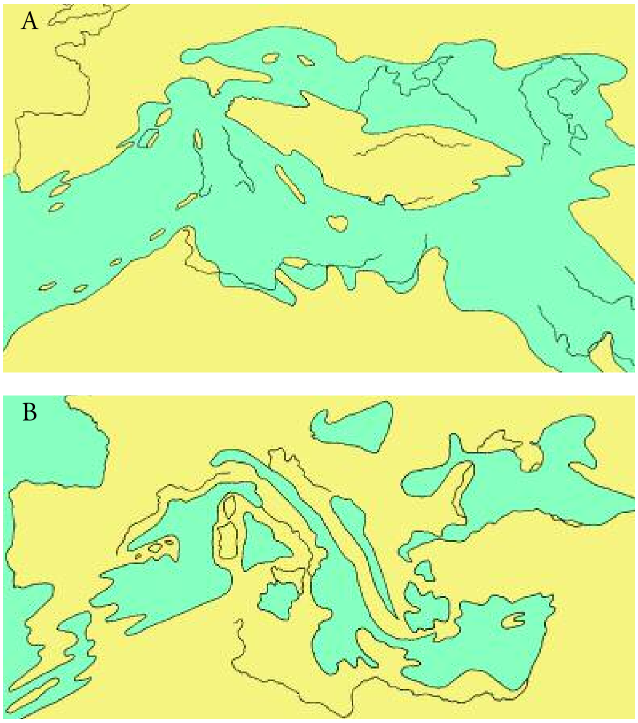


Fig. 2.1 - Paleogeography of the Mediterranean at the beginning of the Miocene (a), and in the Upper Miocene (Messinian) (b), according to STEININGER *et al.* (1985), redrawn. Legend: the sea area in blue, emerged land in yellow, the black thin lines indicate the present outline of the coastlines.

While the most ancient traces of paleogeographic and paleoclimatic events (such as the drifting of microplates and the Messinian Salinity Crisis) are more difficult to identify today owing to the successive overlapping of further processes with the passing of time, the more recent Pleistocene glacial events are clearly visible and are extensively studied by biogeographers.

The glaciations deeply affected the animal population in Italy and led to:

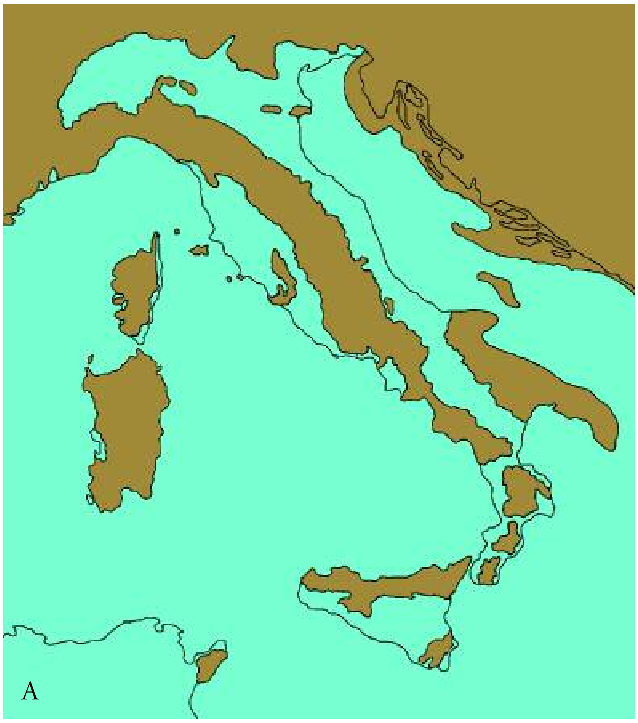


Fig. 2.2 - The paleogeography of Italy in the Pliocene (a) and in the Pleistocene, during the Riss Glaciation (b), according to LA GRECA (2002), redrawn. Legend: a) emerged land during the Pliocene in colour, the sea areas in blue, the dotted lines indicate the present coastlines; b) the Riss Glaciers are shown in a light colour, emerged land during the Riss due to lower sea level in grey, the sea areas in blue, present emerged land in brown.

1. the southwards movement of thermophilic species, who were able to survive in coastal environments or in xerothermic areas;
2. the colonisation of southern areas by northern species, who were able to migrate southwards owing to the colder climate and which, when the new warm period arrived, survived as "glacial relicts";
3. the continual fragmentation of populations into isolated populations due to the formation of small glaciers that acted as barriers;
4. the subsequent re-expansion northwards of populations that had been restricted to the south.

All these phenomena have been well-documented by faunal studies and phylogenetic analyses conducted on morphological, biochemical and molecular aspects of numerous animal groups (CARPANETO, 1975; CAPANNA, 1993; BULLINI *et al.*, 1998; HEWITT, 1999; HUGOT and COSSON, 2000).

The marine environment has its own autonomous biogeographical history, independent from that of the land if one excludes the continental shelf, and it does not offer geographic models of distribution that can contribute in a significant manner to the study of the history of its fauna.

The historical aspects of flora

The paleogeographic events already mentioned regarding fauna have also greatly affected the history of flora, though in different ways owing to the great difference that separates plants and animals as regards dispersal.

Italy is a collage of regions with very different paleogeographic pasts (DE GIULI *et al.*, 1987; BOCCALETTI and MORATTI, 1990; COSENTINO *et al.*, 1993; DOGLIONI and FLORES, 1995) which constitutes one of the reasons for the great diversity of flora in this country. In particular, in outlining the phytogeographic heterogeneity of Italy, it may be useful to briefly mention the following paleogeographic events.

Sardinia, together with Corsica and the Balearics, belonged to the Iberian plate that broke away at the beginning of the Miocene. Hence, there are numerous interesting Sardinian-Balearic-Iberian disjunctions or vicariances, as well as relict palaeoendemic species thanks to Sardinia's relative tectonic stability (ARRIGONI, 1980).

The Alps were formed in the Cretaceous period, while the Apennines orogenesis (and the contemporaneous opening of the Tyrrhenian Sea) is much more recent, having started in the Oligocene and with a final uplifting up to the present altitudes that goes back to the Pleistocene. In the Pliocene, the Apennines were an archipelago of large islands, and traces of this isolation are still found in flora.

The northern mountains of Sicily also belong to the Apennines, while Calabria (together with the Peloritani Mountains in Sicily) was originated from a stretch of the Alpine chain. As northern Corsica is geologically homogeneous to the Alps, there is a possibility that the Alpine chain continued towards the south during the Cretaceous and Eocene epochs (the Tyrrhenian Sea was not yet open). The particular history of Calabria can help to explain the disjunct ranges of some species (*Genista anglica*, an Atlantic European species that reappears in Calabria; *Alnus cordata* and *Pinus laricio*, both disjunct between the Southern Apennines and Corsica).

Apulia was a sector of the African plate left undisturbed by the Appenine orogenesis. In the Miocene and Pliocene, it was connected to Dalmatia via the presentday Gargano-Tremiti-Pelagosa ridge. This partly explains the trans-Adriatic affinity in flora, which however was probably also greatly influenced by the Quaternary variations in sea level.

In the Messinian, the afore-mentioned drying of the Mediterranean basin most certainly led to great climatic variations (continental and arid), hence its influence on flora is not only limited to the creation of geographic "bridges" (which can explain, for example, Sardinian-Sicilian-North African vicariants: ARRIGONI, 1980). The climatic crisis also forced steppe species, xerophyle and halophyle species along these new routes of communication (BOCQUET *et al.*, 1978). Therefore, spiny shrub vegetation (cushion-heaths) of Mediterranean high mountain regions have considerable vicariances among the various mountain chains of the Mediterranean basin; sea cliff species are related to species of the desert mountain environments of central Asia; and halophilous plant species of our salt environments closely resemble desert species of the Middle East and Asia (PIGNATTI, 1994). The Messinian crisis could also be connected to the very great disjunctions between the Mediterranean and eastern Africa (or even southern Africa) as demonstrated by several genera (*Helichrysum*, *Silene*) and even species (*Erica arborea*) (BOCQUET *et al.*, l.c.). However, the recurring pattern of disjunctions and vicariants at the margins of the African continent, that seem to be relicts of a extinct pan-African biome, has probably a more complex explanation (cfr. BRAMWELL, 1985).

For flora as with fauna, limited traces of events that occurred during the Tertiary Period can still be seen in presentday plant landscape, if compared to the enormous impact in more recent periods since the Quaternary glaciations. During the glacial period, not all regions of the Mediterranean were entirely covered by glaciers. In fact, in southern Europe geomorphological traces have been found only of small and isolated glaciers (cfr. e.g. JAURAND, 1999). Palinological data of the Mediterranean regions regarding the Alpine and north European glacial cycle period, though characterised by the absence of pollen from arboreal species, do not indicate the presence of tundra species (unlike central Europe). Instead they indicate great quantities of *Graminaceae*, *Chenopodiaceae* pollen, and above all, *Artemisia* (FOLLIERI *et al.*, 1988; TZEDAKIS, 1993; FOLLIERI and MAGRI, 1997; MAGRI and SADORI, 1999; ELENGA *et al.*, 2000). These pollen fossils are interpreted as indicators of a steppe-like vegetation; consequently, it is possible that Mediterranean regions were subjected to arid climates, perhaps even continental though not necessarily very cold during the "glaciations" of central and northern Europe, (SUC, 1984; FOLLIERI and MAGRI, 1994 and 1997; ELENGA *et al.*, l.c.). This means that a mainly herbaceous vegetation dominated the plant landscape of a large part of Italy for most of the past million years, interrupted by brief forest periods (FOLLIERI and MAGRI, 1997).

During these cycles, arboreal flora survived in southern "refuge" areas, that have yet to be clearly identified. Recent studies have indicated the possibility of forest belts at a mean altitude, situated principally in the three Mediterranean peninsulas (Iberian, Italian and Balkan) and in the Caucasus region (BENNETT *et al.*, 1991; TZEDAKIS, 1993; CARRIÓN GARCÍA *et al.*, 2000; HEWITT, 2000; TARASOV *et al.*, 2000). At the end of each glacial cycle, a very rapid wave of recolonisation took place from these refuge sites to areas made suitable for woody vegetation, up to the extreme northern tip of Europe.

The primary consequences of these Pleistocene climatic oscillations on phytogeography in Italy can be summed up as follows.

Floristic impoverishment compared to other continents

Compared to sectors of North America and Eastern Asia with similar climatic characteristics, Europe has a very low number of woody species. Macrofossils and palinological data clearly indicate that this impoverishment was due to glacial events. The absence of these massive extinctions in temperate regions of other continents has often been attributed to the fact that the species did not encounter geographical obstacles in the constant north-south migrations, while in Europe, the east-west mountain chains and the Mediterranean impeded the escape passages southwards. However, according to BENNETT *et al.* (1991), palinological data indicate that climatic oscillations of the Quaternary provoked "one-way" migrations. At the beginning of every warm phase, the species migrated from the refuge sites of southern Europe towards the north while with the start of the cold phase there was no migration back south, but simply the extinction of northern populations and the survival of only southern populations that had remained in the refuge areas. This hypothesis implies the survival of European trees through the Quaternary period occurred only thanks to those sites in which the species could survive during both the glacial and the interglacial phases. If in these sites of southern Europe, the extinction of a species occurred during the interglacial stage, then the entire species would probably have become extinct during the following glacial stage (cfr. also: TZEDAKIS, 1993; MAGRI, 1998). The paucity of European woody flora compared to that of North America could be explained, according to this model, by the fact that southern Europe is immediately bordered by North African deserts, hence the areas that would remain permanently wooded during the whole Pleistocene would be very small.

Flora richness compared to central Europe

On the one hand, the Pleistocene extinctions explain why Italy has a certain floristic impoverishment compared to regions of other continents with similar climate and geography; while on the other hand, it helps explain the very high plant diversity in Italy when compared to central and northern Europe. In fact, apart from the great heterogeneity of the physical environment, the flora richness present in Italy is largely due to the fact that this peninsula was one of the refuge areas during the glaciations.

Populations separated by glaciations

During the glaciations, the Alps were covered by a large ice cap. However, some mountain tops due to their peripheral position or very steep morphology, remained free from ice (the so-called nunataks). Many taxa of present-day flora have a range that coincides perfectly with those of the nunataks identified based on geomorphology, which essentially form two alignments north and south of the mountain chain. The following cases have occurred: a) species with a fragmented distribution that corresponds to the single nunatakkers (e.g. *Cytisus emeriflorus*); b) series of related species born from a unitary species that was fragmented on these refuge sites during the glaciations (e.g. the group of *Papaver alpinum*); c) pairs of related species originating from the north-south disjunction on both sides of the Alps (e.g. *Callianthemum anemonoides*/ *C. kernerianum*); d) species separated by the glaciations and having two disjunct populations on either side of the Alpine chain, that have not differentiated (e.g. *Rhododendron hirsutum*) (PIGNATTI, 1994; CONTE and CRISTOFOLINI, 2000).

Glacial relicts

Species with a boreal/alpine ecology and chorology are at times found at very low altitudes: such as the wetlands of the Tuscan coastline from Versilia to the mouth of the Arno River which host *Drosera rotundifolia*, *Eriophorum gracile*, *Rynchospora alba*, etc. (GIACOMINI, 1958). These species are considered relicts of a tundra climate that have survived thanks to particular bioclimatic conditions (enhanced oceanity and scarce summer aridity) of northern Tuscany. Instead, small populations of *Fagus sylvatica* found at low altitudes that occur in various areas of central and southern Italy (cfr. e.g.: ANZALONE, 1961a e 1961b; SCOPPOLA and CAPORALI, 1998), are also defined as "glacial relicts" at times, when in reality they should be interpreted on the basis of present peculiarities of the environments in which they are found (ravines, volcanic slopes, etc.). The beech tree did not move "downwards" in terms of altitude or latitude during the glaciations, in reality there was only a very great expansion (from the Italian and Balkan refuge sites) during the last interglacial stage (even during the previous interglacial stage it did not have the role that it has today in central Europe) (BENNETT *et al.*, 1991; POTT, 1997; MAGRI, 1998).

Steppe species

From what has been said beforehand regarding the "steppe" character of ice ages in the Mediterranean, not only the tundra species, but even those *taxa* currently having their chorological centre of mass in the Asian steppes should be considered as traces of the glaciations in Italy. In Italy, they can be found in the primary high-mountain grasslands, as well as in the secondary grasslands (particularly in sub-Mediterranean climate environments and/or those that are to a certain extent continental).

Influence on insular flora

As seen above, the sea level was at least 100 metres lower than today during the glaciations. Many of the present minor Italian islands, therefore, were linked to the mainland and to each other for a very long period (cfr. e.g. ARRIGONI, 1974).

Trans-Adriatic affinity

A significant effect of the lowering of the sea level was the drying of the Adriatic sea almost up to Gargano. This helps clarify the great floristic and vegetation similarity between the Apennines and the Balkans. In fact, there are numerous cases of trans-Adriatic disjunctions (MONTELUCCI, 1972; PIGNATTI, 1982; CONTI, 1998), that are particularly apparent in the case of arboreal and shrub species. At times, the Italian sector of the distributional range of these phanerophytes has a relictual character (*Quercus trojana*, *Quercus macrolepis*, *Styrax officinalis*). However, these woody Balkan species often play an important role in vegetation even in Italy (*Quercus frainetto*, *Carpinus orientalis*, *Paliurus spina-christi*, *Cercis siliquastrum*). Furthermore, although they do not show a disjunct range in the true sense, we must not forget that in the Balkan barycentre there are also two of the species that most dominate the vegetation physiognomy of the Apennines: *Quercus cerris* and *Ostrya carpinifolia.* In any case, at the present state of knowledge, it is not easy to recognise which of the trans-Adriatic disjunctions and vicariants are due to variations of the sea level during the Pleistocene, and which are connected to even more ancient events that go back to the Messinian crisis or to tectonic changes of Tertiary paleogeography.

FAUNA AND FLORA DISTRIBUTION MODELS

Fauna distribution models

When comparing species richness per surface area in different Italian regions, one can see that the latitudinal gradient is opposite to the one indicated at European level, consistent with a faunal impoverishment from the north towards the south. This gradient, found for many different animal groups such as birds and various groups of insects, especially coleoptera (MASSA, 1982; AUDISIO *et al.*, 1995; FOCHETTI *et al.*, 1998), could be due to the so-called "peninsula effect", that is, exchanges with other regions are limited to the area of continuity with the rest of the continental mass.

To study the relationships of faunal affinity among the different districts in Italy, several authors have proceeded to identify the natural regions (which substantially correspond to the administrative regions) and to study the affinities on the basis of the animal population. Utilising various groups of coleoptera (carabids and chrysomelids) BARONI URBANI *et al.* (1978) highlighted the presence of three distinct groups of regions: (1) insular (major islands); (2) Padano-Alpine (regions of the Alpine arc); (3) Appenine (all the other regions). These groups were subsequently confirmed for alticinae chrysomelids (BIONDI, 1988), meloids (BOLOGNA, 1991) and again for carabids (VIGNA TAGLIANTI, 1999). These affinities refer more to ecological factors (climate) than to historical ones (paleogeographic and paleoecological), and are consistent with the different presence of northern elements (mostly in the Alpine district) and southern elements (mainly in the Apennine and insular districts). To a large extent, similar results were also obtained for a region system based on fluvial basins for plecoptera and aquatic coleoptera (AUDISIO *et al.*, 1995; FOCHETTI *et al.*, 1998). Instead, when utilising dermaptera, VIGNA TAGLIANTI (1993) obtained a less defined outline, whereas the Tyrrhenian regions form a very homogeneous group, which includes Sicily and Sardinia. In this case, it seems that the population shows the opposite discontinuity, that is longitudinal, which probably reflects the co-presence of western (Tyrrhenian) and eastern elements (Adriatic-Balkan).

Approaches of this type which provide a general picture of the animal population in Italy, must however be supported by more in-depth studies based on recurring distribution models (so-called chorotypes) that are capable of characterising the peculiarities of the single groups of regions. In particular, it seems clear that the "Apennine group" is a system of very complex and heterogeneous regions, in which faunal components with very different histories can be identified.

In general, Italian species can be ascribed to chorotypes relative to Palaearctic Asia (Figure 2.3), to Europe (Figure 2.4) or to the Mediterranean area (Figure 2.5), while very few species show ranges extended to palaeotropic regions, or are considered cosmopolitan or subcosmopolitan elements. As far as endemic and subendemic species are concerned, they should be attributed to general chorotypes based on their phylogenetic affinity (VIGNA TAGLIANTI *et al.*, 1993). Many Alpine, Alpine-Apennine and Apennine elements are attributed to central European or southern European chorotypes, while other Apennine elements (at times with trans-Adriatic or transitional distribution) (Figure 2.6) should be attributed to Mediterranean chorotypes, as should the Tyrrhenian, Sicilian (at times with a Sicilian-Maghrebi distribution), Sardinian and Sardinian-Corsican elements (Figure 2.7).

At a strictly geographic level, the position of Italy at the centre of the Mediterranean basin gives it a "transition" character, where there is an overlapping of western-Mediterranean, eastern-Mediterranean, as well as North African fauna. For numerous animal groups, there are high percentages of W-Mediterranean and E-Mediterranean chorotypes side along the obvious Mediterranean component. These last mentioned include the so-called trans-Adriatic and trans-Ionian elements, whose biogeographical importance already highlighted by GRIDELLI (1950), continues to attract the attention of biogeographers. This fact testifies to the repeated and paleogeographically very different contact that south-eastern Italy had with the Balkan peninsula (GIACHINO and VAILATI, 1993, CASALE *et al.*, 1996; LA GRECA, 1999; CIANFICCONI and TUCCIARELLI, 1999). For example, as already mentioned for flora, distributions of this type could have originated as a consequence of the Messinian crisis or to land that had emerged between the Italian coastlines and those of the Balkans (Gargano-Balkan bridge) in the Pleistocene.

The North-African elements which are generally the least represented group, have a fairly big faunal contingent in Sardinia, and particularly in Sicily. These two regions have interesting affinities with North Africa, deriving from vicariance events that involved ancient microplates, as well as dispersal events (GIUSTI and MANGANELLI, 1984; STEININGER *et al.*, 1985; LA GRECA, 1990; ESTABROOK, 2001).

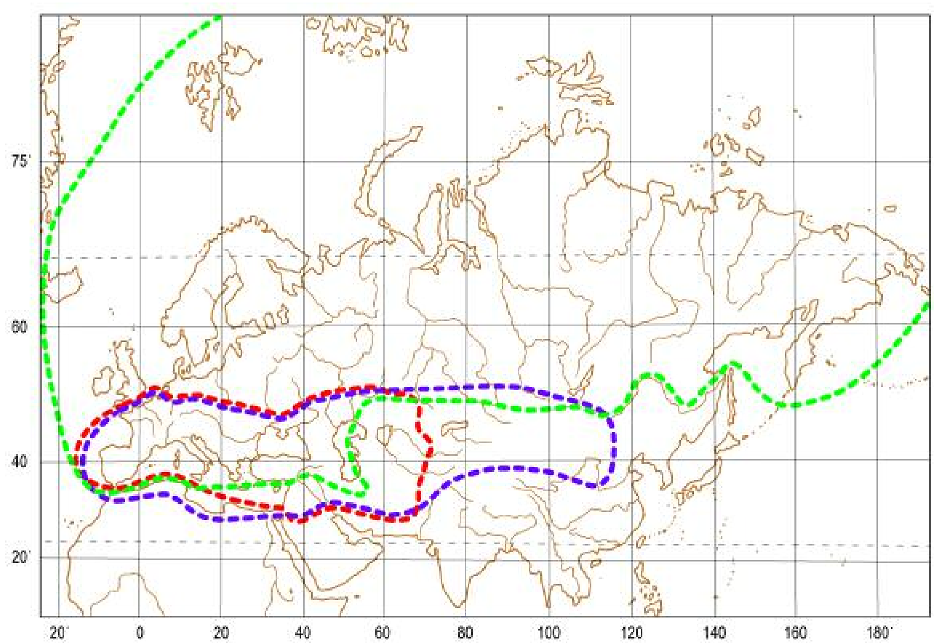


Fig. 2.3 - Several chorotypes of animal species with a wide Palearctic distribution (Siberian-European, Central Asiatic-European-Mediterranean, Turanic-European).

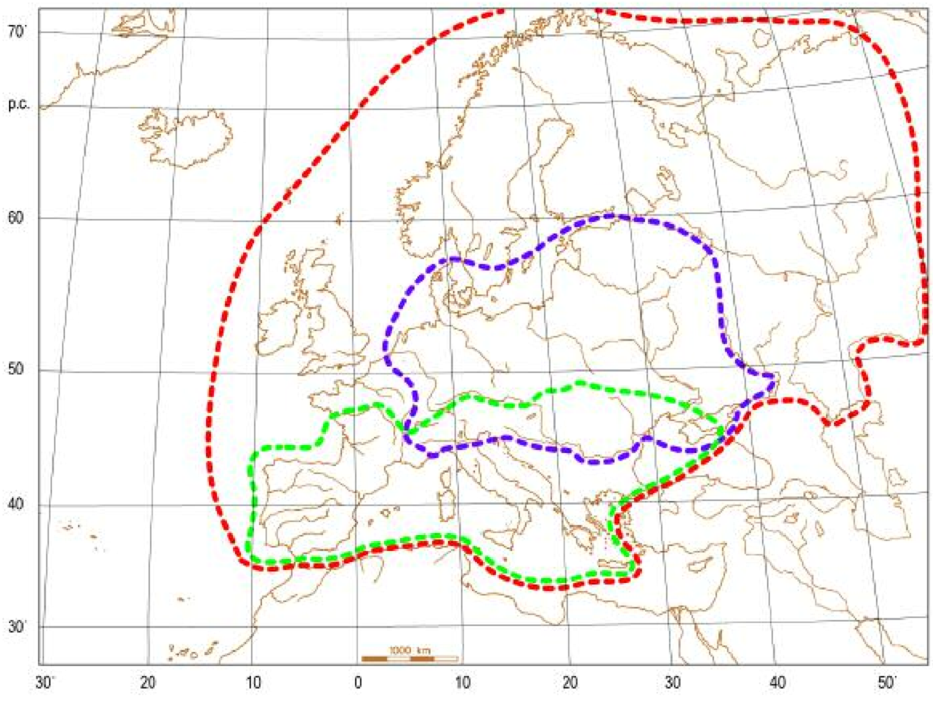


Fig. 2.4 - Several chorotypes of animal species with a wide European distribution (European, Central European, S-European).

Instead, only three principal types of faunal components can be identified for marine fauna (BIANCHI *et al.*, 2002): endemic species of the Mediterranean (including the paleoendemic relict species of the Tetide), Atlantic-Mediterranean species, and the species with a very wide range (pan-oceanic). To these, one must add the Atlantic subtropical and boreal components (that entered the Mediterranean during the glacial-interglacial transitions), the most recent migrants from the eastern Atlantic, through the Strait of Gibraltar, and the species from the Red Sea after the opening of the Suez Canal ("Lessepsian" species, from the name of the diplomat who was responsible for the opening of the canal, inaugurated in 1869).

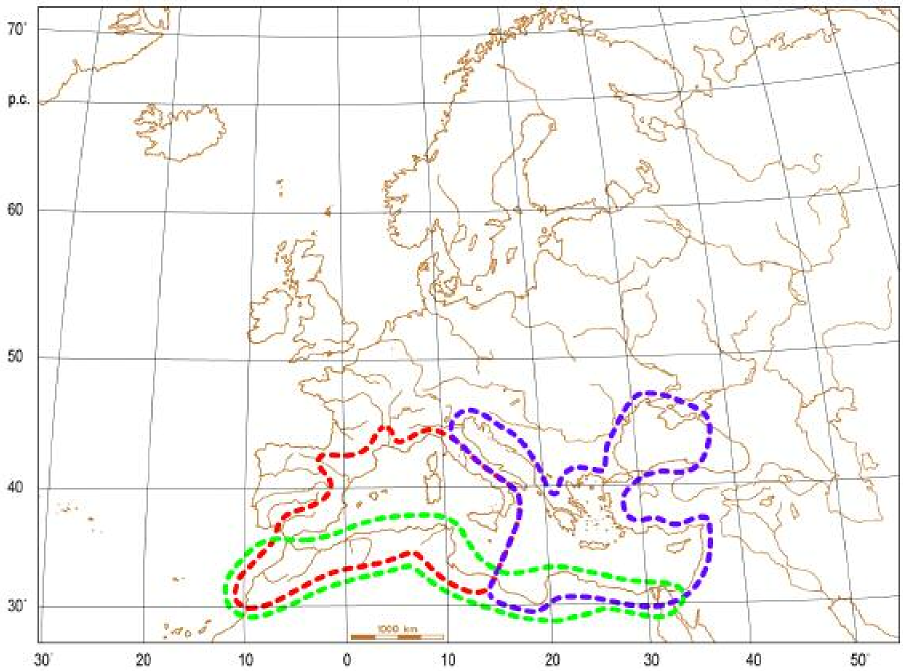


Fig. 2.5 - Several chorotypes of animal species with a wide Mediterranean distribution (W-Mediterranean, E-Mediterranean, N-African).

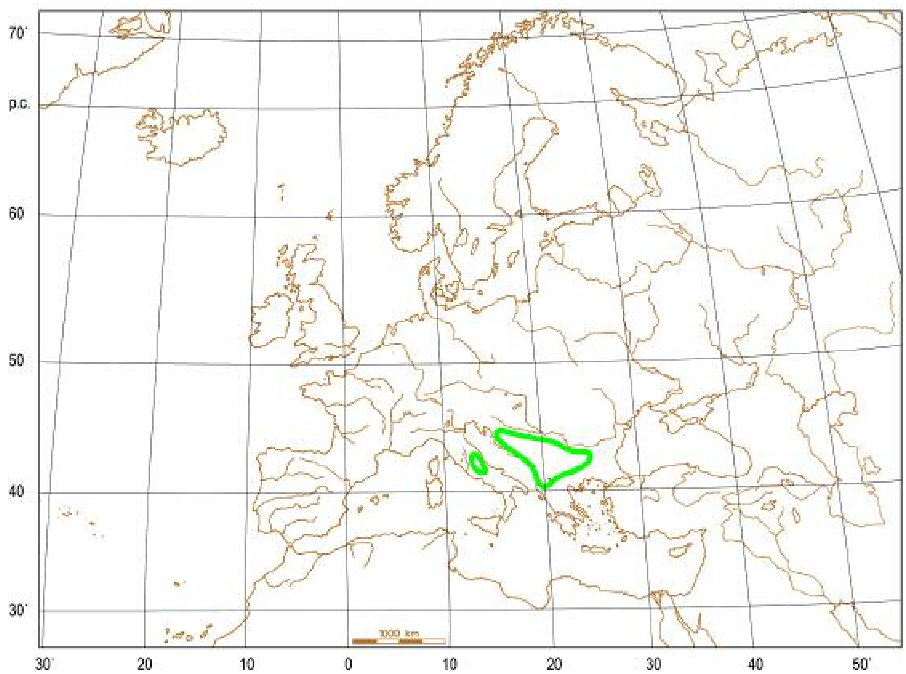


Fig. 2.6 - An example of disjunct Apennine-Dinaric distribution: *Carabus cavernosus*, a steppe coleopteran, with trans-Adriatic range.

Italian flora distribution models

As far as the distribution of flora diversity in Italy is concerned, reference should be made to the data and considerations provided by Abbate *et al.* in this volume. Consequently, we can limit ourselves to saying that the distribution of floristic richness in Italy does not have a peninsula effect as it does for fauna. In fact, the highest diversity is to be found in the central Apennines (3,000 species in Abruzzi, 2,000 in the small region of Molise and 1,900 species in a provisional list of the Abruzzo National Park) (Conti, 1995 and 1998; Lucchese, 1995), and in coastal areas of the Peninsula (the promontory of Monte Argentario in southern Tuscany contains 1,160 species in an

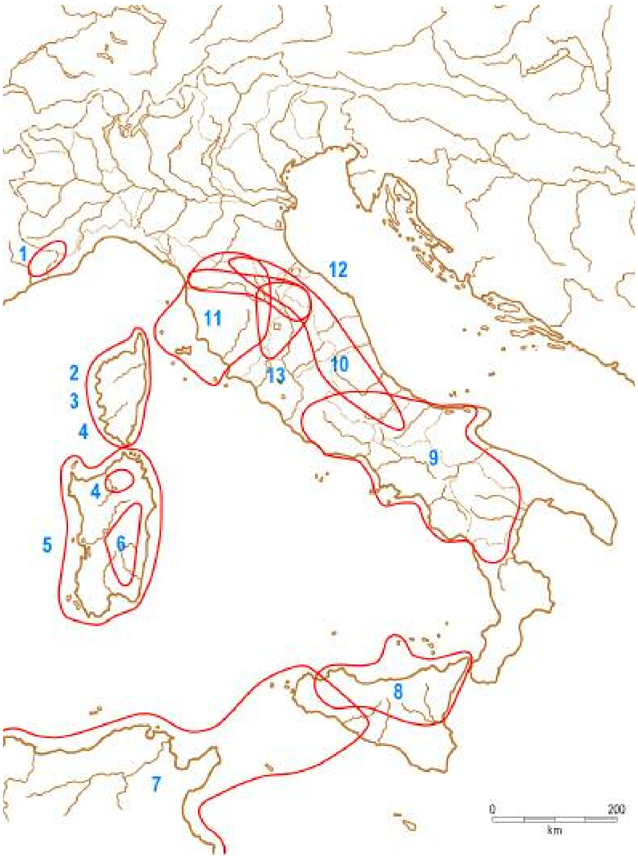


Fig 2.7 - The distribution range of species of the genus *Percus* (carabid coleopteran): pre-Quaternary W-Mediterranean specimens, whose dispersal and speciation is connected to historical factors (the Messinian Salinity Crisis and Plio-Pleistocene events): 1. *villai*, 2. *corsicus*, 3. *reichei*, 4. *grandicollis*, 5. *strictus*, 6. *cylindricus*, 7. *lineatus*, 8. *lacertosus*, 9. *bilineatus*, 10. *dejeani*, 11. *paykulli*, 12. *passerinii*, 13. *andreinii* (the two species of the Balearics are not indicated).

area of only 6,000 hectares; 1,900 *taxa* have been identified for Monti Aurunci in the Tyrrhenian Lazio region, and a preliminary list of Cilento in southern part of the Campania Region indicates almost 2,000 species) (MORALDO *et al.*, 1990; BALDINI, 1995; MOGGI, 2001). There are several reasons that explain this difference in patterns between fauna and flora richness. First of all, it is important to remember that the Italian Peninsula was a refuge area from which plant species re-colonised Europe after the last glaciation; therefore it is logical that the gradient of diversity decreases from the peninsula towards the continent, contrary to what occurs in peninsulas colonised by dispersal starting from the continental mass. Secondly, central Italy and southern Italy have a high degree of climatic heterogeneity, a factor that has a greater effect on plant diversity than it does on animal diversity. Last of all, at global level Mediterranean ecosystems are hotspots of floristic richness, though not to the same extent for faunal diversity (cfr. e.g. WORLD CONSERVATION MONITORING CENTRE, 1992).

As far as the distribution of chorotypes in the Italian territory is concerned, according to a work by PIGNATTI (1994) on the basis of administrative regions, one can note that:

- Eurimediterranean chorotypes are frequent in all the regions, without a specific gradient;
- instead Stenomediterranean chorotypes are most frequent in Sicilia, Sardegna, Puglia, and Calabria; decreasing northwards, least frequent in Trentino and Friuli;
- southern-European-orophyles have greatest level in Alpine regions;
- Eurasian chorotypes decrease (even though in an irregular manner) from north to south, reaching minimum levels in Sicilia and Sardegna;
- Atlantic chorotypes have the lowest levels throughout the country, though with an evident concentration in western regions in the following order: Sardegna, Toscana, Piemonte, Liguria, Lazio, and Sicilia.

Generally speaking, the particular geographic position of Italy creates an overlapping of floras (as already mentioned for fauna) with different geographical and historical origins (cfr. MONTELUCCI, 1972 and 1977). In fact, the northern Tyrrhenian part of the peninsula is strongly influenced by W-Mediterranean elements and even species with an Atlantic chorotype, while the Adriatic sectors and the central Tyrrhenian coastlines are characterised by a strong E-Mediterranean and Illyrian element. Eurasian, Circumboreal, and southern-European-orophyle elements occur along the entire Apennine chain down to Sicilia, mixing with the Mediterranean-montane component. Southern-Stenomediterranean species (corresponding to the North African element in zoology), together with the Saharan-Syndic and the Mediterranean-Turanic elements, maintain a connection (possibly of Messinian origin) with the arid North African-Middle Eastern belt.

Zoogeographic regions

An evaluation of the number of species belonging to the various chorotypes in different regions has allowed us to identify six zoogeographic provinces that are regions of distintive fauna based on paleogeographic, paleoecological and ecological factors: Alpine, Padanian, Apennine, Apulian, Sicilian, and Sardinian (RUFFO and VIGNA TAGLIANTI, 2002).

Alpine Province

The fauna that populated the newly formed Alpine chain in the Tertiary Period is mainly seen today in land and cavernicolous arthropods, with a limited range in the marginal sectors of the Alps that survived the Quaternary glaciations in refuge sites in the Ligurian Alps, the Julian, Venetian and Lombardy Pre-Alps. The fauna of the Alps is characterised by a very high percentage of species with a range that corresponds to "northern" chorotypes (European, Eurasian, and Siberian-European), the consequence of cold climatic phases during the Quaternary when widespread migration of fauna from northern Asia towards southern Europe occurred. The faunal richness is also due to the altitudinal range of the Alps allowing the colonisation of species with different ecological needs, from those of broad-leaved and coniferous forests to those of high mountain grasslands or the Alpine tundra. Another consequence of the Quaternary glacial-interglacial transitions is the presence of numerous fauna (about 200) with a discontinuous "boreal-alpine" distribution (northern Europe and the Alps) (Figure 2.8). The percentage of Mediterranean chorotypes is very low, no more than 2%, except in particular areas of the Pre-Alps also known as "xerothermic areas" that have a warmer and drier climate, such as Colli Euganei, Colli Berici, the southern slopes of the Veronese Pre-Alps, or west of Val di Susa.

Padanian Province

The Padano-Veneto plain formed in relatively recent post-Pliocene times due to the great Alpine and Apennine rivers, makes it a transition territory between the Alpine district and that of the Apennines. The biotopes are those of residual forests with Quercus and Carpinus of the ancient "Padana woods", heaths, riparian forests of the great rivers, and what remains of the vast marshy areas drastically reduced in size today. The fauna of these environments generally have central-European chorotypes, above all north of the Po River, or else display affinity with eastern chorotypes. The freshwater fauna of this province, those of surface waters as well as those that dwell underground are of great interest for the presence of species, including endemics, that penetrate well into the Padana Plain, up to Piemonte.

Apennine province

This province corresponds to the peninsular territory which has the Apennine range as its axis. The Apennines were fragmented during the Miocene and the Pliocene into a series of islands, which were colonised by elements of ancient Aegean and Tyrrhenian fauna. The relict Paleomediterranean species, richer and more diversified than those in the Alps, were overlapped during the Quaternary climatic crisis by fauna of northern origin, made up of Alpine, European, Asian-European, and Siberian-European elements that had reached the extreme southern tip of the peninsula and Sicilia. Following better climatic conditions during the Würmian glaciation, the species of northern origin were numerically greatly reduced and were found at increasingly higher altitudes from north to south. At the same time, Mediterranean thermophile elements expanded greatly in the opposite direction.

Apulian province

This province includes the territory of Gargano, the Murge and the Salentino *Serre*, whose geological history is linked to the ancient Egeide, perhaps its extreme western limit. The Apulian province is also characterised by a moderate elevation of mountains that do not exceed 1,000 metres in height, madeup of carbonate rocks with different groundwater systems that have evolved in them. The

Fig. 2.8 - An example of disjunct "Boreal-Alpine" distribution of an animal species with a Holarctic chorology, the Rock ptarmigan *Lagopus mutus*.

faunal peculiarity of the Apulian province regards the invertebrates above all, which include a great many species with trans-Adriatic and trans-Ionian distribution (of which there are more than 100 coleopterans). An important biogeographic characteristic is the remarkable richness and abundance of groundwater animals, including endemic species of marine origin that occur in the Salento-Murge district, which display affinity with Indopacific and/or Caribbean species, relicts of ancient fauna of the Mediterranean when it was still part of the Tetide.

Sicilian province

Sicilia represents the insular prolongation of the Apennine province. The coastal chains from Peloritani to the Madonie were colonised by species of northern origin during the Quaternary when it was connected to the mainland that represent about 30% of Sicilian fauna, concentrated above all, in the beech-tree and oak-tree woods on the Tyrrhenian side. Along with this temperate-cold component there is a strong presence of xerothermophyle species, particularly along the southern inland slopes which accentuates the arid Mediterranean character of the mountains in Sicilia. Moreover, Sicilian fauna has a significant number of Paleomediterranean and Paleotyrrhenian species which derive from Tertiary fauna of the Tyrrhenian areas.

Sardinian province

Sardinian fauna has a strong "insular"character: the biodiversity of species is lower (there are about about 10,500 species that occur in Sardegna compared to 14,000 in Sicily) and many species that are both abundant and widespread in Italy do not occur in Sardinia. The Mediterranean component of Sardinian fauna is among the the highest of all the Italian zoogeographic provinces, while the species that correspond to northern chorotypes are much fewer in number. Instead, there are a high number of Paleomediterranean species and especially Paleotyrrhenian ones with western affinity, which are the most ancient faunal contingent (derived from the pre-Miocene fauna of the Sardinian-Corsican microplate), with a high percentage of endemic species (6.5% of Sardinian fauna compared to 4.2% of Sicilian fauna). Particularly interesting are the several faunal troglobian species. The isolation of Sardinia was interrupted during the Miocene, when Sardegna was connected either directly or indirectly with the Apennine region, Sicily and North Africa, which is confirmed by the presence of Sardinian-Tuscan, Sardinian-Sicilian, or Sardinia-Sicilian-Maghrebine species.

Phytogeographic regions

Unfortunately, recent and in-depth studies have not yet been conducted on the subdivision of Italy into phytogeographic provinces. GIACOMINI (1958) subdivided Italy up into the Central-European Region (*Medioeuropea*) and the Mediterranean Region (Figure 2.9). The first includes the Alps, the Padana Plain, and the Apennines down to Abruzzi, and is subdivided into the Alpine province and the Apennine province; along the Adriatic coast it reaches the sea only up to Ravenna. The Mediterranean Region includes the islands, southern Italy and the coastal sectors of northern Italy, excluding the coasts from Ravenna to Trieste which belong to the Central-European Region. According to this scheme, in Italy, the Mediterranean Region is subdivided into a Ligurian-Tyrrhenian Province, which outside the country also includes Provence and Corsica, and an Adriatic Province, which also includes a narrow strip of the ex-Jugoslavia coastline (while the hinterland is part of the Illyrian Province of the Central-European Region). This model

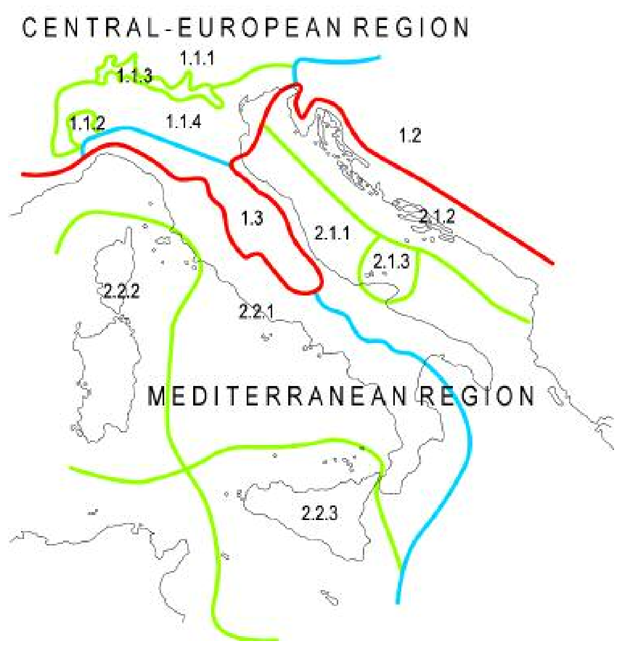


Fig. 2.9 - Phytogeographic subdivisions of Italy, according to GIACOMINI (1958), redrawn. Legend: 1.1 Alpine Province (1.1.1 Alpine District, 1.1.2 Monferrino-Langhiano District, 1.1.3 Insubrico District, 1.1.4 Padano District); 1.2 Illyrian Dominion; 1.3 Apennine Province; 2.1. Adriatic Province (2.1.1 W-Adriatic District, 2.1.2 E-Adriatic District, 2.1.3 Gargano District); 2.2 Ligurian-Tyrrhenian Province (2.2.1 Tyrrhenian District, 2.2.2 Sardinian-Corsican District, 2.2.3 Sicilian District).

was taken up by TAKHTAJAN (1986), in his floristic division of the entire planet.

The proposal made by ARRIGONI (1980) (Figure 2.10) diverges from this model with regards to the extent of the two regions and also the different internal division. This author identifies in Italy a Central-European Dominion of the Eurosiberian Region, subdivided into an Alpine Sector (the Alps), a Pannonic-Padano Sector (which pools together the Padana Plain and the northern Adriatic coasts of the peninsula to the Pannonic area) and an Apennine Sector (which descends down to Aspromonte). According to this model, the Eurosiberian Region descends along the Adriatic coast to Gargano and inland to Aspromonte. The Mediterranean Region, in Italy, is subdivided into the Italic-Provencal Dominion (Tyrrhenian coasts of the peninsula and Provence), a Sardinian-Corsican Dominion (Sardegna and Corsica) and an Apulian-Sicilian Dominion, which encompasses Sicilia, the Calabrian coasts and Puglia, though not the Balkan coast that comes within the Illyrian Dominion.

A similar scheme to that of GIACOMINI was provided by RIVAS-MARTINEZ *et al.* (2001), in a Phytogeographic Map of Europe on a scale of 1:16,000,000 that subdivides Italy as follows (Figure 2.11). The Eurosiberian Region descends along the Apennine to include Campania. On the Adriatic side it reaches the coast up to Ancona, while on the Tyrrhenian side it moves inland near the Apuan Alps. It is subdivided into an Alpine Province limited to the Alps and an Apennine-Balkan Province, which encompasses the Padana Plain (Padana Sector), the Apennines (Apennine Sector), the Balkans (the Illyrian Sector) as well as inland Greece and Bulgaria. The Mediterranean Region is divided into the Adriatic Province, which encompasses Puglia (Apulian Sector), the coastal belt of ex-Jugoslavia and Albania (Epirus-Dalmatian Sector) and Greece (Peloponnesian Sector); a Tyrrhenian Province, which unlike the other two proposals does not extend to Provence, but only includes the western coasts of the peninsula (Italic Sector), Sicilia (Sicilian Sector), Sardegna and Corsica (Sardinian Sector and Corsican Sector).

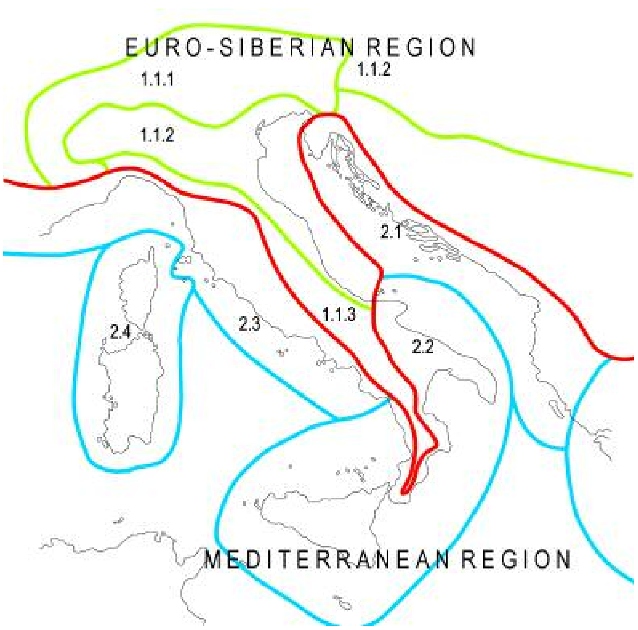


Fig. 2.10 - Phytogeographic subdivisions of Italy, according to ARRIGONI (1980), redrawn. Legend: 1.1 Mid-European Dominion (1.1.1 Alpine Sector, 1.1.2 Pannonic-Padana Sector, 1.1.3 Apennine Sector); 2.1 Illyrian Dominion; 2.2 Apulian-Sicilian Dominion; 2.3 Italic-Provencal Dominion; 2.4 Sardinian-Corsican Dominion.

Fig. 2.11 - Phytogeographic subdivisions of Italy, according to RIVAS-MARTINEZ *et al.*. (2001), redrawn. Legend: 1.1 Alpine Province; 1.2 Apennine-Balkan Province (1.2.1 Padana Sector, 1.2.2 Apennine Sector, 1.2.3 Illyrian Sector); 2.1 Adriatic Province (2.1.1 Apulian Sector, 2.1.2 Epirus-Dalmatian Sector); 2.2 Tyrrhenian Province (2.2.1 Italic Sector, 2.2.2 Sicilian Sector, 2.2.3 Sardinian Sector, 2.2.4 Corsican Sector).

Endemic species

Italy has a great number of endemic animal species which account for about 10% of the total fauna. The same percentage of endemism is also found in vascular plants, which includes about 13% of sub-endemic species, that is, those species whose range extends slightly beyond the political Italian borders, 10% if one speaks of endemic species in the strict sense of the word (PIGNATTI, 1982 and 1994; see section *Vascular plants*).

The percentage of endemism in Italian fauna (species within the "political" Italian borders), particularly among land and freshwater animals, varies greatly depending on the groups. It is more than 25% in numerous orders of insects and in several large families (e.g. plecopterans, orthopterans, carabid coleopterans, and staphylinids) and reaches almost 60% in pseudscorpions and in diploids. The number of Italian endemic species is much lower in marine fauna (less than 1.5%) given the greater environmental continuity of Italian seas in the Mediterranean, which vice versa has a rate of endemism of more than 25%.

Generally speaking, as far as land fauna is concerned, endemic species are found either at high altitudes, in caves or on the islands. Once again, it is the complex articulation of the Italian territory along with its palaeogeographic and palaoclimatic vicissitudes that account for such high levels. The upthrust of the Alpine chain and the Apennine range into distinct massifs, the subsequent isolation of these mountain areas during the Pleistocene glaciations, along with the variations in altimetric distribution of vegetation belts caused by climate change, were all factors that surely contributed to the processes of speciation, which gave rise to isolated populations (and therefore endemic ones) in the various mountain districts (BRANDMAYR and ZETTO BRANDMAYR, 1994; ZUNINO and ZULLINI, 1995; LA GRECA, 1996; BULLINI *et al.*, 1998; BLONDEL and ARONSON, 1999). The extensive Karstic system, above all in north-eastern Italy, with the great many caves, contributed to enrich Italian fauna with a high contingent of cavernicolous endemic species. Finally, the presence of two large islands (Sicilia and Sardegna) and numerous small islands that are generally of recent origin (often volcanic) has led to a significant number of insular and microinsular endemic species. In the case of Sardegna and Corsica, there are also endemic species of ancient origin considered relict species of the Sardinian-Corsican plate (CACCONE *et al.*, 1994; PALMER and CAMBEFORT, 1997; PALMER, 1998). Instead, the numerous endemisms of the small islands are the result of very recent and rapid speciation, consequent to the formation of very small and isolated insular populations subjected to genetic drift.

Bibliography

ALEFFI M., SCHUMACKER R., 1995 – *Check-list and red-list of the liverworts (*Marcantiophyta*) and hornworts (*Anthocerotophyta*) of Italy.* Fl. Medit., 5: 73-161.

ANZALONE B., 1961a – *Sul limite altimetrico inferiore del faggio nella regione laziale.* Ann. Bot. (Roma), 27 (1): 80-106.

ANZALONE B., 1961b – *Osservazioni fitosociologiche su alcune faggete depresse del Lazio.* Ann. Bot. (Roma), 27 (1): 120-133.

ANZALONE B., 1996 – *Prodromo della Flora Romana (elenco preliminare delle piante vascolari spontanee del Lazio) (Aggiornamento). Parte 2.* Ann. Bot. (Roma), 54: 7-47.

ARRIGONI P.V., 1974 – *Rapporti floristici tra l'Arcipelago Toscano e le terre vicine.* Lav. Soc. Ital. Biogeog., n.s., 5: 55-65.

ARRIGONI P.V., 1980 – *Aspetti corologici della flora sarda.* Lav. Soc. Ital. Biogeog., n.s., 8: 83-109.

ASHTON K.G., 2001 – *Are ecological and evolutionary rules being dismissed prematurely?* Diversity and Distribution, 7: 289-295.

AUDISIO P., DE BIASE A., BELFIORE C., FOCHETTI R., 1995 – *A multimethod approach to the zoogeography of the Italian river basins, based upon distributional data of freshwater invertebrates. I. The genus* Hydraena *Kugelann s.l. (Coleoptera, Hydraenidae).* Bollettino di Zoologia, 62: 401-411.

AZZAROLI A., 1990 – *Palaeogeography of terrestrial vertebrates in the perithyrrhenian area.* Pal. Pal. Pal., 77: 83-90.

BALDINI R.M., 1995 – *Flora vascolare del Monte Argentario (Arcipelago Toscano).* Webbia, 50 (1): 67-191.

BARONI URBANI C., RUFFO S., VIGNA TAGLIANTI A., 1978 – *Materiali per una biogeografia italiana fondata su alcuni generi di Coleotteri Cicindelidi, Carabidi e Crisomelidi.* Memorie della Società entomologica italiana. 56 (1977): 35-92.

BENNETT K.D., TZEDAKIS P.C., WILLIS K.J., 1991 – *Quaternary refugia of north European trees.* Journ. Biogeogr., 18: 103-115.

BIANCHI C.N., BOERO F., FRASCHETTI S, MORRI C., 2002 – *La fauna del Mediterraneo.* In: MINELLI A., CHEMINI C., ARGANO R., RUFFO S. (a cura di), La fauna in Italia. Touring Editore, Milano e Ministero dell'Ambiente e della Tutela del Territorio, Roma, pp. 248-335.

BIONDI M., 1988 – *Considerazioni biogeografiche sui Crisomelidi Alticini della fauna italiana (Coleoptera).* Atti del XV Congresso nazionale italiano di Entomologia, L'Aquila, 1988: 689-696.

BLONDEL J, ARONSON J., 1999 – *Biology and wildlife in the Mediterranean region.* Oxford University Press, Oxford, 328 pp.

BOCCALETTI M, MORATTI G. (eds.), 1990 – *Neogene Palaeogeography of the Perithyrrenian Area.* Pal.Pal. Pal., 77:1-90.

BOCQUET G., WIDLER B, KIEFER H., 1978 – *The Messinian Model: A new outlook for the floristic and systematics of the Mediterranean area.* Candollea, 33: 269-287.

BOLOGNA M., 1991 – *Coleoptera Meloidae*. Fauna d'Italia, 28. Edizioni Calderini, Bologna, XIV + 541 pp.

BRAMWELL D., 1985 – *Contribución a la biogeografía de las Islas Canarias*. Bot. Macaron., 14: 3-34.

BRANDMAYR P, ZETTO BRANDMAYR T., 1994 – *The evolutionary history of the genus* Abax *(Coleoptera, Carabidae)*. In: DESENDER K., DUFRÊNE M., LOREAU M., LUFF M.L., MAELFAIT J.P. (eds.), Carabid Beetles: Ecology and Evolution. Kluwer Academic Publishers, Dordrecht/Boston/London, pp. 19-24.

BULLINI L., PIGNATTI S, VIRZO DE SANTO A., 1998 – *Ecologia generale*. UTET, Torino, XVI + 519 pp.

CACCONE A., MILINKOVITCH M.C., SBORDONI V, POWELL J.R., 1994 – *Molecular biogeography: using the Corsica-Sardinia microplate disjunction to calibrate mitochondrial rDNA evolutionary rates in mountain newts (*Euproctus*)*. Journal of Evolutionary Biology, 7: 227-245.

CAPANNA E., 1993 – *Emergenze sistematiche e biogeografiche sui micromammiferi della regione circummediterranea*. Faune attuali e faune fossili, XIX Seminario sulla Evoluzione biologica ed i grandi Problemi della Biologia. Accademia nazionale dei Lincei, Contributi del Centro Linceo Interdisciplinare "Beniamino Segre", 86: 53-78.

CARPANETO G.M., 1975 – *Note sulla distribuzione geografica ed ecologica dei Coleotteri Scarabeoidei Laparosticti nell'Italia appenninica (I Contributo)*. Bollettino dell'Associazione romana di Entomologia, 29 (1974): 32-54.

CARRIÓN GARCÍA J.S., MUNUERA GINER M., NAVARRO CAMACHO C, SAÉZ SOTO F., 2000 – *Paleoclimas e historia de la vegetación cuaternaria en España a través del análisis polínico. Viejas falacias y nuevos paradigmas*. Complutum, 11: 115-142.

CASALE A., GIACHINO P.M., VAILATI D, VIGNA TAGLIANTI A., 1996 – *Il genere* Duvalius *in Grecia: stato attuale delle conoscenze, interesse biogeografico e descrizione di una nuova specie (Coleoptera, Carabidae, Trechinae)*. Bollettino del Museo civico di Storia naturale di Verona, 20 (1993): 303-335.

CIANFICCONI F, TUCCIARELLI F., 1999 – *Considerazioni zoogeografiche sulla Tricotterofauna dell'Anatolia*. Biogeographia, Lavori della Società italiana di Biogeografia, (n.s.) 20: 213-221.

CONTE L, CRISTOFOLINI G., 2000 – *Infraspecific diversity of* Cytisus emeriflorus *Rchb. (*Leguminosae*), an endemic plant with disjunct distribution: evidence from isozyme data*. Plant Biosyst., 134 (3): 373-384.

CONTI F., 1995 – *Prodromo della flora del Parco Nazionale d'Abruzzo*. Liste preliminari degli organismi viventi del Parco Nazionale d'Abruzzo: 7. Ente Autonomo PNA, Roma, 127 pp.

CONTI F., 1998 – *An annoted checklist of the flora of the Abruzzo*. Bocconea, 10: 1-274.

CORTINI PEDROTTI C., 1992 – *Check-list of the Mosses of Italy*. Fl. Medit., 2: 119-221.

COSENTINO D., PAROTTO M, PRATURLON A., 1993 – *Lazio*. Guide Geologiche Regionali, 5. Società Geologica Italiana, Roma.

CRISTOFOLINI G., 1998 – *Qualche nota sulla diversità floristica, sulla biodiversità in generale, e sui modi per misurarla*. Inf. Bot. Ital., 30 (1-3): 7-10.

DAVIS M., 1983 – *Quaternary history of deciduous forests of Eastern North America and Europe*. Ann. Missouri Bot. Gard., 70: 550-563.

DAVIS P.H. (ed.), 1965-1985 – *Flora of Turkey and the East Aegean Islands*. Edinburgh University Press, Edinburgh. 9 voll.

DE GIULI C., MASINI F, VALLERI G., 1987 – *Palaeogeographic evolution of the Adriatic area since Oligocene to Pleistocene*. Riv. It. Paleont. Strat., 93 (1): 109-126.

DOGLIONI C, FLORES G., 1995 – *An introduction to the Italian geology*. Editrice Il Salice, Potenza.

ELENGA H., PEYRON O., BONNEFILLE R., JOLLY D., CHEDDADI R., GUIOT J., ANDIREU V., BOTTEMA S., BUCHET G., DE BEAULIEU J.-L., HAMILTON A.C., MALEY J., MARCHANT R., PEREZ-OBIOL R., REILLE M., RIOLLET G., SCOTT L., STRAKA H., TAYLOR D., VAN CAMPO E., VINCENS A., LAARIF F, JONSON H., 2000 – *Pollen-based reconstruction for southern Europe and Africa 18,000 yr BP*. Journ. Biogeog., 27: 621-634.

ESTABROOK G.F., 2001 – *Vicariance or dispersal: the use of natural historical data to test competing hypotheses of disjunction on the Tyrrhenian coast*. Journal of Biogeography, 28: 95-103.

FOCHETTI R., DE BIASE A., BELFIORE C., AUDISIO P., 1998 – *Faunistica e biogeografia dei plecotteri italiani (Plecoptera)*. Memorie della Società entomologica italiana, 76: 3-19.

FOLLIERI M., MAGRI D., 1994 – *Significati delle conoscenze palinologiche e paleobotaniche del Quaternario Laziale*. Mem. Descr. Carta Geol. d'It., 49: 169-176.

FOLLIERI M., MAGRI D., 1997 – *Paesaggi vegetali del Quaternario in Italia centrale*. Biogeographia, 19: 57-67.

FOLLIERI M., MAGRI D., SADORI L., 1988 – *250,000-year pollen record from Valle di Castiglione (Roma)*. Pollen et Spores, 30 (3-4): 329-356.

GIACHINO P.M., VAILATI D., 1993 – *Revisione degli Anemadinae Hatch, 1928 (Coleoptera Cholevidae)*. Monografie di Natura Bresciana, 18: 314 pp.

GIACOMINI V., 1958 – *Conosci l'Italia: La Flora*. TCI, Milano.

GIUSTI F, MANGANELLI G., 1984 – *Relationships between geological land evolution and present distribution of terrestrial gastropods in the western Mediterranean area*. In: SOLEM A., VAN BRUGGEN A.C. (eds.), *World-wide snails - Biogeographical studies on non-marine Mollusca*. E.J: Brill/Dr. W. Backhuys, Leiden, pp. 70-91.

GRIDELLI E., 1950 – *Il problema delle specie a diffusione transadriatica con particolare riguardo ai Coleotteri*. Memorie di Biogeografia adriatica, 1: 7-299.

HEWITT G., 2000 – *The genetic legacy of the Quaternary ice ages*. Nature, 405: 907-913.

HEWITT G.H., 1999 – *Post-glacial re-colonization of European biota*. Biological Journal of the Linnean Society, 68: 87-112.

HUGOT J.-P, COSSON J.-F., 2000 – *Constructing general areas cladograms by matrix representation with parsimony: a western palearctic example*. Belgian Journal of Entomology, 2: 77-86.

JAURAND E., 1999 – *Il glacialismo negli Appennini. Testimonianze geomorfologiche e riferimenti cronologici e paleoclimatici*. Boll. Soc. Geogr. Ital., serie 12, 4 (3): 399-432.

LA GRECA M., 1990 – *The Insects Biogeography of West Mediterranean Islands. Biogeographical Aspects of Insularity*. Accademia nazionale dei Lincei, Atti dei Convegni Lincei, 85: 469-491.

LA GRECA M., 1996 – *Storia biogeografica degli Ortotteri d'Italia: origine e distribuzione*. Bollettino del Museo civico di Storia naturale di Verona, 20 (1993): 1-46.

LA GRECA M., 1999 – *Il contributo degli Ortotteri (Insecta) alla conoscenza della biogeografia dell'Anatolia: la componente gondwaniana*. Biogeographia, Lavori della Società italiana di Biogeografia, (n.s.) 20: 179-200.

LA GRECA M., 2002 – *Vicende paleogeografiche e componenti della fauna italiana.* In: MINELLI A., CHEMINI C., ARGANO R., RUFFO S. (a cura di), La fauna in Italia. Touring Editore, Milano e Ministero dell'Ambiente e della Tutela del Territorio, Roma, pp. 360-376.

LUCCHESE F., 1995 – *Elenco preliminare della Flora spontanea del Molise.* Ann. Bot. (Roma), 53 (12): 1-386.

MAGRI D., SADORI L., 1999 – *Late Pleistocene and Holocene pollen stratigraphy at Lago di Vico, central Italy.* Veget. Hist. Archaeobot., 8: 247-260.

MAGRI D., 1998 – *Quaternary history of* Fagus *in the Italiana peninsula.* Ann. Bot. (Roma), 56 (1): 147-154.

MASSA B., 1982 – *Il gradiente faunistico nella penisola italiana e nelle isole.* Atti della società italiana di scienze naturali e del Museo civico di Storia naturale di Milano, 123: 353-374.

MINELLI S., 1996 – *La Checklist delle specie della fauna italiana - Un bilancio del progetto.* Bollettino del Museo civico di Storia naturale di Verona, 20 (1993): 249-261.

MINELLI S., RUFFO S., LA POSTA S. (eds.), 1993-1995 – *Checklist delle specie della fauna italiana.* 1-110. Calderini, Bologna.

MOGGI G., 2001 – *Catalogo della Flora del Cilento (Salerno).* Inf. Bot. Ital., 33 (suppl. 3): 1-116.

MONTELUCCI G., 1972 – *Considerazioni sul componente orientale nelle foreste della Penisola.* Ann. Acc. It. Sc. Forest., 21: 121-169.

MONTELUCCI G., 1977 – *Lineamenti della vegetazione del Lazio.* Ann. Bot. (Roma), 35-36: 1-107.

MORALDO B., MINUTILLO F, ROSSI W., 1990 – *Flora del Lazio meridionale.* Quaderni Acc. Naz. Linc., 264: 219-292.

OESTERBROEK P., 1994 – *Biodiversity of the Mediterranean region.* In: FOREY P.L., HUMPHRIES C.J., VANE-WRIGHT R.I. (eds.), Systematics and Conservation Evaluation. The Systematics Association Special Volume No. 50, Clarendon Press, Oxford, pp. 289-307.

PALMER M., CAMBEFORT Y., 1997 – *Aptérisme et diversité dans le genre* Thorectes *Mulsant, 1842 (Coleoptera: Geotrupidae): une étude phylogénétique et biogéographique des espèces méditerranéennes.* Annales de la Société entomologique de France, (n.s.) 33: 3-18.

PALMER M., 1998 – *Taxonomy, Phylogeny, and Biogeography of a Species-Group of West-Mediterranean* Tentyria *(Coleoptera: Tenebrionidae).* Annals of the Entomological Society of America, 91: 260-268.

PIGNATTI S., 1982 – *Flora d'Italia.* I-III. Edagricole, Bologna, 790 + 732 + 780 pp.

PIGNATTI S., 1994 – *Ecologia del paesaggio.* UTET, Torino.

POTT R., 1997 – *Invasion of beech and establishment of beech forests in Europe.* Ann. Bot. (Roma), 55: 27-58.

RIVAS-MARTINEZ S., PENAS A., DIAZ T.E., 2001 – *Biogeographic map of Europe 1:16 000 000.* University of Leon.

ROHLING E.J., FENTON M., JORISSEN F.J., BERTRAND P., GANSSEN G., CAULET J.P., 1998 – *Magnitudes of sea-level lowstands of the past 500,000 years.* Nature, 394: 162-165.

RUFFO S., VIGNA TAGLIANTI A., 2002 – *Generalità sulla fauna italiana.* In: MINELLI A., CHEMINI C., ARGANO R., RUFFO S. (a cura di), La fauna in Italia. Touring Editore, Milano e Ministero dell'Ambiente e della Tutela del Territorio, Roma, pp. 24-28.

SCOPPOLA A., CAPORALI C., 1998 – *Mesophilous woods with* Fagus sylvatica *of northern Latium: synecology and syntaxonomy.* Plant Biosyst., 132 (2): 151-168.

STACE C., 1991 – New Flora of the British Isles. CUP, Cambridge.

STEINIGER F.F., RABEDER G., RÖGL F., 1985 – *Land mammal distribution in the Mediterranean Neogene: a consequence of geokinematic and climatic events.* In: STANLEY D.J., WEZEL F.-C. (eds.), *Geological evolution of the Mediterranean basin.* Springer-Verlag, New York-Berlin-Heidelberg-Tokyo, pp. 559-571.

STOCH F., 2000 – *How many endemic species? Species richness assessment and conservation priorities in Italy.* Belgian Journal of Entomology, 2: 125-133.

SUC J.-P., 1984 – *Origin and evolution of the Mediterranean vegetation and climate in Europe.* Nature, 307: 429-432.

TAKHTAJAN A.L., 1986 – *Floristic regions of the world.* University of California Press, Berkeley-Los Angeles-London.

TARASOV P.E., VOLKOVA V.S., WEBB T. III, GUIOT J., ANDREEV A.A., BEZUSKO L.G., BEZUSKO T.V., BYKOVA G.V., DOROFEYUK N.I., KVAVADZE E.V., OSIPOVA I.M., PANOVA N.K, SEVASTYANOV D.V., 2000 – *Last glacial maximum biomes reconstructed from pollen and plant macrofossil data from northern Eurasia.* Journ. Biogeogr., 27: 609-620.

TZEDAKIS P.C., 1993 – *Long-term tree populations in northwest Greece through multiple Quaternary climatic cycles.* Nature, 364: 437-440.

VIGNA TAGLIANTI A., 1993 – *Aspetti zoogeografici del popolamento italiano dei Dermatteri.* Atti dell'Accademia nazionale italiana di Entomologia, Rendiconti, 39-41 (1991-1993): 97-119.

VIGNA TAGLIANTI A., 1999 – *I Carabidi nella faunistica e biogeografia.* Atti dell'Accademia nazionale italiana di Entomologia, Rendiconti, 46 (1998): 245-276.

VIGNA TAGLIANTI A., AUDISIO P.A., BELFIORE C., BIONDI M., BOLOGNA M.A., CARPANETO G.M., DE BIASE A., DE FELICI S., PIATTELLA E., RACHELI T., ZAPPAROLI M., ZOIA S., 1993 - *Riflessioni di gruppo sui corotipi fondamentali della fauna W-paleartica ed in particolare italiana.* Biogeographia, Lavori della Società italiana di Biogeografia, (n.s.) 16 (1992): 159-179.

VIGNA TAGLIANTI A., AUDISIO P.A., BIONDI M., BOLOGNA M.A., CARPANETO G.M., DE BIASE A., FATTORINI S., PIATTELLA E., SINDACO R., VENCHI A., ZAPPAROLI M., 1999 – *A proposal for a chorotype classification of the Near East fauna, in the framework of the Western Palearctic region.* Biogeographia, Lavori della Società italiana di Biogeografia, (n.s.) 20: 31-59.

WORLD CONSERVATION MONITORING CENTRE, 1992 – *Global Biodiversity: Status of the Earth's living resources.* Chapman & Hall, London. XX+549 pp.

ZUNINO M., ZULLINI A., 1995 – *Biogeografia. La dimensione spaziale dell'evoluzione.* Casa Editrice Ambrosiana, Milano, IX + 310 pp.

BIODIVERSITY AND CLIMATE

[Carlo Blasi, Leopoldo Michetti]

Climate is generally defined as a combination of meteorological conditions (temperature, atmospheric pressure, etc.) that characterise a region or an area for relatively long periods of time and which are determined, or at least influenced, by environmental factors (latitude, altitude, etc). The distribution of vegetation is principally correlated to climatic characteristics and, in particular, to trends in temperature and rainfall. In homogeneous floristic contexts, vegetation structure is determined, apart from climate, by morphological and pedologic characteristics that shape the natural heterogeneity of the territory, which is the main feature in defining the phytoclimatic potential of an area.

A new science was developed in the last century (phytoclimatology) to study the relationships that exist between trends in temperature and rainfall and the distribution of phytocoenosis. Phytoclimatology, and more generally speaking, bioclimatology, have had a great importance in recent decades also in relation to the increasing availability of data and the easier utilisation of this great quantity of information following advances in statistics and information technology.

Integrating the mean values of temperature, rainfall and humidity relative to the vegetative period (May-July) with the values of the minimum mean temperature and the indication of the time of the first and last cold period, MAYR (1906-1908) identified six forest zones for the northern hemisphere on a physyonomic basis (*Palmetum*, *Lauretum*, *Castanetum*, *Fagetum*, *Picetum* and *Alpinetum* or *Polaretum*). Successively, PAVARI (1916) proposed a climatic model that partly emended that of MAYR. The use of additional parameters regarding the entire year (temperature of the hottest/coldest month, mean maximum temperature, distribution and quantity of rainfall/year and for the hottest season) contributes to better defining the climatic forest zones into "types" and "subzones". After these studies, and in particular, after those of KÖPPEN (1900-1931), proposals of "ecological classification" increased in number, as more factors were combined in indices that highlighted the existing correlation between climate and real vegetation distribution. For example, the proposal made by DE MARTONNE (1926) who defined the vegetation distribution in Mediterranean environments in relation to aridity. More recently, BAGNOULS and GAUSSEN (1957) and WALTER and LIETH (1960) defined new climatic belts and zone biomes for the entire planet which coincided with the zonal areas for vegetation and soil types (WALTER, 1983).

On a more limited geographic scale, from 1949 to 1978, studies by GIACOBBE contributed to a clearer evaluation of the Mediterranean Basin climate. On the basis of annual temperature and rainfall, he proposed two indices (thermic and aridity) which could be used to identify the biochores of the Italian territory (Mediterranean evergreen, Mediterranean montane, Submediterranean, Subcontinental, Continental, Alpine, Nival). On this basis, RIVAS MARTINEZ (1981-1996) proposed a "Mediterranean" indices to quantify summer aridity for the Iberian Peninsula which were then integrated with a thermal index (indicator of winter temperatues), which led to the identification of 3 bioclimatic regions, 15 bioclimatic plains and 32 bioclimatic horizons.

For Italy, contributions which systematically covered the entire territory were made by DE PHILIPPIS (1937), GIACOBBE (1978) and TOMASELLI *et al.*(1973) (1973).

On a local scale, contributions were made by ARRIGONI for Sardegna and Toscana (1968, 1972), by MACCHIA for Salento (1984) and by BIONDI and BALDONI (1995) for the Marche region. In 1988, BLASI and collaborators formulated a new methodological approach to define the phytoclimate of the Campania region (BLASI *et al.* 1992). Instead of utilising the indices, the authors defined the climatic types by utilising raw data from weather stations, obtaining the mean monthly temperatures, calculated for a 30-year period, drawing up a matrix formed by the monthly minimum and maximum temperatures and by the monthly rainfall. Successively, many more bioclimatic studies were conducted utilising the classification of raw data through multivariate analysis. It is necessary at this point to recall that DE PHILIPPIS (1937) had already underlined the importance of integrating information from indices with temperature and rainfall data given that the indices do not provide the complete picture. In 1994, 15 phytoclimatic types were identified on a scale of 1:250,000 with the Phytoclimatic Map of Lazio (BLASI, 1994), which were obtained by classifying 36 thermopluviometric variables utilised for the Campagnia Region. These types were placed within the two principal regions (Mediterranean and Temperate) and two transition regions (Transitional Mediterranean and Transitional Temperate), which substituted the submediterrean region. These phytoclimatic types that were obtained principally on a climatic basis, gained phytoclimatic significance through thermopluviometric diagrams and the calculation of the ombrothermic and thermal indexes of RIVAS MARTINEZ (1996). In this manner, there is an integration which optimises the importance of information from raw data with that of the bioclimatic indices.

THE CLIMATE OF ITALY[1]

The great latitudinal development of the Italian peninsula, the presence of complex longitudinal and latitudinal orographic systems, and the proximinity of the African and Eurasian continental masses generate a great variety of climatic regions, bioclimates and climatic types, depending on whether tropical or mid-European influences predominate. As plant species are coherent with a given climate, the greater the climatic variation, the greater the biodiversity.

To ascertain climatic variability that is useful for phytoclimatic purposes, the consolidated model proposed by BLASI and collaborators (BLASI, 1994; BLASI *et al.*, 1988) was used. Monthly temperature/rainfall were recorded for a 30-year-time interval which is a sufficiently long period to provide data that indicates a "normal climate" from a statistical point of view.

The multivariate analysis applied to raw data (maximum/minimum monthly temperatures and monthly rainfall) from 400 weather stations in operation from 1955 to 1985 led to the identification of 28 "groups" or "classes" that can be distinguished from each other on the basis of the annual trend of the 36 variables considered (Figure 2.12).

Fig. 2.12 - Distribution of 400 thermo-pluviometric stations grouped according to class.

A phytoclimatic map of Italy was obtained by distributing the 28 groups geographically.

For every class, the climatic region was defined by applying the normal and compensated summer ombrothermic index, (Ios2, Ios3, Ios4) by RIVAS MARTINEZ (1996). If the index was greater than two then this indicated a Temperate Region, if it was less than two, then this indicated a Mediterranean Region.

The Mediterranean Region extends along the entire Tyrrhenian area, with the exclusion of a tract of the east-

[1] Analyses conducted by the Department of Plant Biology of the University "La Sapienza" of Rome in the context of the convention "Completion of Naturalistic Knowledge" stipulated with the Ministry for the Environment Land and Sea Protection, Nature Protection Directorate.

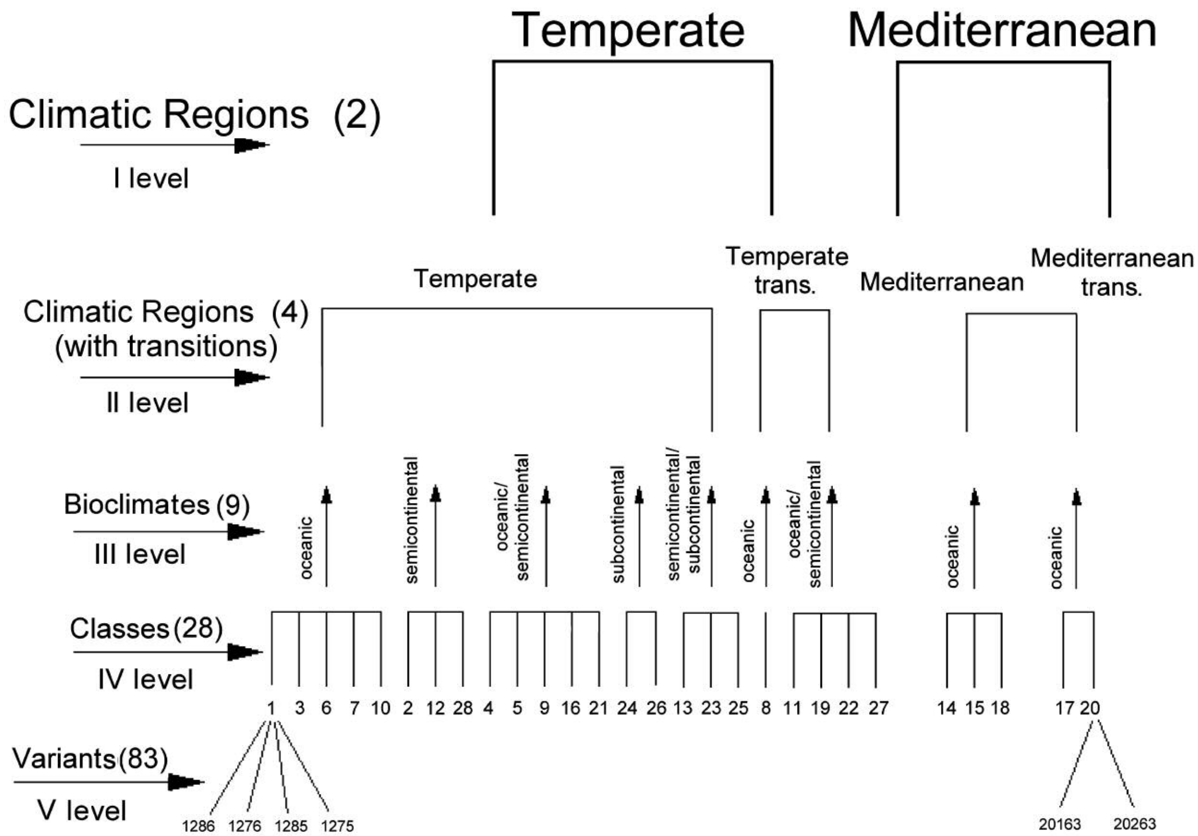


Fig. 2.13 - Hierarchical scheme of the phytoclimatic classification from regions to variants.

ern coastline in Liguria, it continues to the large and small islands, in the Ionian sector and in the Adriatic area up to Pescara in the Abruzzi Region.

The Temperate Region is situated in northern Italy, in all the Apennine, the Antiapennine and in the large islands at average and high altitudes.

The Transitional Mediterranean Region "borders" the Mediterranean climate and belongs to those mixed classes in which there is a transition from Mediterranean to Temperate climatic stations with prevalence of the former; the same occurs with the Transitional Temperate Region, in which the temperate station prevails on the Mediterranean stations.

As the same climatic region can characterise more than one class, these have been grouped on the basis of bioclimate that is highlighted through the value of the "continental" index Ic. A bioclimate with a range of temperature up to 18°C is defined as *oceanic*, from 18 to 21°C the bioclimate is *semicontinental*, from 21°C to 28°C it is *subcontinental*, and if it is greater than 28°C the bioclimate is *continental*.

The progression from 28 classes to 83 climatic variants was obtained by calculating the indices It (thermic) and Io (ombric or pluvimetric) proposed by RIVAS MARTINEZ (l.c.).

A summary of the various steps is presented in Figure 2.13.

The *spatialisation* of the classes (and therefore the map) is based on raw data regarding monthly minimum/maximum temperatures and rainfall, and the indices were used to quantify the various fields of the map in bioclimatic terms.

As already mentioned, the use of raw data, bioclimatic indices and thermopluviometric diagrams led to the *spatialisation* of two Climatic Regions with the relative transitions: Mediterranean, Transitional Mediterranean, Temperate and Transitional Temperate (Figures 2.14 and 2.15).

The nine bioclimates (climatic complexes) that were defined, highlight vast territorial regions that are homogeneous in physical features (altitude, Tyrrhenian or Adriatic basin, particular morphologies such as Alpine valleys, internal Apennine valleys, major islands, coastal plains) and the trend of climatic parameters (temperature, rainfall) (Figures 2.16 and 2.17).

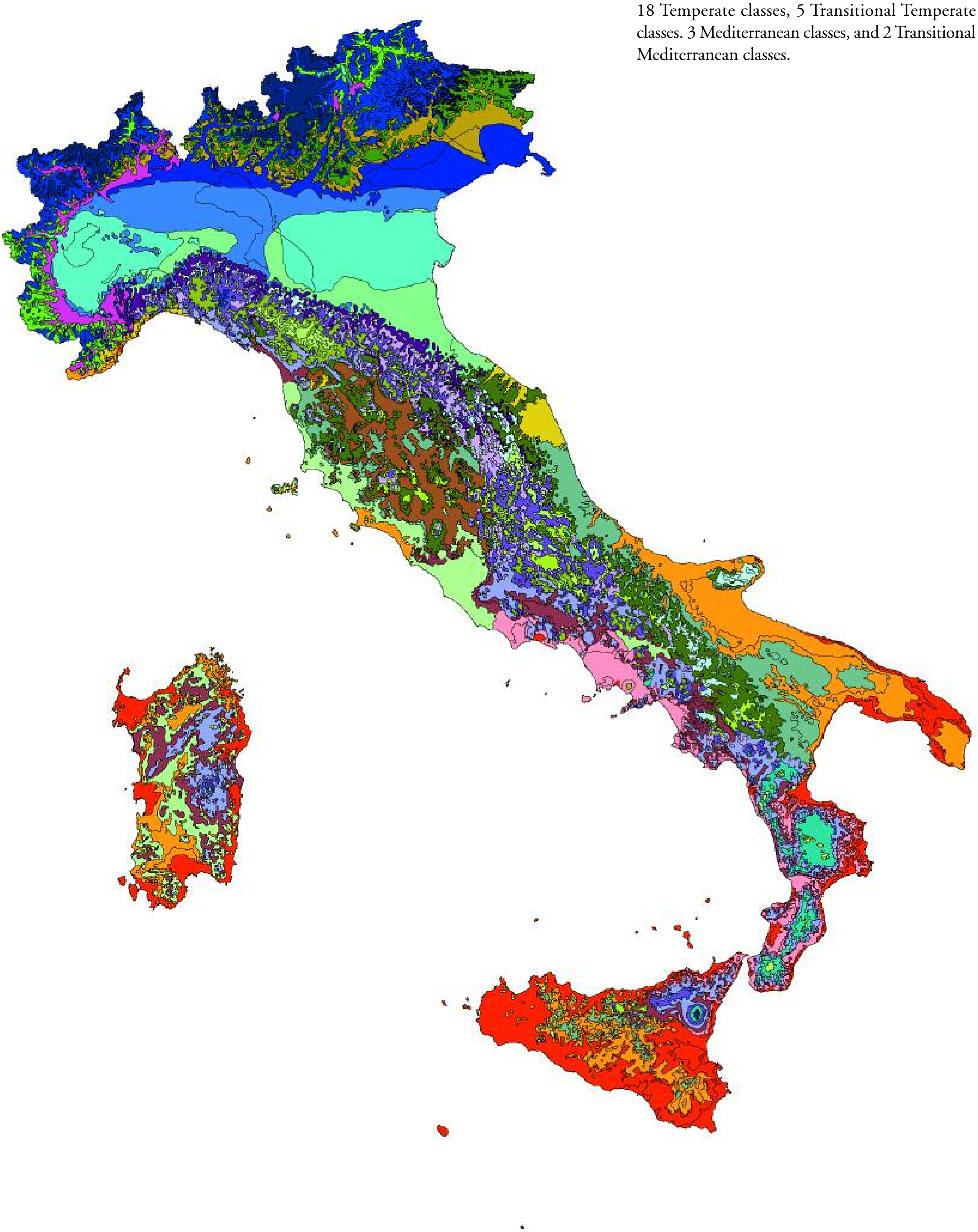


Fig. 2.14 - Phytoclimatic Map of Italy. There are 18 Temperate classes, 5 Transitional Temperate classes. 3 Mediterranean classes, and 2 Transitional Mediterranean classes.

LEGEND

1) Temperate oceanic bioclimate; western and central Alps, also on highest peaks of Apennines and Sicilia (Criorotemperate ultrahyperhumid/hyperhumid)
2) Temperate semicontinental bioclimate; western and eastern Alps (Supratemperate/Orotemperate humid-subhumid/hyperhumid)
3) Temperate oceanic bioclimate; Alps (Orotemperate hyperhumid)
4) Temperate semicontinental-oceanic bioclimate; Alps and pre-Alpine District (Supratemperate/Orotemperate hyperhumid-ultrahyperhumid)
5) Temperate oceanic semicontinental bioclimate; mainly on northern and central Apennines, locally also on Ligurian Alps (Supratemperate hyperhumid-ultrahyperhumid)
6) Temperate oceanic bioclimate; Apennines and locally also on high mountain of Sicilia (Supratemperate ultrahyperhumid-hyperhumid)
7) Temperate oceanic bioclimate; mainly on central and southern Apennines, also in Calabria, Sicilia and Sardegna (Supratemperate hyperhumid)
8) Temperate oceanic (transitional) bioclimate; mainly on Preapenninic District, also in Sicilia and Sardegna (Mesotemperate/Mesomediterranean humid/hyperhumid)
9) Temperate oceanic-semicontinental bioclimate; mainly on pre-Apenninic Adriatic District (Supratemperate/ Mesotemperate humid/hyperhumid)
10) Temperate oceanic bioclimate; Apennines (Supratemperate/Mesotemperate hyperhumid/humid)
11) Temperate semicontinenta-oceanic bioclimate; mainly at mid-altitudes on the Adriatic side of the Apennines (Supratemperate/Mesotemperate humid)
12) Temperate semicontinental bioclimate; mainly Alpine valleys in western and central Alps (Supratemperate humid/hyperhumid)
13) Temperate semicontinental-subcontinental bioclimate; northern Italy only (Supratemperate hyperhumid/humid)
14) Mediterranean oceanic bioclimate; southern Italy, Sicilia, Sardegna (Thermomediterranean/Mesomediterranean/ Inframediterranean dry/subhumid)
15) Mediterranean oceanic-semicontinental bioclimate; southern and central Adriatic District, Ionian District, Italy, Sicilia, Sardegna and also along Tyrrhenian coasts (Mesomediterranean/Thermomediterranean dry/subhumid)
16) Temperate oceanic-semicontinental bioclimate; central Adriatic plains, southern Adriatic lower hills, central Apenninic inner valleys, Sardegna (Mesotemperate humid/subhumid)
17) Mediterranean oceanic (transitional) bioclimate; lower altitude in the Tyrrhenian and Ionian Districts (Mesomediterranean/Thermotemperate humid/subhumid)
18) Mediterranean oceanic bioclimate; plains of the Tyrrhenian and Ionian coasts, also in Sicilia (Thermomediterranean/Mesomediterranean subhumid)
19) Temperate oceanic/semicontinental (transitional) bioclimate; inner areas of Marche, Abruzzo and Toscana (Mesotemperate/Mesomediterranean subhumid)
20) Mediterranean oceanic (transitional) bioclimate; plains of central and northern Tyrrhenian District, also in Sicilia and Sardegna (Mesomediterranean subhumid)
21) Temperate oceanic-semicontinental bioclimate; inner hills of central Italy (Mesotemperate subhumid/humid)
22) Temperate oceanic-semicontinental (transitional) bioclimate; central Adriatic coasts, inner plains of the pre-Apenninic District and Sicilia (Mesotemperate/Mesomediterranean humid/subhumid)
23) Temperate subcontinental/semicontinental bioclimate; alluvial plains of northern Italy and inner hills of the Adriatic coasts (Supratemperate/Mesotemperate humid/subhumid)
24) Temperate subcontinental bioclimate; Po valley (Supratemperate humid-subhumid)
25) Temperate bioclimate; northern Italy (Mesotemperate/Supratemperate humid)
26) Temperate subcontinental bioclimate; northern Italy (Supratemperate/Mesotemperate humid-subhumid)
27) Temperate semicontinental-oceanic (transitional) bioclimate; inner valleys of southern and central Apennines (Supratemperate/Supramediterranean humid/subhumid)
28) Temperate semicontinental bioclimate; inner valleys of central and southern Apennines and western Alps (Supratemperate humid-subhumid)

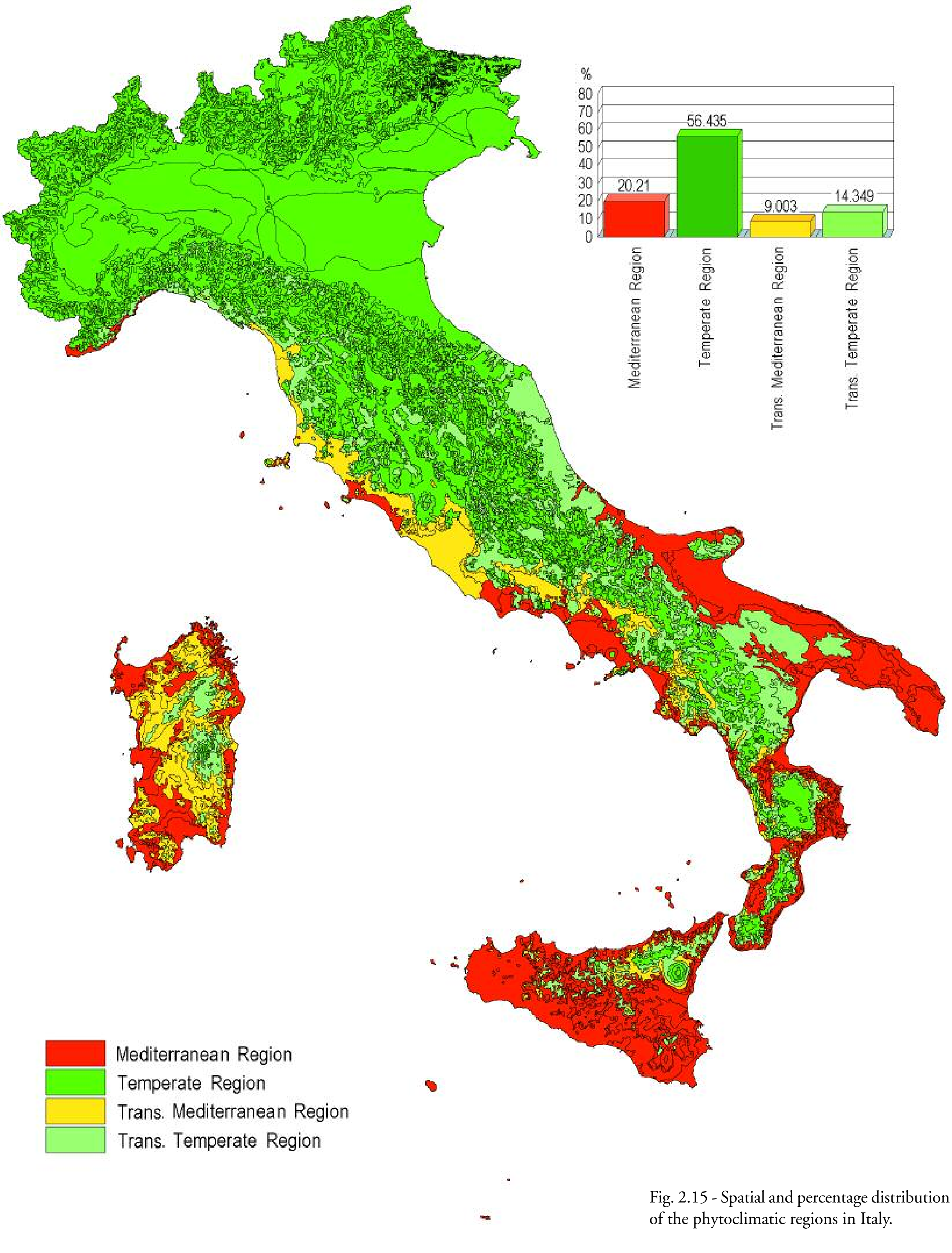


Fig. 2.15 - Spatial and percentage distribution of the phytoclimatic regions in Italy.

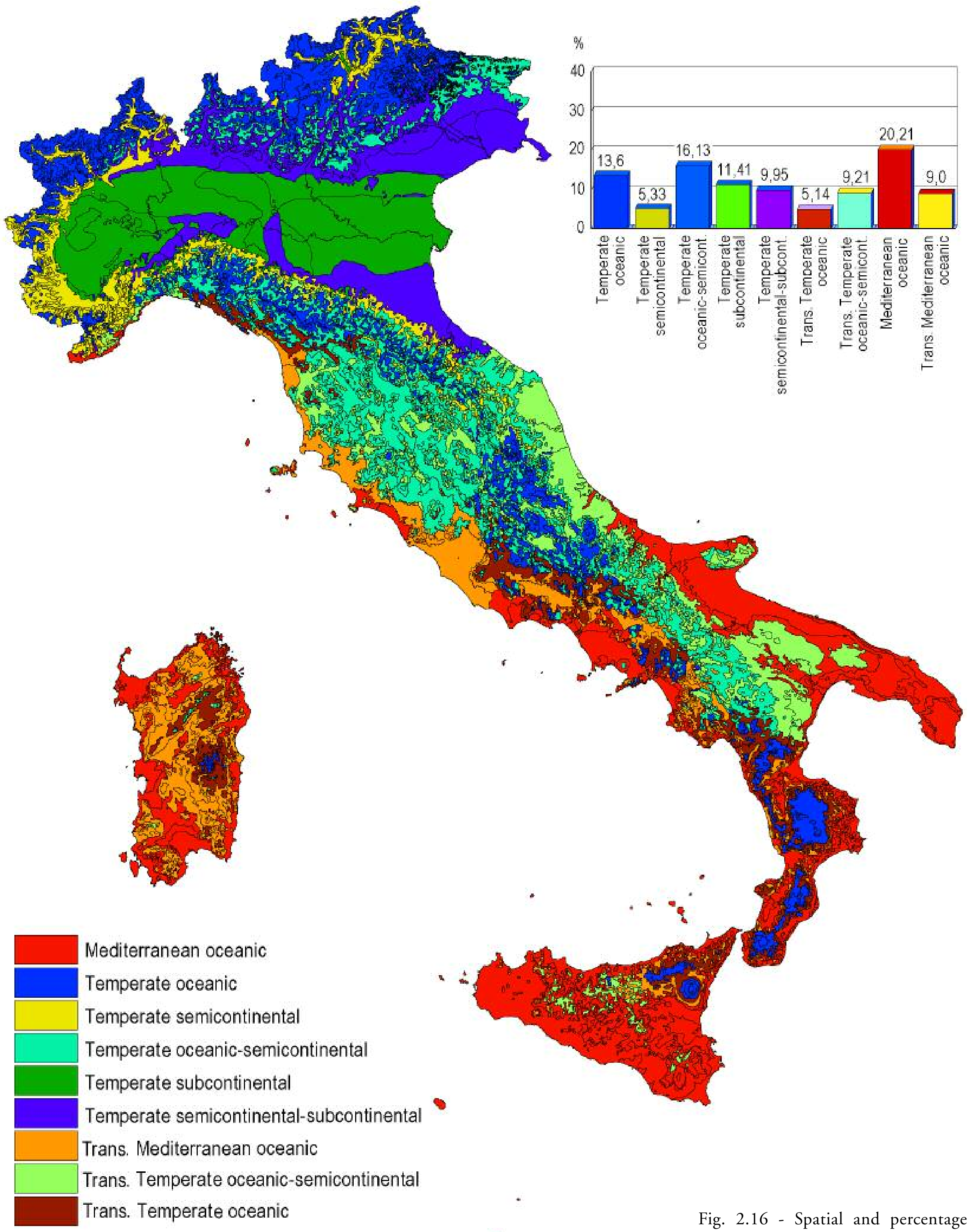
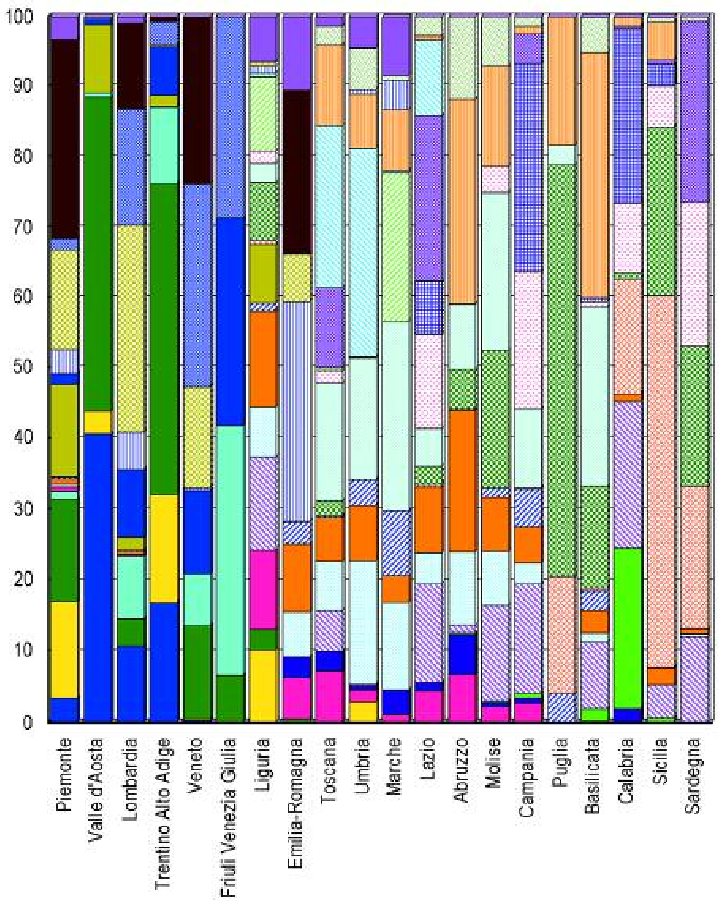


Fig. 2.16 - Spatial and percentage distribution of the bioclimates in Italy.



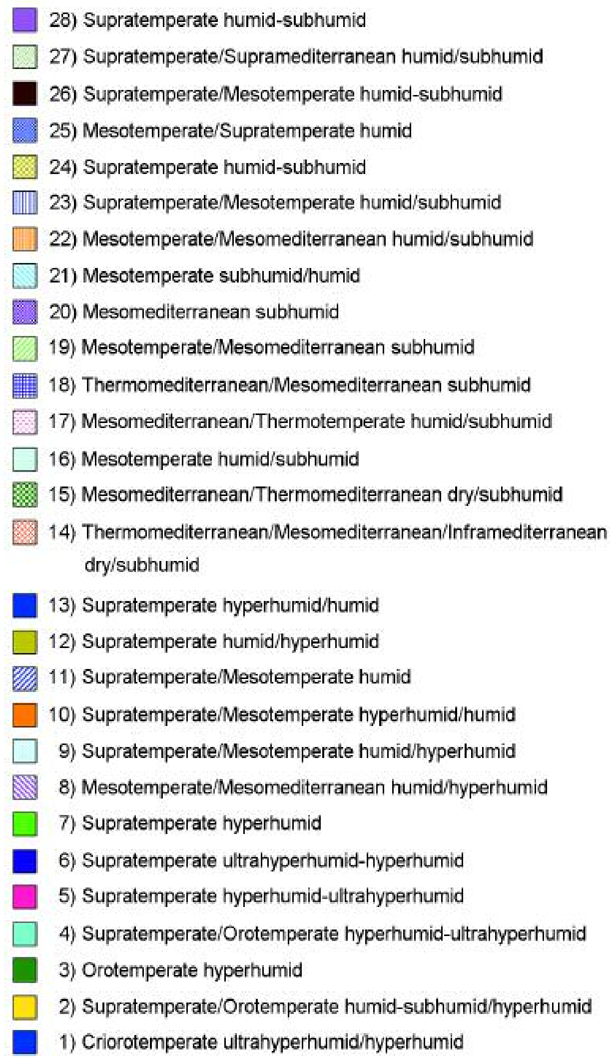


Fig. 2.17 - Percentage of the presence of phytoclimatic classes in Italian Administrative Regions.

Fig. 2.18 - Temperate oceanic climate (*Foresta della Lama*. Photo by L. Rosati).

Fig. 2.19 - Temperate semicontinental climate (*N.P. Foreste Casentinesi M.Velino-Cafornia*, Fucino plain near Massa d'Albe. Photo by L. Rosati).

In short, the distribution of the nine bioclimates in Italy is the following:

1. Temperate oceanic climate (Figure 2.18): comprising classes 1-3-6-7-10, typical of the entire Alpine arc, middle and high elevation of the Apennines and the high mountains in Sicilia. The climatic types vary from cryorotemperate ultrahyperhumid-hyperhumid to mesotemperate hyperhumid-humid.

2. Temperate semicontinental climate (Figure 2.19): comprising classes 2-12-28, situated in Alpine valleys and in inland valleys of the central northern Apennines, generally with an Adriatic aspect. The climate types vary from orotemperate humid-subhumid/hyperhumid to supratemperate humid-subhumid.

3. Temperate oceanic semicontinental climate (Figure 2.20): comprising classes 4-5-9-16-21, situated in the central and eastern Pre-Alps, hilly zones of the mid-Adriatic and inland valleys of all the Apennine range down to Basilicata, with a Tyrrhennian aspect. Locally present in Sardegna. The climatic types vary from supratemperate/orotemperate hyperhumid-ultrahyperhumid to mesotemperate humid subhumid.

4. Temperate subcontinental climate: comprising classes 24-26, it is of the Padana Plain type from Piemonte to the mouth of the River Po. The climate types vary from supratemperate humid-subhumid to mesotemperate humid-subhumid.

5. Temperate semicontinental-subcontinental climate: comprising classes 13-23-25 and is situated south of the River Po, in the central Pre-Alpine moraine valleys and in the alluvial plains in the north-estern Italy. The climate types vary from supratemperate hyperhumid/humid to mesotemperate humid-subhumid.

6. Transitional temperate oceanic climate (Figure 2.21): comprising class 8 and is situated mainly in all the valleys of the Ionian and Tyrrhenian Anti-Appennines, with a significant presence in the major islands. The climatic types vary from mesotemperate to mesomediterranean humid/hyperhumid.

7. Transitional temperate oceanic-semicontinental climate (Figure 2.22): comprising classes 11-19-22-27 and is mainly localised in the plains and the first hilly spurs of the mid and lower Adriatic and Ionian; significant presence in some inland zones of the Madonie and in some parts of Sardegna. The climate types vary from supratemperate humid-subhumid to mesomediterranean humid-subhumid.

8. Mediterranean oceanic climate (Figure 2.23): comprising classes 14-15-18 and surrounds Italy from Liguria to Abruzzi (Pescara) and the major islands. The climatic

Fig. 2.20 - Temperate oceanico-semicontinental climate (North of Viterbo between Vico and Tuscania Photo by L. Rosati).

Fig. 2.21 - Transitional temperate oceanic climate (Turano lake. Photo by L. Rosati).

Fig. 2.22 - Transitional temperate oceanic-subcontinental climate (Val Marecchia badlands. Photo by L. Rosati).

types vary from inframediterranean dry-subhumid to thermomediterranean subhumid.

9. Transitional Mediterranean oceanic climate (Figure 2.24): comprising classes 17-20 and has a continuous presence on the coasts of the mid and upper Tyrrhenian. More fragmented in the lower Tyrrhenian and Sicilia, with an important presence in the inland plains and first spurs of Sardegna. The climate types vary from thermotemperate humid-subhumid to mesomediterranean humid-subhumid.

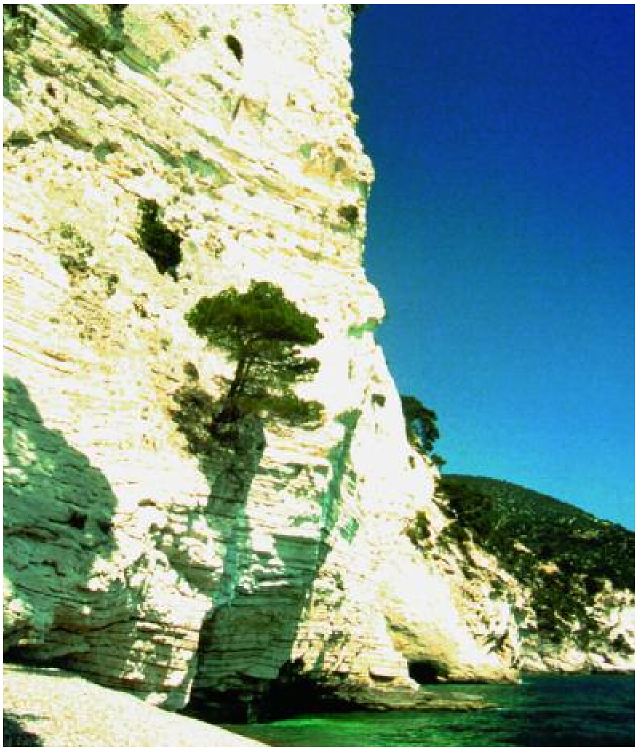


Fig. 2.23 - Mediterranean oceanic climate (Gargano, the coast between Vieste and Mattinata. Photo by L. Rosati).

Fig. 2.24 - Transitional Mediterranean oceanic climate (Sardegna, Supramonte, Lanaittu valley. Photo by L. Rosati).

Bibliography

ARRIGONI P.V., 1968 – *Fitoclimatologia della Sardegna.* Webbia 23 (1): 1-100.

BAGNOULS F., GAUSSEN H., 1957 – *Les climats biologiques et leur classification.* Ann. Geogr., 66, 355: 193-220.

BIONDI E., BALDONI M., 1991 – *Bio-climatic characteristics of the Italian peninsula.* Atti del Convegno "*Effetti degli inquinanti atmosferici sul clima e la vegetazione*", Taormina 26-29 Settembre, 1991. A cura di Gea Program s.r.l. Roma. Pp. 225-250.

BIONDI E., BALDONI M., 1995 – *A possibile method for geographic delimitation of phytoclimatic types: with application to the phytoclimate of the Marche region of Italy.* Doc. Phytosoc., n.s., XV: 15-28.

BLASI C., 1994 – *Fitoclimatologia del Lazio.* Fitosociologia, 27: 151-175.

BLASI C., MAZZOLENI S., PAURA B., 1988 – *Proposte per una regionalizzazione fitoclimatica della Campania, Italia meridionale.* Atti II Colloquio "Probl. Def. Amb. Fis. Biol. Medit.", Castro Marina (Lecce).

GIACOBBE A., 1964 – *La misura del bioclima mediterraneo.* Ann. Acc. Ital. Sc. Forest., 10: 37-68.

GIACOBBE A., 1978 – *Pioggia e mediterraneismo.* Ann. Acc. It. Sc. Forest., 27: 3-10.

KOPPEN W., 1931 – *Grundiss der Klimakunde.* Berlin u. Leipzig (II ed. Di Klimate der Erde) Berlin, 1923.

MARTONNE E., DE, 1926 – *L'indice d'aridité.* Bull. Ass. Geogr. Fr. 9: 3-5.

MAYR H., 1906 – *Fremlaendische Wald- und Parkbaeume fuer Europa.* Berlin.

MAZZOLENI S., LO PORTO A., BLASI C., 1992 – *Multivariate analysis of climatic patterns of the Mediterranean basin.* Vegetatio, 98: 1-12.

PAVARI A., 1916 – *Studio preliminare sulla coltura di specie forestali esotiche in Italia.* Ann. R. Ist. Sup. For. Naz., 1.

PHILIPPIS A., DE 1937 – *Classificazione ed indici del clima in rapporto alla vegetazione forestale italiana.* Nuovo Gior. Bot. Ital., n.s., 54: 1-169.

PIGNATTI S., 1998 – *I boschi d'Italia.* UTET, Torino

PINNA M., 1977 – *Climatologia.* UTET, Torino.

RIVAS MARTINEZ S., 1996 – *Clasificación Bioclimatica de la Tierra.* Folia Bot. Madrit., 16: 1-32.

THORNTHWAITE C.W., 1948 – *An approach toward a rational classification of climate.* Geogr. Rev., 38: 55-94.

TOMASELLI R., BALDUZZI A., FILIPELLO S., 1973 – *Carta bioclimatica d'Italia.* La vegetazione forestale d'Italia. Minist. Agric., Collana Verde, 33. Roma

WALTER H., 1983 – *Vegetation of the Earth and Ecological Systems of the Geo-Biosphere.* Springer, Berlin.

WALTER H., LIETH H., 1960-1967 – *Klima-Diagramm-Weltatlas.* Gustav Fischer, Jena.