

BIODIVERSITY LOSS

THE LOSS OF BIODIVERSITY

[Fausto Manes, Francesca Capogna]

The diversity of the living and their territorial distribution tend to change continuously, due to natural evolution processes, to the effects of long-term and short-term climatic changes and to the consequences of human actions.

The impact of man on natural environment occurs at different spatial and temporal scales. Ecological disasters, industrial pollution, deforestation and natural habitat conversion into farmland and industrial land take place unceasingly over vast areas of every continent. Many plant and animal species habitats are altered by all such human activities, leading to a reduction of biological diversity (Figure 3.1). Where catastrophic environmental changes

occur the major impact on biodiversity takes place immediately, although residual effects may be extended over many years. In another way, a long-term impact leading to habitat modification could develop over a much longer time scale, threatening many species with extinction. Moreover, the alteration of structural and functional characters of a community or of an ecosystem which intervenes upon species extinction leads to an increase of the extinction process itself.

Five important factors, also known as *drivers*, have been identified as directing changes in biodiversity on a global scale (SALA *et al.*, 2000): changes in land use, climatic changes, increased atmospheric carbon dioxide (CO₂) concentration, nitrogen deposition and acid rain, alien plant and animal species introduction.

By using global models future changes in biological di-

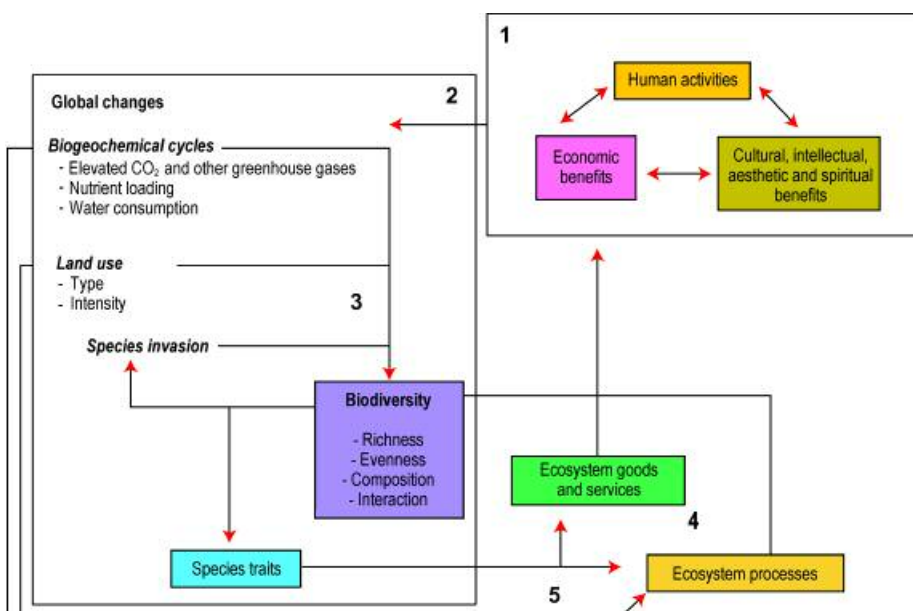


Figure 3.1 - The role of biodiversity in global changes. Human activities (1) driven by intellectual, cultural, economic and spiritual aims are the cause for globally relevant environmental and ecological changes. (2) Through various mechanisms climatic variations influence biodiversity (3); biodiversity changes can directly give rise to ecosystem's alterations (4). Global changes can furthermore have a direct influence on the ecosystems (5) (CHAPIN *et al.*, 2000, modified).

versity have been predicted up until the year 2100 within each of the Earth's main biomes (arctic tundra, alpine tundra, temperate boreal forest, grassland, tropical savanna, chaparral and desert), even taking into account each factor's single contribution to such phenomena. Such studies have furthermore quantified the impact of each factor of change on a global (all biomes) level (Figure 3.2).

Throughout all terrestrial ecosystems changes in land use represent the factor bearing the greatest impact on biodiversity, due to the ensuing habitat loss, to which rapid species extinction is associated; the second factor in descending order of importance is represented by climatic changes, in particular increasing temperatures which are mainly expected to occur at high latitudes. The remaining factors produce variable intensity effects at smaller spatial scales.

Following there is a brief description of the effects the different factors exert on biodiversity; they are going to be examined in full detail in the next sections.

Changes in land use

Human activities connected to changes in land use systematically degrade both habitats and ecosystems, frequently leading to their complete disappearance: actually, when the quality of the environment is so low that it cannot sustain the survival of a key species any more, both habitat loss and entire ecosystem loss can follow as a result. For instance, the conversion of temperate grasslands into croplands, or of tropical forests into grasslands, causes local extinction of the majority of their associated plant

and animal species, particularly those whose habitat is chiefly characterized by vegetation composition. The main cause of land use change is represented by human population growth leading to the conversion of natural ecosystems to man-dominated ecosystems. Fragmentation at habitat and landscape scale level is the main result of such actions (Figure 3.3). According to MALCOM and HUNTER (1996) this process began when man altered natural landscape continuity mainly through aimed agricultural and residential development interventions. As the territory keeps being converted to agricultural use, natural ecosystems come to be isolated from one another thus determining landscape 'fragmentation'.

In almost all instances, fragmentation may decrease native species diversity in their own natural habitats, since small and isolated parts of the territory exhibit: (1) less environmental heterogeneity, (2) less presence of rare and area-sensitive species, (3) small sized populations, which are more vulnerable to local extinction, (4) limited immigration and (5) less presence of vagile species. From the faunistic point of view, the first species to become endangered are the big predators and the large-sized species. Thus fragmentation leads to ecosystems dominated by opportunistic species, displaying good dispersion, colonization and rapid growth abilities and having a short life cycle.

Climatic changes

Climatic change mainly refers to the rise in the earth's average temperature due to the increase in the presence

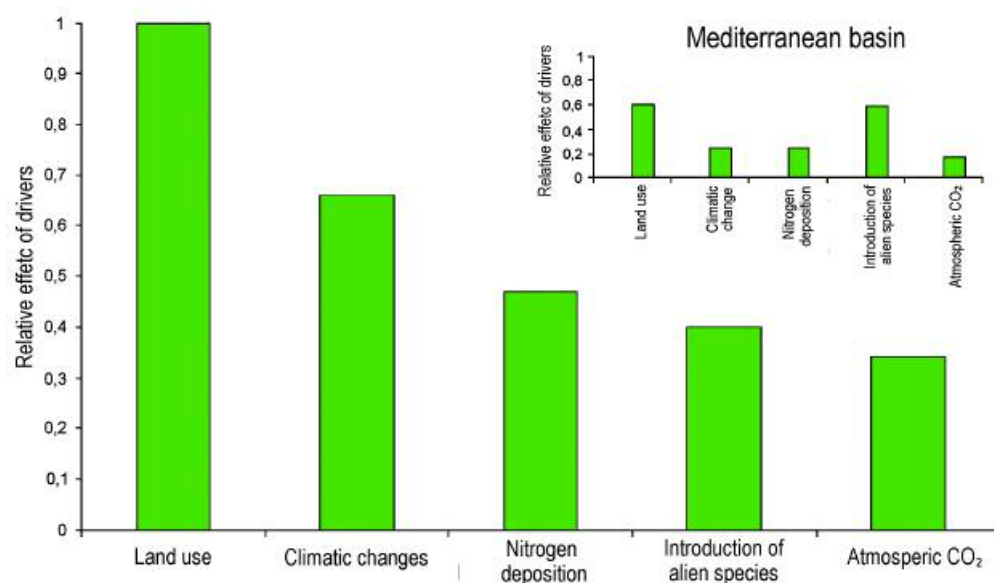


Figure 3.2 - Effects played on biodiversity by major factors of change. In the top right box the case of the Mediterranean Basin is shown (SALA *et al.*, 2000, modified).

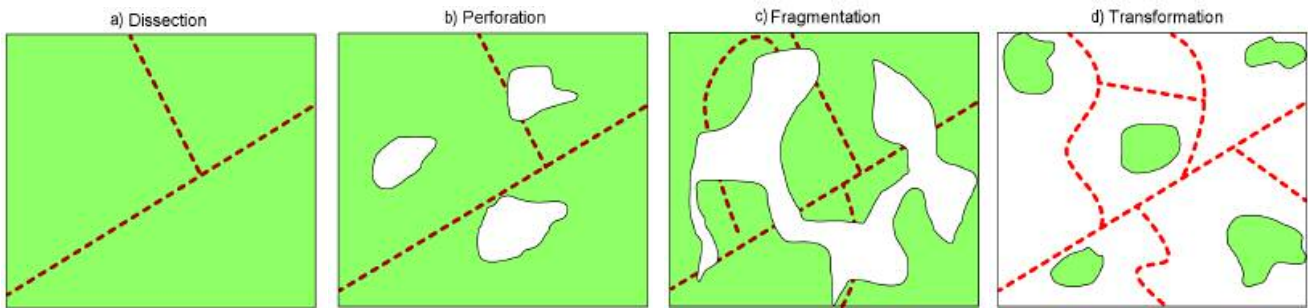


Figure 3.3 - Examples of landscape modifications.

of the so-said “greenhouse gases” in the atmosphere (especially carbon dioxide, water vapour, but also methane, nitrogen oxides, etc.). Such rise in temperature has effects on biological diversity that are mainly found at the level of those biomes with the most extreme climates (arctic, alpine, desert and boreal forest biomes).

Rise in atmospheric carbon dioxide

The rise in atmospheric CO_2 concentration bears a more significant impact on the biodiversity of those biomes where water presence is a limiting factor for plant species, and where vegetation is characterized by the presence of both C_3 and C_4 species; the two exhibit different characteristics in the process of CO_2 assimilation and in the efficiency of water usage. Their enhanced rates of CO_2 uptake and their efficacy in the use of water are distinguishing traits of C_4 plants, giving them competitive advantage in environments where periods of high water stress may develop.

Among the considered biomes, those that may be more severely affected by the negative outcomes of such a factor are the grasslands and the savanna, because of the pronounced aridity that denotes them.

Nitrogen deposition and acid rain

Increasing nitrogen deposition and subsequent acidification processes mainly interest temperate forests, boreal forests and the arctic and alpine biomes. The additional *input* supplied by nitrogen depositions in such biomes as are under nitrogen shortage conditions, could give a competitive advantage to the species with higher growth rates. The grasslands, savannah and chaparral-mediterranean biomes experience an intermediate environmental impact index, since the growth of the plant species is thereby limited by nitrogen and by other factors. In particular, oak forests in the Mediterranean Basin have been

interested, over the centuries, by recurring episodes of nutrient depletion caused both by fires and by biomass uptake. Such types of disturbance have lowered the nutrient reserves of the soil, and the biome has acquired a positive sensitivity to nitrogen depositions. Deserts and tropical forests, on the other hand, are the least sensitive biomes, as they are limited respectively by water presence and by phosphorous availability.

Alien species introduction

This represents another factor whose intensity varies according to environmental conditions and to biogeographical characteristics. The reduced distance between countries, through commerce or through tourism, has increased the number of accidental introductions of non native species. When a species is introduced into an ecosystem to which it was alien, it can produce natural processes imbalance affecting equilibrium maintenance, and this in turn could lead to the disappearance of the native species. The consequences of new species introduction depend on the biology of both the introduced and the native species. The ability to predict the effects of an introduction, be it accidental or not, is always limited, and this suggests the need for an accurate case-by-case evaluation. According to some predictions, however, alien species introduction could have the greatest environmental impact index on the biodiversity of the Mediterranean and of the temperate forests biomes.

LAND USE CHANGES

[Marco Marchetti, Anna Barbati]

MAIN CHANGES IN THE ITALIAN LANDSCAPE

Italian landscape, as it stands before us today, is the result of deep changes in the territory that have occurred at the expense of natural primary ecosystems (grasslands, forests, humid areas), in order to obtain urban and agricultural land covers (Figure 3.4). The moving cause (*driving force*) behind such a process lies in the capability for cultural evolution displayed by the human species (technological level). As MAINARDI observes (2002): “True cultural revolution began with the taming of animals and plants. Following the subsequent advent of sheep farming and agriculture not only the first negative impact on biodiversity took place - a unique plant species cultivated in a field in place of a forest - but, through the progressive increment of resources, demography and territoriality ultimately came to be split”. And, Italy has been home to the development of civilizations since more than three thousand years, thus the ‘cultural’ impact of its societies of men on natural ecosystems is very old.

The first changes of any relevance took place in the Roman times (from 2nd century BC to 4th century AD), that is at the time of the ‘rural border’ expansion. Deforestation followed the territorial conquests by the Romans especially in the plain areas, and was meant to ensure the agricultural use of the lands, which were ‘geometrically’

divided and assigned to the colonial farmers (*centuriation*). The destruction of the primary forests of the Padana plain, which, according to historical documents and paleobiological data, was covered by plain forests and riparian woods, was actually started by the penetration and the colonization of the territories of Gallia Cisalpine, first by the Etruscans then by the Romans. The same destiny befell other ecosystems bound to riparian environments (humid woods, and thickets on sandy and on limy high water beds) of the large valleys both in Padan and peninsular Italy, which over time were almost completely destroyed and replaced with secondary formations or forest plantations, such as poplar groves.

The deforestation of forest territories for agricultural or pastoral land use or for simple wood extraction has continued over the centuries. It has obviously been more incisive in areas that were deemed more appropriate and more profitable for human activities (coastal belts, plains and short hills). In general, after the first stage, during which the forest coverage was thinned out to allow for pasture land use, effective wood cutting and stump clearing followed, so that suitable pasture land was turned into farm land. In uphill and mountainous environments, areas containing stony land were set aside for coppice cultivation, the others for pasture land (Figure 3.5).

More rarely in Italy deforestation has been connected to political instances for the control of the territory. It's the case of the island of Lampedusa, which was completely deforested in 1843 on orders by the King of Naples



Figure 3.4 - The landscape of the first alluvial terraces in the Emilian plain; basin of the Enza creek, Reggio Emilia (Photo by M. Marchetti).



Figure 3.5 - The landscape of mature oak forests of Lazio's volcanic reliefs, the Macchia Grande of Manziana, the big meadow inside the Turkey oak and Italian oak high forest (Photo by M. Marchetti).



Figure 3.6 - The Bagnature 'pool', inside the State-owned forest property of Circeo's National Park (Photo by S. Bonacquisti).



Figure 3.7 - Conero's headland and the Trave cliff. In the foreground, *Arundo pliniana* (Photo by L. Rosati).

Ferdinando di Borbone, so as to become an agricultural colony under the king's control. It was thus rescued from the expansionistic designs of the English, who were at the time already in control of nearby Malta. Lampedusa, originally covered by Mediterranean forests thriving especially along the gulches that were rich in fauna and in fresh water (BACCETTI *et al.*, 1995), by that means was turned into an arid and barren land.

This last century can be described as a particularly intense span of time for the promotion of rapid and extended landscape shaping processes. The changes in life style, sustained by last century's technological evolution, is at the root not only of urban development – industrial and residential – but also of the profound mutations of the rural territory.

Some of the best examples of this are represented by the massive land reclamation programs of coastal and internal plains – e.g. the Maremma of Toscana and Lazio – which determined the fragmentation or disappearance of lake systems and forest swamps. In the 1930s the landscape of the Pontina plain was completely redesigned through integral land reclamation, which led to a drastic reduction in the “Selve” (forest swamps) that were covering it (Figure 3.6). Later on, the canalization of the area was carried out, for stagnant water outflow; and, in rapid succession, land allotment, road construction, and the building of three new cities: Latina (Littoria), Pontinia and Sabaudia.

The development of main Italian metropolitan areas (Rome, Naples, Milan) also took place substantially in the 20th century. Rome, for example, has begun expand-

ing outside the Aurelian Walls only since the mid 1900s; Roman ‘outside the walls’ countryside has since then turned into a vast metropolitan area ringed by Grande Raccordo Anulare.

Again dating back to the last century (about 70 years ago) is the often irreversible destruction of coastal dunes and back-barrier dunes, following construction industry development connected to leisure activities and tourism – in the case of dunes – and the expansion of farming (back-barrier dunes). At present only few, scattered fragments remain of the vast sandy seashores once present along Tyrrhenian and Adriatic coasts (Figure 3.7).

In the 1900s rural territory (crop land, pasture land, woods and untilled land) has experienced progressive changes, not only as a consequence of ‘land subtraction’ resulting from urban development (industrial, residential and infrastructural). The transition from subsistence agriculture to market agriculture that has taken place during the past fifty years has brought about two opposite processes: the shift to industrial and intensive crop and livestock farming on one side, agricultural abandonment and extensive use of economically marginal land on the other side.

Flat to low hill and medium hill country areas have seen the propagation of intensive culture and of artificial fodder productions (artificial grasses). Diffusion of monoculture, and structural simplification of agriculture landscape necessary for mechanization, have determined a drastic reduction in plant biodiversity, although a tendency inversion can be observed in some areas over the last five year period. With intensive agriculture not only have sponta-

neous species, such as wild grasses, disappeared, but all the structural elements that are typical of traditional agriculture landscape have also been eradicated; in particular, hedges, rows of trees, thickets, large trees, all of which are fundamental to the survival of many bird species that are connected to the agricultural environment.

Conversely, rural areas where the structure of traditional agriculture landscape has been conserved (different mosaic patches, presence of ecotonal margins, dividing elements, groves, large trees, etc.) represent concentration ranges of bird fauna (PILASTRO, 2002).

Agricultural abandonment of farm land or of natural meadows – pasture land and semi-natural meadows – in high hill and low to medium mountain marginal areas (both Alpine and Apennine) has represented, by other means, another distress factor impending on biodiversity. Progressive reduction in natural grassland cover – e.g. the tundra's typical terophytic grasslands – which up to then had been preserved by traditional practices such as extensive grazing, has been the most dangerous effect of abandonment. Favourable habitats for birds that are associated to steppic environments for nutrition and reproduction have been supported over a long time by transhumant sheep farming. Its relinquishment (e.g. the abandonment of transhumance from Abruzzo to Capitanata that took place in the second half of the 20th century) and the subsequent conversion of the open xeric environments has caused the diminution of the bird fauna connected to them (e.g. Little Bustard, Grey Partridge, Montagu's Harrier or other steppic predator hawks) or its downright extinction (Small Buttonquail).

In some cases the abandoned agricultural areas have been recolonized by spontaneous forest species; on more degraded territory, they have been reforested, also by occasionally using exotic or at any rate non native species.

From what has been briefly reported, it becomes apparent how much the original landscape of our country has been deeply changed by anthropic activities, which have shaped the different land uses and land covers. As an unavoidable consequence of social, economical and cultural evolution, anthropic perturbations have brought about destruction or transformation of primary ecosystems, leading to the establishment of new - *secondary* – ecosystems, such as the agricultural ecosystems, the semi natural forests, and the so said 'urban ecosystems'.

In the context of specific, locally (AGNOLETTI, 2002) or regionally based, studies, the landscape changes of recent times – the last two centuries – have been measured by employing historical maps of land use, coming from land registers or photointerpretation studies.

CORINE land cover II level	ha	%
2.1 Seeded areas	8,110,643.08	26.85
3.1 Wooded areas	8,007,695.71	26.51
2.4 Heterogeneous agricultural areas	5,356,176.67	17.73
3.2 Areas characterized by shrubby and/or herbaceous vegetation	3,628,297.38	12.01
2.2 Permanent cultivations	2,278,725.34	7.54
1.1 Residential areas	954,156.84	3.16
3.3 Open areas with scarce or absent vegetation	685,409.23	2.27
2.3 Stable meadows	494,109.36	1.63
5.1 Continental waters	223,498.51	0.74
1.2 Industrial, commercial and infrastructural areas	223,134.24	0.74
5.2 Marine waters	97,920.27	0.324
1.3 Mining areas, yards, waste-dumps and artificial and abandoned soils	57,181.66	0.19
4.2 Marine wetlands	49,714.06	0.16
4.1 Inland wetlands	16,501.84	0.05

Table 3.1 - National distribution of the different types of land cover and land use, following CORINE *Land Cover* classification, II level, listed by decreasing cover degree, in hectares and percentage values against total national surface area.

A quantitative analysis of Italian landscape change process has not yet been accomplished at a national scale. At the present state, it is possible to quantify the national distribution of the different types of land cover and land use, following European CORINE land cover classification (AA.VV., 1993) and using the geographic database that implements land use and vegetation coverings cartography on a 1:250,000¹ scale (Tables 3.1 and 3.2).

Wooded and seeded areas - intensively cultivated overall – represent, with equivalent shares, more than 50% of the national territory. Notwithstanding this widespread presence of industrialized agriculture systems, almost 18% of the nation's surface is constituted by complexly structured agricultural areas, which are favourable sites for biodiversity conservation (heterogeneous agricultural areas). Natural prairies - continuous and discontinuous – represent a meagre 6% of the Nation's surface. And, even more troubling, both internal and marine humid areas only add up to 0.2% of the national territory.

¹ Accomplished by different Italian Universities and funded by the Direzione per la Protezione della Natura del Ministero dell'Ambiente e della Tutela del Territorio within the scope of the project "Completamento delle Conoscenze Naturalistiche di base" (ConSCN250).

CORINE II level	CORINE III and IV level	Surface area (ha)
1.1 RESIDENTIAL AREAS		
	111 Continuous residential areas	184,201
	112 Discontinuous residential areas	769,955
1.2 INDUSTRIAL, COMMERCIAL AND INFRASTRUCTURAL AREAS		
	121 Industrial, commercial and private and public services areas	180,171
	122 Highway, railway networks and technical infrastructures	12,081
	123 Port areas	10,709
	124 Airports	20,172
1.3 MINING AREAS, YARDS, WASTE-DUMPS AND ARTIFICIAL AND ABANDONED SOILS		
	131 Mining areas	45,808
	132 Waste-dumps	2,042
	133 Yards	9,331
	141 Urban vegetation	12,524
	142 Recreational and sports areas	14,219
2.1 SEEDED AREAS		
	2111 Intensive cultivations	7,093,553
	2112 Estensive cultivations	449,237
	212 Seeded watered areas	319,731
	213 Rice fields	248,122
2.2 PERMANENT CULTIVATIONS		
	221 Grapevines	539,422
	222 Fruit and minor fruit cultivations	439,481
	223 Olive groves	1,293,248
	224 Other permanent cultivations	6,574
2.3 STABLE MEADOWS		
	231 Stable meadows	494,109
2.4 HETEROGENEOUS AGRICULTURAL AREAS		
	241 Temporary cultivations associated to permanent ones	429,881
	242 Complex cultivation systems and elements	2,586,004
	243 Areas mainly occupied by agricultural crops hosting relevant natural elements	2,078,927
	244 Forestry areas	261,364
3.1 WOODED AREAS		
	3111 Holm oak and Cork oak dominated woods	684,833
	3112 Deciduous oak dominated woods	2,019,509
	3113 Mixed forests dominated by mesophile broadleaves	852,816
	3114 Chestnut dominated woods	769,861
	3115 Beech dominated woods	993,175
	3116 Hygrophilous broadleaves dominated woods	113,998
	3117 Non native broadleaves dominated woods and plantations	150,489
	3121 Mediterranean pines and cypress dominated woods	194,012
	3122 Mountain pine and oromediterranean pine dominated woods	236,463
	3123 Silver Fir or Norway Spruce dominated woods	619,171
	3124 Larch and/or Swiss Pine dominated woods	318,368
	3125 Non native conifers dominated woods and plantations	11,412
	31311 Holm oak and Cork oak dominated mixed woods	60,222
	31312 Deciduous oak dominated mixed woods	102,520
	31313 Mixed forests dominated by mesophile broadleaves	129,006
	31314 Chestnut dominated mixed woods	79,193
	31315 Beech dominated mixed woods	169,942
	31316 Hygrophilous broadleaves dominated mixed woods	849

Table 3.2 - National distribution of the different types of land cover and land use, following CORINE *Land Cover* classification, III and IV level, in hectares (updated to the 1998-2002 period). *To be continued on the following page*

31317	Non native broadleaves dominated mixed woods	9,835
31321	Mediterranean pines and cypress dominated mixed woods	111,612
31322	Mountain pine and oromediterranean pine dominated mixed woods	176,507
31323	Silver Fir or Norway Spruce dominated mixed woods	1,551,443
31324	Larch and/or Swiss Pine dominated mixed woods	45,657
31325	Non native conifers dominated mixed woods	3,014
3.2 AREAS CHARACTERIZED BY SHRUBBY AND/OR HERBACEOUS VEGETATION		
321	Natural pasture land	24
3211	Continuous prairies	781,960
3212	Discontinuous prairies	1,089,208
322	Heaths and shrubland	711,498
3231	Tall scrubland	189,878
3232	Low scrubland and garrigue	855,729
3.3 OPEN AREAS WITH SCARCE OR ABSENT VEGETATION		
331	Beaches, dunes and sands	56,853
332	Naked rocks, cliffs, rocks, rock croppings	578,961
335	Glaciers and perennial snows	49,596
4.1 INLAND WETLANDS		
411	Inland swamps	16,260
412	Bogs	241
4.2 MARINE WETLANDS		
421	Brackish marshes	23,808
422	Salt pans	25,791
423	Intertidal zones	115
5.1 CONTINENTAL WATERS		
511	Watercourses, canals	54,105
512	Water basins	169,394
5.2 MARINE WATERS		
521	Lagoons	96,449
522	Estuaries	420
523	Seas and oceans	1,052

Table 3.2 - National distribution of the different types of land cover and land use, following CORINE *Land Cover* classification, III and IV level, in hectares (updated to the 1998-2002 period). *Following from the previous page*

EFFECTS OF CHANGES IN LAND USE ON BIODIVERSITY

The contraction of a habitat characterized by a specific land cover is accompanied by isolation and by remoteness of the different residual fragments. In this sense the habitat residual fragments can be considered as islands of an archipelago, plunged in a sea (matrix) of a different nature. Under these conditions, the number of species present over a certain habitat area or fragment, or the loss of species following a decrease in the habitat extent, can be estimated in theory by using the MACARTHUR and WILSON's model of 'island biogeography' (1967). This works fundamentally for species that are strongly dependent on restricted ecological conditions linked to habitat specificity - *specialist* or *stenoecious* species - generally endemic species.

According to the model, species endemic to a habitat just disappear, should the latter be destroyed, but in reality these phenomena involve much more complex dynamics.

In view of species survival, the most dangerous effect of habitat reduction and fragmentation is the introduced limitation over possibilities of genetic interchange among isolated and numerically impoverished populations (*rarefaction*). Fragmentation may determine diminished genetic diversity of residual populations, thereby reducing the possibilities of evolutionary change. When the population dimension and thus genetic diversity fall below a certain low limit, future evolutionary options become so scarce that the species is condemned to rapid decline (MASSA, 1999a). Destruction or transformation of original ecosystems have been recognized as the main cause for rarefaction and extinction of a lot of Italian animal species (BOLOGNA, 2002).

The survival chances of fragmented populations are therefore dramatically linked to their dimension - cf. the concept of *minimum viable population size* by SHAFFER, 1981 - and to the existing connections among isolated populations - sub-populations - in the different habitat fragments.

Fragmentation critical to species survival is tailored to the organism of interest. As MASSA observes (1999b), for many insects or amphibians a simple asphalt road may represent a barrier drastically preventing all individuals living in the different blocks from meeting; the critical factor for the big predators is the extent of the residual habitat fragments, every one of which may not even reach the *home range* extent of a single individual. Here is why, among all principal menaces to species conservation in

natural residual habitats, the very construction of new infrastructures - such as ski lifts, roads, railways, highways - is held responsible for yet increasing the severity of habitat fragmentation.

Again, MASSA (1999b) affirms that chances for survival do increase if the animals, at the level of the individual or of the population (*metapopulation*), manage to move effectively between blocks. This happens if the species are not *internal species* - e.g. woodpeckers or jays - which, in order to keep standing inside a fragmented habitat, need buffer areas around their own blocks of habitat, so that the margins of their vital area may be protected from direct contact with the external matrix.

Degree of isolation of the residual habitat fragments, quality of the neighbourhood connection matrix and the pattern of margin effect: these are all the factors influencing endemic species chances for survival.

And then there is the possibility that some species may adapt to secondary habitats, whenever these conserve at least part of the features of a natural habitat. It is the case for example of pastures and lands originating from the destruction of forest habitats, where floristic and faunistic components, coming from pre-existing clearings or habitats, are discovered to be spontaneous (BRANDMAYR, 2002). These habitats, defined as semi-natural, although the original ecosystem physiognomy has been altered, are very rich in native-origin plant and animal species.

Primary habitat destruction, on the other hand, is associated with the creation of new spaces and habitats - agro-ecosystems, urban ecosystems - favourable to the settlement and to the diffusion of *synanthropic* species, that is to say plant and animal species that result to be dependent upon artefacts, processes - e.g. fertilizing, harvesting, ploughing in the fields - or trophic resources - dump areas - placed unintentionally at their disposal by man. Generally they are opportunistic species, both in their diet and in their choice of reproductive sites, and they are highly mobile species, too. This explains the growth, that has been recorded over the last few decades and was never observed before, in the number of animal species - e.g. stork, starling, gull, fox, blackbird, magpie, robin - that are able to colonize urban ecosystems (*urbanization*).

And then in urban parks unexpected presences may be recorded, such as bird fauna typically connected to forest environments; they can be encountered at these green resorts even in particularly great numbers. In this sense, the tawny owl (*Strix aluco*) colony of Monza's Parco Storico may come as an example.

Plant species capable of adapting to the ecological conditions peculiar to the urban environment (dispersed, isolated, heavy trodden, nitrogen-enriched, semi-desert, ephemeral habitats) possess specific survival strategies: high productivity, short life cycles, light lignification. Repeatedly, these characteristics belong to species of an exotic provenance (*allochthonous*), which may become so competitive in the ecological niches of native species – or in the niches that have just been mentioned – that they can overwhelm and eliminate the native elements (*invasions*).

Different considerations have to be taken into account in the case of suburban landscapes, where the conditions of ecological transition, together with environmental degradation and maybe limitations to physical connections, such as are posed by unrestrained fencing, for example, are often matched by low quality installations

and poor urban development affecting man himself.

To sum it up, there are two opposite effects of landscape modification by man on biodiversity: the extent of secondary ecosystems increases, and, since they are linked to human activities' contingent needs, they are more unstable than natural ecosystems (e.g. forests). Under such conditions, endemic populations, which are naturally sedentary and specialized, tend to be replaced by mobile opportunistic species, less demanding in terms of open spaces.

On the other side, general biodiversity at landscape scale – regional and national – decreases along with the rise in anthropic pressure, as intrinsically different communities come to be replaced by communities that are similar to each other over vast expanses of territory (BRAND-MAYR, 2002).

CLIMATIC CHANGES

[Carlo Blasi, Leopoldo Michetti]

Many minor components of the atmosphere interact with infrared radiation from the Earth, thus causing the so-said “greenhouse effect”. The greenhouse effect is what makes the earth suitable for life, as its presence accounts for the 33 °C rise in the planet’s surface temperature as opposed to the value it would have in its absence. The main greenhouse gas is water vapour, which behaves differently from other greenhouse gases, being subject to substantial variations in concentration, both over time and space (IPCC, 1995).

Since the beginning of the industrial revolution man has modified the composition of the atmosphere, by introducing large volumes of “minor” greenhouse gases, among which carbon dioxide (CO₂) is the best known.

We can notice that the value of CO₂ natural concentration, that is the value assuring the benefic natural greenhouse effect, was about 280 ppmv (parts per million in volume), whereas in 150 years – but essentially in the last 70 – we brought carbon dioxide concentration to little less than 364 ppmv (1998 value), close to a 30% increase. With present day growth rate trend the preindustrial value is expected to double (560 ppmv) in just about 35 years. Within the end of the century the value could be four times greater (see Figures 3.8 and 3.9). In other words we will have produced a variation

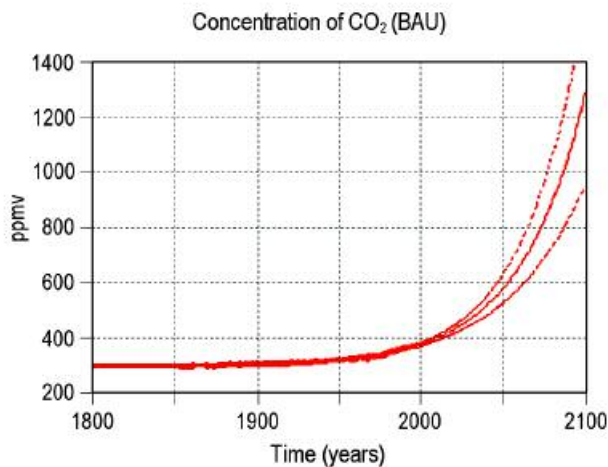


Figure 3.9 - Extrapolation of CO₂ concentration at the year 2100. The best estimated value is 1330 ppm_v (scenario IPCC IS92e. Statistics: GDI 1997).

in atmospheric CO₂ concentration three times greater than the biggest variation recorded in a little less than half a million years. Looking at the very strong correlation between medium temperature and greenhouse gases concentration – but similar data are available for methane concentration too – it is reasonable to expect a greenhouse effect of vast proportions, accompanying the massive and rapid anthropogenic variations of CO₂ concentration.

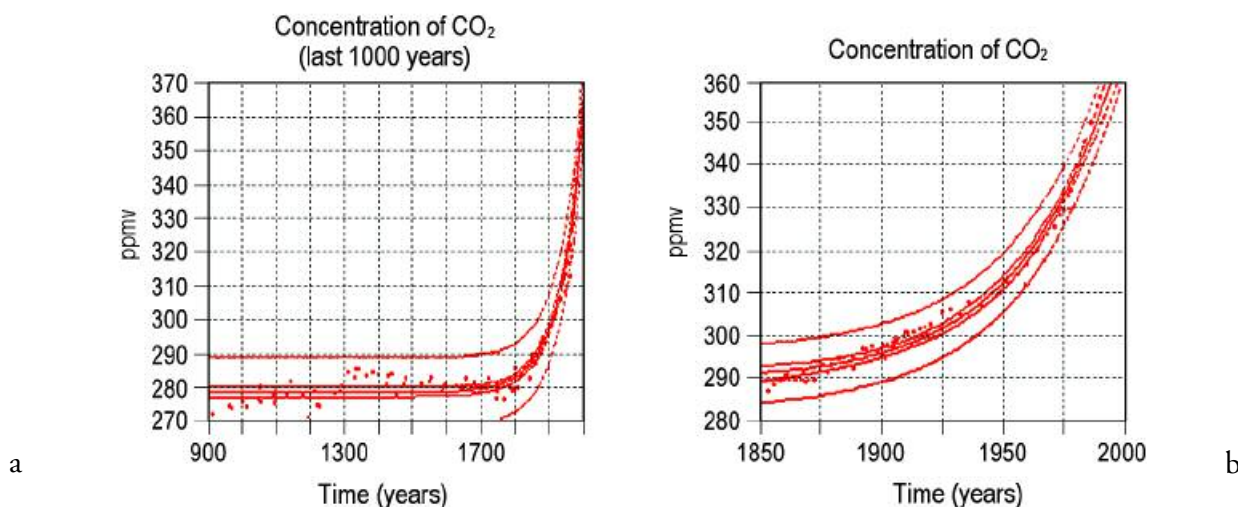


Figure 3.8 - a) CO₂ natural variations and anthropogenic increase after the industrial revolution of the 1800s. Data from IPCC (1995); GDI (*Global Dynamics Institute*) statistics, 1997. b) closeup of the 1850-2000 time interval, where the exponential trend of CO₂ concentration after the industrial revolution is exposed.

ATTESTED CLIMATIC VARIATIONS

The current rate of Earth's surface warming is 0.15°C per decade, and it can be verified at all scales: world, European and national.

The greatest variations have been recorded in the northern hemisphere at the highest latitudes (Arctic Circle, Europe, Asia, America), with a temperature rise during the last decade of $3/5^{\circ}\text{C}$ compared to the previous century. Over the same period the temperature rise contracts to 0.5°C at the Equator, with no significant variations in the southern hemisphere. In particular, at the European continental scale the majority of the areas have shown in the last century average temperature rises up to 0.8°C . The rise does not seem to be continuous: it is present until 1940, then an inflection follows until 1970 and the subsequent new drastic rise ensues from the '70s onwards. These characteristics are more evident at medium to high latitudes. During the '90s the warming up has been very relevant, with rises varying from 0.25 up to 0.5°C over just 10 years. Not only does it get warmer by day, it also gets less cold by night: actually over the last century the rise in minimum temperatures amounts to twice the rise in maximum temperatures. Thus, in our hemisphere, a shortening of the cold season is under way, with the subsequent reduction of the amount of snow covering, and an acceleration in the regression of glacier surface on the mountains and in the Arctic, where the polar cap thickness has thinned by 40%.

As to the evaluation of the climatic variations opinions have begun to be drafted, which are not only based on models, rather on the trends exhibited by real data sets, as considered over significant periods of time (50 to 100 years) (Figure 3.10).

In Italy there is a vast number of thermometric and pluviometric series, but only a limited part of them is available for climatology research. Among the available ones, the UCEA (Ufficio Centrale di Ecologia Agraria, in Rome) series in particular deserve special attention, since they supply meteorological information for many areas nationwide. They were revised and digitized in the '70s, as part of a project by the Consiglio Nazionale delle Ricerche (CNR), which sustained the review of maximum temperature, minimum temperature and daily precipitation recordings out of 27 secular series. These series spanned the 1870-1970 period, and reportedly contained missing data. There is evidence from data analysis that for Italy there has been a warming of about 1°C from

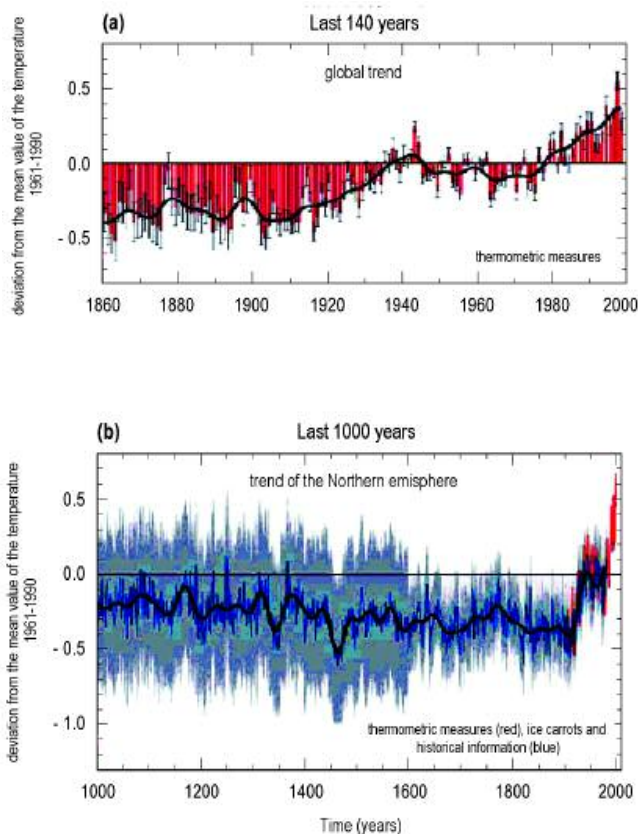


Figure 3.10 - Trend of how annual average global temperature diverges from the mean value, in the period 1961-1990. The continuous lines represent the mobile mean over a ten year period. Above, the last 140 years (thermometric measures in ground stations). Below, the last millennium (data from various sources) (IPCC, 2001).

1860 to date, with a substantial portion of the increase ($0.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$) dating from 1900. Thus, the temperature increase for the Italian territory over the last 40 years has been led by a growth rate of about 0.03°C per year, higher than average both at the global scale and at the European scale. The '90s have been the warmest decade of the last millennium: in 1997 and in 1998 the highest values were attained.

As an example the cases of northern Italy (Figure 3.11) and of Maiella, where the variation over the last 30 years has been reducing the degree of continentality in favour of oceanicity (Figure 3.12), are analyzed.

As far as rainfall is concerned, during the '90s an increase at the high latitudes has been observed overall (between 0.5% and 1% per decade) and a decrease at medium to low latitudes ($-0.3/-0.5\%$ per decade). In Central and North Europe a good part of the increase in the an-

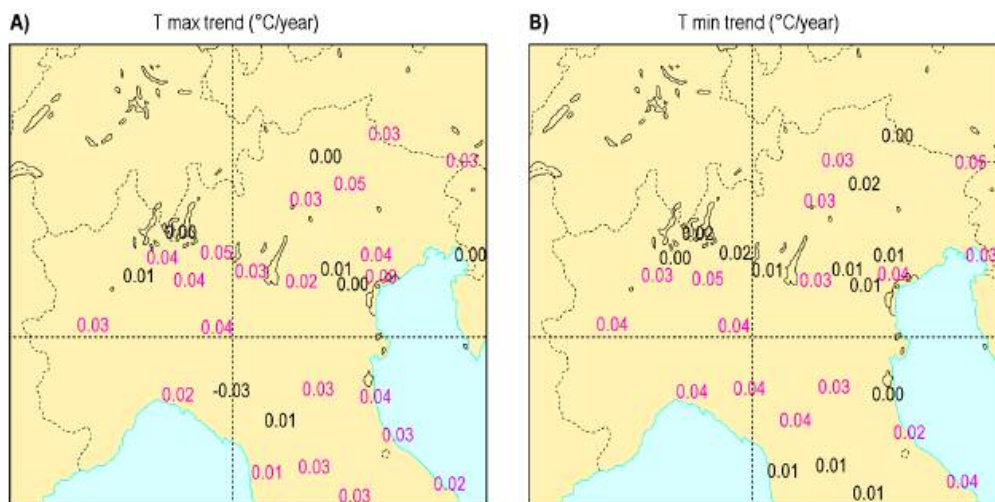


Figure 3.11 - Annual increase of maximum and minimum temperatures measured in North Italy over the period 1961-1998. The pink colour points out the statistically significant positive temperature variations (ZUCCHERELLI, 2000). *Trend* of Tmax annual (°C/year). *Trend* of Tmin annual (°C/year).

annual precipitation totals seemingly stems from winter and spring seasonal increases; whereas rainfall seems to drop during the summer season.

But in the Mediterranean Basin the rainfall diminution, starting from the end of the '50s to date, apparently stands out quite significantly over all seasons. The orographic barrier constituted by the Alps is conducive to the modifying of precipitation trends, which result as being on the increase in continental Europe (North of the Alps) and on the decrease in Mediterranean Europe.

Total amount aside, precipitation have changed also

the form with which they tend to occur: in tropical and subtropical regions increasingly present heavy rainfall is recorded, together with a diminution of the total number of rainy days. At medium to high latitudes the frequency of intense rainfall has gone up from 2% to 4%.

In Italy the number of days characterized by heavy rainfall (more than 25 mm per day) has been observed to be on a significant increase, whereas the days with lesser rain (less than 25 mm per day) are on the decrease. The direct consequences of this trend are in the first place expressed by the greater incidence of flooding from heavy rainfall (the na-

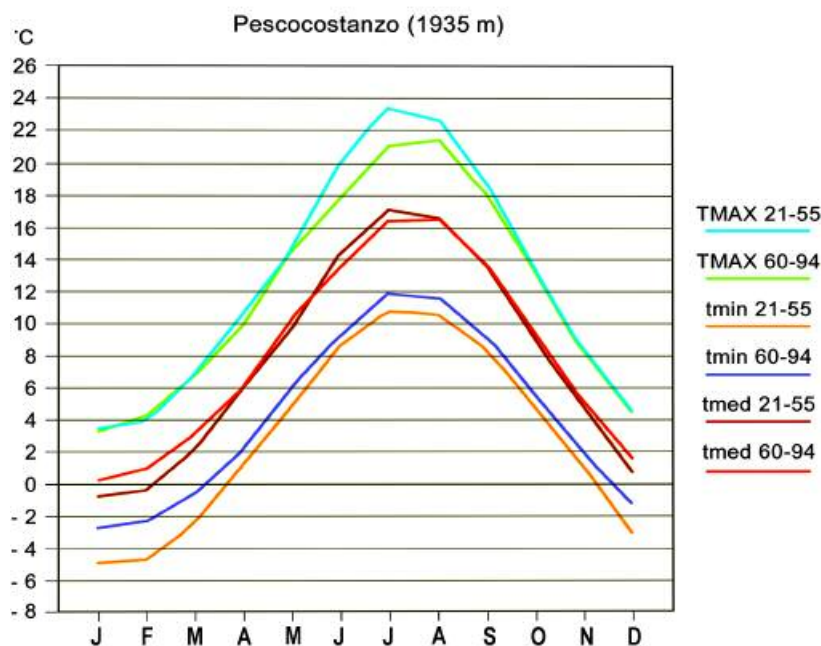


Figure 3.12 - Diachronic comparison (1921-1955 and 1960-1994) between Tmax, Tmin and Tmed at the Pescocostanzo station (1359 m). Tmin in the interval 1921-1955 is lower by approximately 2 °C in the winter period with respect to the interval 1960-1994, while Tmax in the interval 1921-1955 is approximately 2 °C higher in the summer period with respect to the interval 1960-1994. Continentality decreases in favour of oceanicity (very cold winters and cooler summers). By applying the regression to the thermopluviometric stations of Maiella, which Pescocostanzo is a part of, it is clear how the bioclimatic limits (RIVAS-MARTINEZ, 1996) change over the two analyzed time intervals. Over the 1921-1955 period the limit between supratemperate and orotemperate is placed at around 1680 m, while between orotemperate and criotemperate it is found at around 2.330 m. In the 1960-1994 interval the mentioned limits are placed respectively at around 1850 m and at around 2470 m.

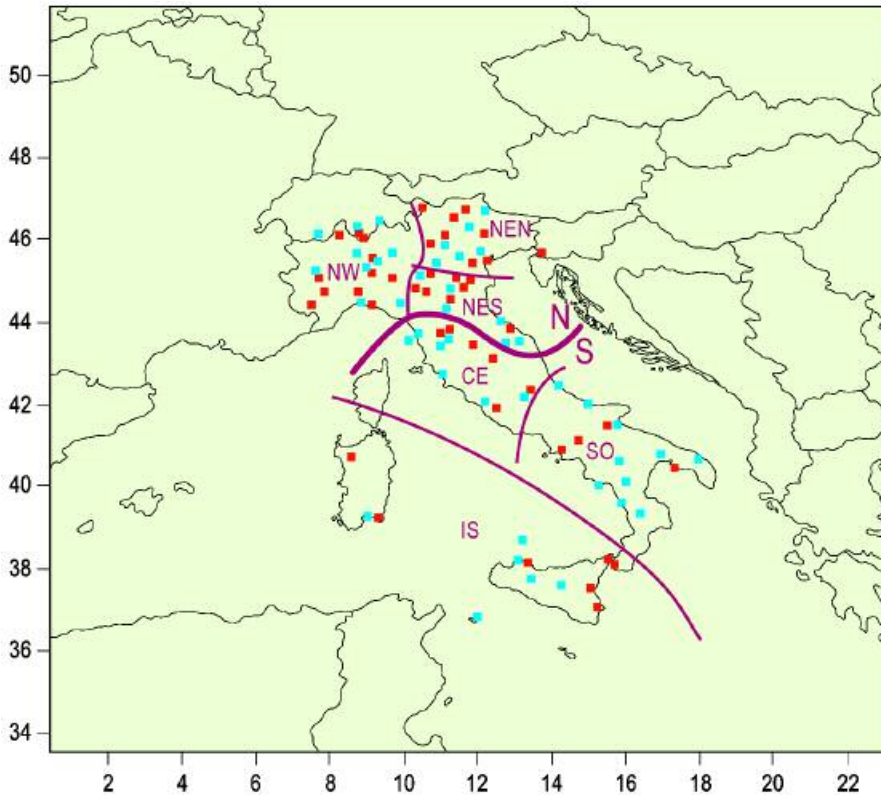


Figure 3.13 - Geographic distribution of the stations. The red square points to the stations with centennial series, whereas the blue square to the ones with series spanning over the last 50 yrs. The regions are also indicated (N and S), as well as the subregions (NW = NorthWest, NEN = NorthEastNorth, NES = NorthEastSouth, CE = Central, SO = South, IS = Islands) (BRUNETTI *et al.*, 2002).

ture of the rain not being the single scoring factor here, management of the territory is of equal importance), and by the progressive tendency of the vegetation to use up more and more water, as an issue of the rising temperatures.

For our country the variation in rainfall totals and pe-

riodicity stands out as the major element in the face of environmental shifts. As a matter of fact, the orographic and morphologic complexity singles out rainfall as the most predictive climate parameter consenting sectorialization, as reported in Figure 3.13 and in Table 3.3.

	Rainy days							
	NW	NEN	NES	CE	SO	IS	N	S
Winter	-26 +/- 17	-	-41 +/- 15	-38 +/- 13	-34 +/- 11	-19 +/- 9	-34 +/- 15	-31 +/- 10
Spring	+	+	-	-	-	+	+	-
Summer	-26 +/- 10	-18 +/- 6	-	+	-	+	-16 +/- 7	+
Autumn	-	-	-	-	-23 +/- 9	-	-	-
Year	-14 +/- 7	-12 +/- 5	-18 +/- 6	-12 +/- 6	-21 +/- 5	-	-14 +/- 5	-14 +/- 5
	Intensity							
	NW	NEN	NES	CE	SO	IS	N	S
Winter	+	+	-	-	-	+	+	-
Spring	+	+	+	+12 +/- 5	+	-	+	+
Summer	+	+	+17 +/- 7	+17 +/- 7	-	-	+10 +/- 4	+
Autumn	+	-	+	+17 +/- 8	+	+	+	+11 +/- 5
Year	+11 +/- 5	+	+9 +/- 4	+10 +/- 4	+	-	+7 +/- 3	+6 +/- 3

Table 3.3 - Variations in the number and intensity of rainy days throughout the sub-regions for the period 1951-1996. The bold numbers stand at a level of significance greater than 95%; the non-bold numbers stand at a level of significance between 90 and 95%; when the level of significance is lower than 90% the simple trend is reported (positive or negative).

PHENOLOGY AND CLIMATIC CHANGES

[Loretta Gratani, Maria Fiore Crescente]

The global warming of the atmosphere in the last 100 years has resulted in an average earth temperature increase of about 0.6 °C and this phenomenon manifested itself more evidently between 1910 and 1945 and later between 1976 and today. The warming rate of the latter period is reported to be the highest over the last 1000 years, especially as a result of the increase in minimum temperatures, which have grown at double the rate of maximum temperatures; as a consequence, at medium to high latitudes periods with temperatures below 0 °C are scarcer, and this, from 1960 to date, has led to a diminution in snow cover and in the areal extent of ice sheets by at least 10% (WALTHER *et al.*, 2002). Moreover, a non uniform change in the rainfall regime has been noticed, with a 0.5-1% increase per decade at medium to high latitudes in the northern hemisphere and a 0.3% decrease per decade at sub-tropical sites (CLIMATE CHANGE, 2001). Quite a few researches point out that climatic changes have been influencing a large number of organisms with different geographic distributions (HUGHES, 2000). At the ecosystem level, the effects become apparent through the alteration of such processes as are most sensitive to climatic factors variations (PARMESAN and YOHE, 2003).

A substantial contribution to the knowledge of the impact of climatic change on natural systems is offered by phenology, which investigates the periodicity and the phase lengths of the seasonal cycle or of the vital cycle of the organisms. More recently, such studies have been oriented to the evaluation of the effects of climatic change on the phenological cycle, and of the consequences of such effects on species distribution and ecosystem functioning. Phenological recordings forward an integrated indication of the species sensitivity to the variation of environmental – in particular climatic - factors. The changes in the length and periodicity of the phenophases and in particular the interannual variations of spring activities, which are in control of CO₂ annual fixation rate, are thus sensitive indicators of climatic change.

Phenological monitoring at European level has a long tradition of collecting data series, which also prove to be invaluable for appraisal of the impact of climatic change on natural systems. The European network of International Phenological Gardens (IPG), established in 1957, spans a broad latitudinal range (42° N – 69° N, from Scandinavia to Macedonia) and longitudinal range (10° W – 27° E, from Ireland to Finland in the North, and

from Portugal to Macedonia in the South) over Europe (Figure 3.14 and Table 3.4); 55 Phenological Gardens are involved (CHMIELEWSKI, 1996; RÖTZER and CHMIELEWSKI, 2000). The network employs genetically selected clones of tree and shrub species (*Betula pubescens*, *Fagus sylvatica*, *Larix decidua*, *Picea abies*, *Pinus sylvestris*, *Populus canescens*, *Populus tremula*, *Prunus avium*, *Quercus petraea*, *Quercus robur*, *Ribes alpinum*, *Robinia pseudoacacia*, *Salix aurita*, *Salix acutifolia*, *Salix glauca*, *Salix smithiana*, *Salix viminalis*, *Sambucus nigra*, *Sorbus aucuparia*, *Tilia cordata*), so as to obtain comparable data on plants uninfluenced by genetic differences. One of the objectives of IPG is also to build a global phenological network, for world-level collection of data useful for long term monitoring activities.

Italy has a long phenological tradition too, especially by virtue of the work of MINIO and MARCELLO, who coordinated the Italian Phenological Network respectively from 1922 to 1936 and from 1953 to 1965, of Dalla Fior, who coordinated the regional phenological network of Trentino from the '20s into the '60s, and of MONTELUCCI, who collected data from the 1960-1982

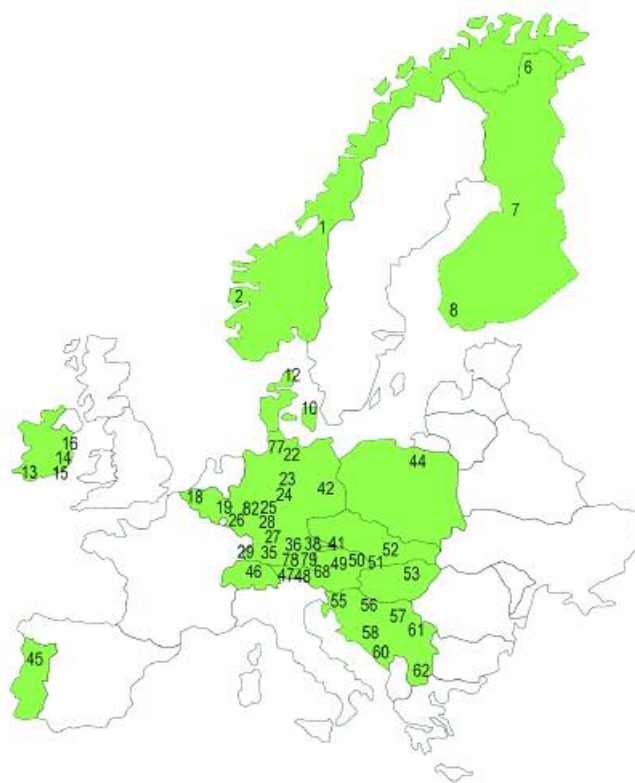


Figure 3.14 - Distribution of the International Phenological Gardens (IPG) (CHMIELEWSKI, 1996, redrawn).

n° IPG	Latitude	Longitude	Altitude	Observation
01	63°29'	10°53' E	25	1964 -
02	60°16'	05°21' E	50	1964 -
06	69°45'	27°00' E	180	1968 -
07	64°31'	26°27' E	115	1968 -
08	60°23'	22°33' E	10	1965 -
10	55°40'	12°18' E	30	1971 -
12	57°14'	09°55' E	20	1972 -
13	51°56'	10°15' W	14	1966 -
14	52°20'	06°35' W	80	1966 -
15	52°18'	06°31' W	60	1967 -
16	53°23'	06°20' W	30	1966 -
18	50°59'	03°48' E	15	1963 -
19	50°00'	05°44' E	500	1972 -
22	53°39'	10°12' E	46	1970 -
23	51°20'	09°40' E	500	1965 -
24	50°06'	08°47' E	99	1959 -
25	49°59'	07°58' E	118	1973 -
26	49°45'	06°40' E	265	1960 -
27	48°43'	09°13' E	380	1961 -
28	48°49'	09°07' E	330	1968 -
29	48°03'	07°36' E	285	1972 -
30	48°04'	07°41' E	265	1968 -
31	48°00'	07°51' E	270	1970 -
32	48°01'	07°59' E	500	1976 -
33	47°55'	07°54' E	1210	1970 -
34	47°52'	08°00' E	1485	1971 -
35	47°57'	08°31' E	680	1973 -
36	48°11'	11°10' E	540	1963 -
38	48°51'	13°31' E	737	1974 -
39	48°55'	13°19' E	756	1974 -
40	48°56'	13°20' E	956	1974 -
41	48°56'	13°31' E	1370	1976 -
42	50°59'	13°32' E	360	1962 -
44	53°47'	21°35' E	127	1967 -
45	41°15'	08°30' W	30	1968 -
46	47°20'	08°48' E	600	1963 -
47	47°17'	11°24' E	600	1973 -
48	47°15'	11°30' E	900	1968-85; 1991 -
49	48°15'	16°22' E	202	1960 -
50	48°15'	16°43' E	150	1960-88; 1992 -
51	48°20'	18°22' E	180	1962 -
52	48°27'	18°56' E	540	1966 -
53	47°36'	19°21' E	220	1974 -
55	46°04'	14°30' E	310	1962 -
56	46°02'	16°34' E	146	1962 -
57	45°47'	19°07' E	90	1975
58	43°45'	18°01' E	1000	1962 -
60	42°05'	19°05' E	5	1975 -
61	44°22'	20°57' E	121	1974 -
62	41°39'	22°51' E	240	1962 -
68	47°48'	13°04' E	440	1985 -
77	53°44'	09°53' E	13	1988 -
78	47°34'	12°57' E	1430	1994 -
79	47°35'	12°58' E	950	1994 -
83	49°46'	07°03' E	480	1995 -

Table 3.4 - Distribution of the International Phenological Gardens (IPG) (CHMIELEWSKI, 1996).

period. However, the establishment of a network of Phenological Gardens is a relatively recent deed, and the first Garden was founded in 1982 in San Pietro Capofiume (in the province of Bologna). A network of nine Gardens spread over the national territory is currently active (Figure 3.15), and its activities are coordinated by the National Phenological Gardens Workgroup, established in 1933, in cooperation with the Italian Botanical Society, regional institutions, the Italian Association of Aerobiology and university institutes and centres. The Workgroup has drafted a list of indicator species common to all Gardens, obtained via vegetative propagation from mother plants that were present in the San Pietro Capofiume Garden. Included in the list are the following species: *Crataegus monogyna*, *Corylus avellana*, *Ligustrum vulgare*, *Robinia pseudoacacia*, *Sambucus nigra*, and, in addition, three different *Salix* species (*S. acutifolia*, *S. viminalis* and *S. smithiana*) from the IPG (BOTARELLI and SACCHETTI, 1998).



Figure 3.15 - Distribution of the Italian Phenological Gardens. 1) Arboreto di Arco (Trento); 2) Bonisiolo di Mogliano Veneto (Treviso); 3) San Pietro Capofiume (Bologna); 4) Montepaldi San Casciano (Florence); 5) Orecchiella Garfagnana Corfino (Lucca); 6) Fontanella Sant'Apollinare di Marsciano (Perugia); 7) Portici, Naples; 8) Pantanello di Bernalda (Matera); 9) Fenosù Oristano (Sassari) (MANDRIOLI, 1998).

The phenological monitoring conducted by IPG has evinced increasing temperatures by the recording of spring events starting ahead of time. Actually, the phenophases of temperate zones – such as budding, foliation, and blossoming - respond to the accumulation of temperature over a threshold value, which is species-specific; an increase in the average winter and spring temperatures is mirrored by phase anticipation (RATHCKE and LACEY, 1985). In particular, CHMIELEWSKI and RÖTZER (2000) have revealed how in Europe, over the 1969-1998 period, the average start of vegetative activity has shifted ahead in time by a total of 8 days – 2.7 days per decade. Similar results were obtained by KOCH (2000) for *Fagus sylvatica*, *Acer platanoides*, *Betula pendula*, *Aesculus hippocastanum*, *Larix decidua*, *Malus domestica*, *Prunus avium*, *Syringa vulgaris* and species of the *Quercus* genus, by analyzing recordings collected in Switzerland, Austria and Slovenia over the 1960-1999 period. MENZEL (2000) has used phenological data from clones of tree and shrub species to underline, for the 1959-1996 stretch, a 6 days anticipation period (-0.21 days/year) for the foliation process, as well as a 4.5 days delay period (+0.15 days/year) for the leaf senescence process, the two combining to produce a 10.8 days average lengthening of the growing season since 1960. RÖTZER and CHMIELEWSKI (2000), by using multiple regression models, have pointed out the relationship between the starting date of the phenophases and factors such as altitude, latitude and longitude (Figure 3.16). The altitude factor varies from 2.0 days/100m for the start of foliation in *Fagus sylvatica* to 4.6 days/100m

for the start of blossoming in *Robinia pseudacacia*; the latitude factor from 1.8 days/° for the start of foliation in *Fagus sylvatica* to 4.5 days/° for the start of foliation in *Prunus avium*; the longitude factor from 0.23 days/° for the start of foliation in *Fagus sylvatica* to 0.83 days/° for the start of foliation in *Prunus avium*. GRATANI *et al.* (2000) have pinpointed a difference of about 15 days in the bud opening date for *Quercus ilex* L. between the center of Italy (Castelporziano, Roma, 41°45'N 12°26'E, at sea level) and the North (Nago, Trento, 45°55'N 10°53'E, 260m over sea level), and of about three weeks in the duration of the process of bud elongation. Topography plays a major role in determining the spatial variability of the phenophases, since it bears upon local temperature variations. GRATANI *et al.* (1999), as a result of a study conducted at Campo Imperatore (Gran Sasso d'Italia), have pointed out significant phenological differences for the species of the subalpine zone associations (1,800-2,000m over sea level) as confronted with the mountain zone (1,440-1,800m over sea level); also indicating, within the same zone, variations in topographically different areas. For example, in the mountain zone flowering begins from 10 to 15 days earlier than in the subalpine zone, and reaches its maximum peak about 20-25 days later. Phenological activity is expressed over a shorter time in the presence of more severely limiting microclimatic conditions; also, locations that are more exposed to the action of the wind are characterized by a restricted fruiting period.

OSBORNE *et al.* (2000) have shown how the flowering phase of *Olea europaea* is strongly influenced by the av-

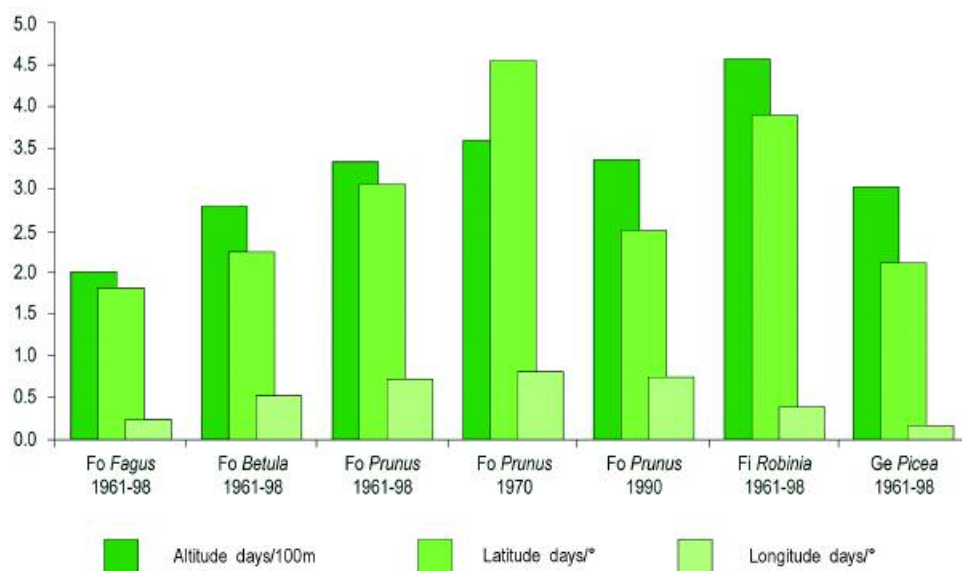


Figure 3.16 - Relation between phenophase and altitude, latitude and longitude. Fo=foliation start; Fi=flowering start; Ge=budding start (RÖTZER AND CHMIELEWSKI, 2000).

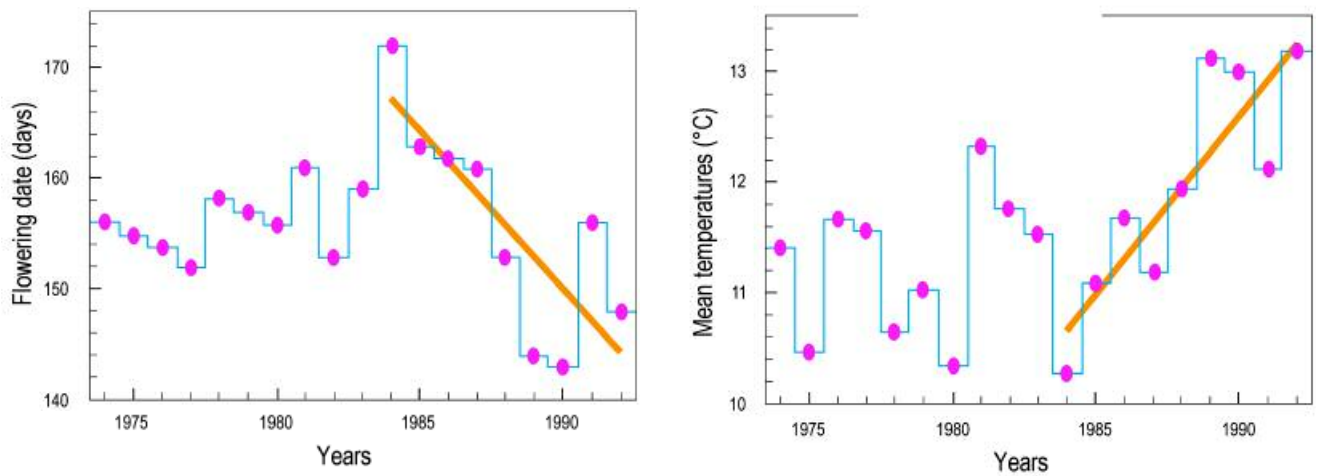


Figure 3.17 - Variations in the time of flowering exhibited by *Olea europaea* in response to the temperature variations (OSBORNE *et al.*, 2000).

erage spring temperatures, and have conjectured a 3 to 23 days anticipation lag taking place from 1990 to 2030 (Figure 3.17); the authors suggest that this species could be used as the climatic change indicator in the Mediterranean Basin.

As the warming up of the climate causes changes to occur in the thermal regime without corresponding changes happening to the photoperiod, species that are locally adapted to a specific combination of light and temperature may become damaged as a result. Generally speaking, it may be argued (LECHOWICZ, 2001) that species may adopt one of three different answers when confronted with climatic change: 1) the species may migrate, in order to retain the same climatic regime to which they have become adapted phenologically; evidence of such an occurrence stems from the end of glacial periods; 2) the species may adapt to the new climatic conditions; there always is a certain degree of variability among the individuals of a population as far as the length and periodicity of the phenophases are concerned, and from an evolutionary point of view the preservation of such variability is to be expected. The differences

among the individuals of a population may favour a phase shift in face of climatic change, and, over a sufficiently long time lag, they may determine an adaptive response; 3) the species may react negatively to the climatic change, by losing the dominance they enjoyed within the system, or else by extinction. As for the first point, it must be mentioned that habitat fragmentation rises barriers to migration processes, thereby reducing the species roaming and lowering the genetic variability present within the populations, which become more vulnerable through isolation.

From what has been said, phenological monitoring emerges as a useful tool to draw forth informations relevant to climatic change. Thanks to the long series of collected phenological data, Europe is particularly active in the development of phenological models. The establishment of a global Phenological Network will certainly contribute to the extrapolation of results from single researches, thus allowing for the improvement of climatic change impact estimates on agricultural productivity, on forest management, on biodiversity and on all issues pertaining to human health.

CHANGES IN CO₂ CONCENTRATION AND NITROGEN DEPOSITIONS

[Fausto Manes, Francesca Capogna]

CO₂ CONCENTRATION

One of the major effects that take origin from the changes in territory use concerns the carbon cycle, and in particular the changes in the atmospheric concentration of CO₂ (FAO/UNEP, 1999).

The concentration of CO₂, in effect, has been on the rise from the known value it had in 1600 A.D. (285 ppmv) up to the value of 366 ppmv which was reached in 1998 (KEELING and WHORF, 1999). In the last century the growth rate per decade has been persistent and the most rapid ever over the last millennium. Such rate of change may be accounted for by the cumulative effects developing from fossil fuel consumption, deforestation and the response of the ocean and of the biosphere to the action of man.

From 1850 to 1998, 270 ± 30 Gt of C have been emitted from fossil fuel combustion and from cement production (MARLAND *et al.*, 1999); 176 ± 10 Gt of C have been piled up in the atmosphere (ETHERIDGE *et al.*, 1996; KEELING and WHORF, 1999). Cumulative uptake by the oceans during the same period has been evaluated at 120 ± 50 Gt of C (KHESHI *et al.*, 1999; JOOS *et al.*, 1999). Carbon balance over this period underlines the presence of a net global amount of C on the Earth surface, reaching 26 ± 60 Gt. In other words, the Earth system can be assimilated to a source.

During the period from 1850 to 1998, global net cumulative emissions of CO₂ coming from changes in land use have been estimated at about 136 ± 55 Gt of C. About 87% of these emissions was due to changes that had taken place in forest areas, and about 13% to mid-latitude cultivated areas and grasslands (Houghton, 1999; Houghton *et al.*, 1999, 2000). At this point a global demand for a residual 110 ± 80 Gt of C would be necessary in order to balance the difference between the net source from the Earth (26 ± 60 Gt of C) and the greater terrestrial source fueled by the effects on carbon reservoirs brought about by changes in territory use.

Numerous studies substantiate the fact that atmospheric CO₂ increase acts on many plant species by producing an increase in net photosynthesis, in plant biomass (POORTER, 1993; CEULEMANS and MOUSSEAU, 1994; WULLSCHLEGER *et al.*, 1995, 1997) and in water use efficiency (SAXE *et al.*, 1998; WOODWARD *et al.*, 2002).

SAXE *et al.* (1998) have demonstrated that doubling atmospheric CO₂ concentration leads to an approximate 50% increase in biomass production for angiosperm tree species and to an approximate 130% increase for gymnosperm. However, as recently illustrated by IDSO and KIMBALL (2001), this initial growth incentive is likely to decline significantly in subsequent years through acclimatization, and then reach a new equilibrium level many years later. Late experiments (LEAVITT *et al.*, 2003) have ratified the rising trend in water use efficiency, primarily due to the anthropogenic increase in atmospheric CO₂ concentration; a circumstance that could cause much more rapid growth of trees in arid environments, the trees acting as carbon reservoirs for CO₂ in excess. Actually, arid ecosystems, which occupy approximately 20% of the Earth surface, are amongst the most sensitive to high atmospheric concentrations of CO₂ associated to climatic changes. Primary production in the deserts is strongly limited by water and by nitrogen content. Under high CO₂ concentration conditions, the immediate and positive response in water use efficiency gets to improve plant water relations in favour of primary production. Moreover, different species' diverse reactions to high CO₂ are liable to modify the competitive interactions, potentially changing the composition of a community. In North America, high CO₂ concentrations have facilitated in the long run the dominance of a few exotic grasses over numerous annual native species. Such a change in species composition in favour of annual exotic grasses, driven by global change, has the potential of accelerating the fire cycle effects typical of those environments, of reducing biodiversity, and of altering ecosystem function in North American deserts (SMITH *et al.*, 2000).

As of today, however, knowledge of long term effects played by CO₂ fertilization on carbon absorption by the forests can be said to be still limited.

INCREASE IN CO₂ CONCENTRATION

In Italy the monitoring of CO₂ atmospheric concentration has only been practiced over recent times. In our country two stations exist for CO₂ base measurement, which may be taken as representative of the Mediterranean area (ENEA, 2001). The readings performed by the station of Monte Cimone (in the province of Modena), running since 1978, constitute the longest historical series for the Mediterranean area. The data series available for the period 1990-1999 is shown in Figure 3.18. Annual average CO₂ atmospheric concentration is 360.5 ppm. Informations on the trend over the period, point at a growth of approximately 4%, from 354.2 ppm in 1990 to 368.6 in 1996. These results confirm the general tendency to the modification of atmospheric composition, in agreement with data coming from the other stations of the world monitoring net, also evaluated over larger temporal scales than the one set forth here.

The second monitoring station, active since May 1992, is established in the island of Lampedusa (in the province of Trapani, Sicilia). The data series relative to the 1992-2001 period is shown in Figure 3.19. The island of Lampedusa was chosen as a remote referral site as it meets all criteria of base CO₂ representativity required by WMO (*World Meteorological Organization*), it being located in the centre of the Mediterranean and not being influenced by CO₂ disturbances from anthropogenic sources (urban or industrial areas, traffic, or other) or from sensitive natural sources (photosynthesis and respiration cycles of woods, forests, or other expanded vegetation). The average concentration over the analyzed period is 365.5 ppm, with a 3% growth, from 360.8, in 1993, to 372.5, during the first nine months of 2001. The constant growth of CO₂ concentration as recorded in the two stations is endorsed by the rising figures resulting from energy component measurements (10%) between 1994 and 1999. Only serious intervention in the areas of energy and en-

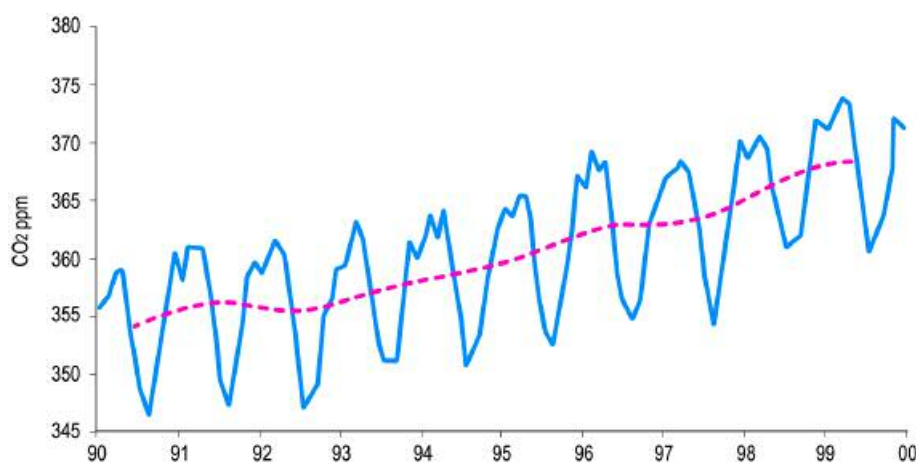


Figure 3.18 - CO₂ concentrations (Monte Cimone Station). Years 1990-1999 (ppm_v) (ENEA, 2001, modified).

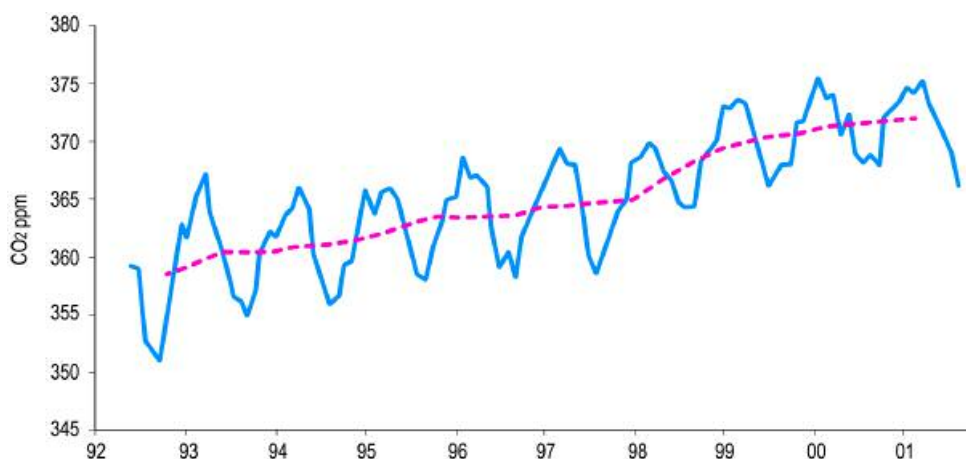


Figure 3.19 - CO₂ concentrations (Lampedusa Station). Years 1992-2001 (ppm_v) (ENEA, 2001, modified).

vironmental policies applied to this sector, could allow us to abide with the Kyoto Protocol commitment to the 6.5% reduction of greenhouse gases emissions by 2012, with respect to 1990 emissions.

The trend of the 4 countries that have contributed the most to carbon dioxide emission in the context of the European Union is reported in Figure 3.20. Germany and the United Kingdom are the only countries to have reduced their emissions with respect to 1990

(respectively by 16% and by 9%), whereas all other countries have increased them. Italy, with an increase of 5%, is the country with the least increment in its emissions, right after Sweden. Actually, Italy presents, over the year 1999, per capita CO₂ emissions of approximately 8 tons, against a European value of 8.7. This result places Italy at the 11th place in the list guided by Finland (12 tons per capita) with Portugal at the rear end, with 6 tons per year (Figure 3.21).

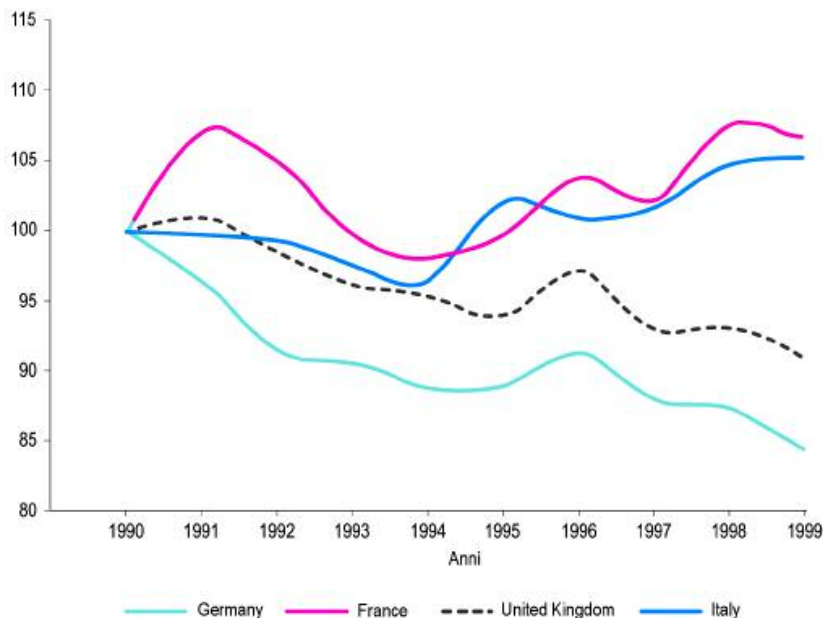


Figure 3.20 - CO₂ emissions out of energy processes in a few UE countries (Source: European Environment Agency, 2001) (ENEA, 2001, modified).

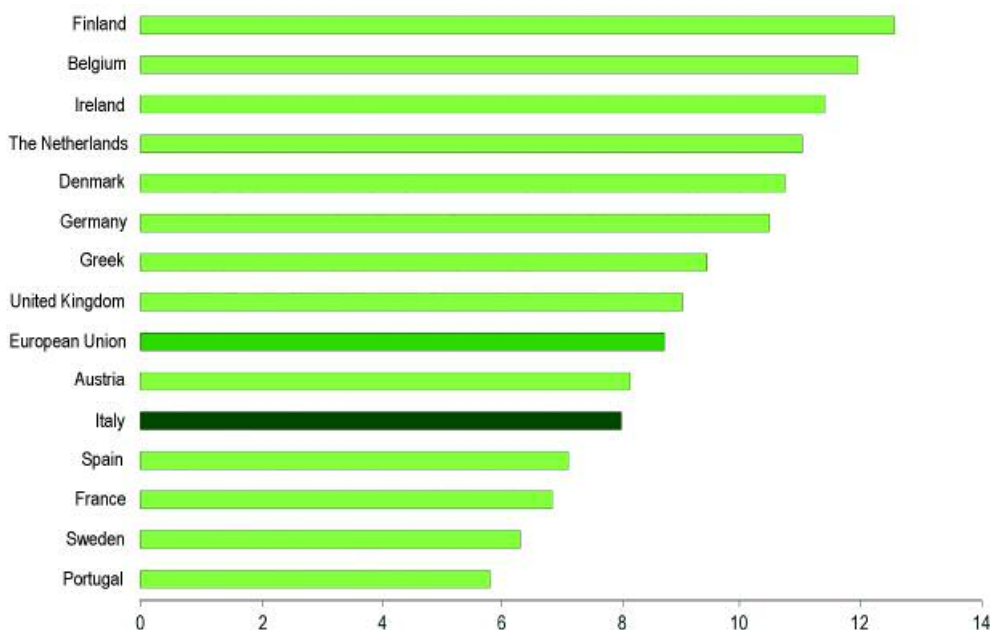


Figure 3.21 - CO₂ emissions in the year 1999 (tons per capita) (ENEA, 2001, modified).

NITROGEN DEPOSITIONS

Nitrogen fertilization represents a valid way to increase agricultural production and turns out to be particularly efficient in increasing the productivity of forest plantations in chaparral/Mediterranean, temperate and boreal climatic regions (LINDER *et al.*, 1996). Nitrogen and phosphorous fertilizations promote photosynthesis, and, in particular, nitrogen stimulates the increase in number of leaves and in leaf growth, determining larger foliage extension or density.

Over the last few years atmospheric nitrogen deposition on forest ecosystems has been on the rise, as a consequence of the high emission rate of oxidized nitrogenous substances produced by industrial activities and by surface transport, and of reduced nitrogenous substances out of livestock raising and farming (GALLOWAY, 1995). In North Europe and in a few sites over the United States (FENN *et al.*, 1998), a large increase in nitrogen deposition with respect to pre-industrial levels has been documented (SUTTON *et al.*, 1993). In Eastern United States, NO_x release coming from fossil fuel consumption has raised nitrogen depositions by ten-fold approximately, if compared to pre-industrial era (HICKS *et al.*, 1990). Recent studies predict rising N emissions all over the world – the event will be particularly intense in Asia and Africa – following indiscriminate use of fertilizers and fossil fuel consumption (GALLOWAY, 1995).

A data survey from different sampling sites has evidenced that tree growth is on the rise in Europe (SPIECKER *et al.*, 1996). Humid and dry nutrient depositions could have contributed to such forest growth. In general, the total annual (oxidized and reduced) nitrogen deposition (humid and dry) in rural areas oscillates between 5 and 40 kg ha⁻¹ year⁻¹; lower concentrations are found in remote forest areas, especially at high latitudes and at the tropics (FREYDIER *et al.*, 1998).

However, in some districts, the load of nitrogenous depositions on forests has exceeded ecosystem assimilation capacity, leading to an unbalance in the nutrient content and to NO_3^- leaching by stream waters, in a process known as “nitrogen saturation” (ABER *et al.*, 1989, 1998). Nitrogen saturation has been described for forests that receive a large quantity of inorganic nitrogen, varying between 20 and 100 kg ha⁻¹ year⁻¹, in the Netherlands, in Great Britain and in the United States.

Little is known about atmospheric nitrogen depositions in the rural areas of the Mediterranean Basin and about the potential effects of such phenomena on the Mediterranean forests.

For hundreds of years holm oak forests of the Mediterranean Basin have been subject to recurring nutrient losses due to raging fires and to tree logging. These disturbances could have lowered soil nutrient resources. Lower nutrient availability could be held as at least partially responsible for low net epigeous primary production of holm oak forests (6.3 t ha⁻¹ year⁻¹ in Spain, IBANEZ *et al.*, 1999), even though other limiting factors, such as water, may be involved as well.

An experiment conducted in a holm oak forest in Spain revealed that net epigeous production increased both after irrigation and after fertilization with 250g of N ha⁻¹ (RODÀ *et al.*, 1999). Nitrogen fertilization greatly increases leaf and acorn production, thereby proving that Mediterranean forests are apt to respond positively to an increase in nitrogen availability in spite of strong water limiting conditions.

Obviously, continuous low-dose nitrogen contributions could have widely different effects from those brought about by single, heavy administration of fertilizer. At any rate, circumstantial evidence proves that nitrogenous atmospheric depositions are likely to be kept at the vegetation and soil level, within the ecosystems. Atmospheric nitrogen could be used by trees to maintain their growth rate, but the long term effects of such increased nitrogen availability are yet to be investigated. For instance, the uncertainty is held unresolved as to how much - and for how long - forest growth and forest Net Ecosystem Productivity (NEP) are going to be sustained by the current annual rate of nitrogen deposition.

Numerous studies have pointed to a relationship existing between the changes in species richness and the nutrient availability gradient. The typical observed response was the bell-shaped curve: species richness is low for low nutrient levels, peaks for intermediate levels and gradually slopes downward for high nutrient levels (PAUSAS and AUSTIN, 2001). A relatively small number of species manages to tolerate extreme conditions of lack of nutrients. Upon an increase in the resources, more species are able to survive and thus species richness augments. At higher nutrient levels, few highly competitive species become dominant, thereby leading anew to a diversity decrease.

NITROGEN OXIDES (NO_x) EMISSIONS, NITROGEN DEPOSITIONS AND ACIDIFICATION

Relative to the year 1999, estimated nitrogen oxides emissions for Italy totalled approximately 1,467 Gg, a little less than 15% of the total European amount. The energy sector, and, in particular, the automotive transportation sector, hold major responsibility for near to total emission amount. The temporal trend of such national emissions has been prone to constant decrease (24% diminution in ten years). From 1980 to 1992 the general tendency of nitrogen oxides was toward an increment; in subsequent years the tendency turned upside down (Figure 3.22). The objective of 1,814 Kt/year by 1994, imposed by the Sofia Protocol, was actually achieved that very same year, whereas the top limit of 1,000 Kt/year, which by the year 2010 will not have to be exceeded, is yet far from reach.

The mapping of critical nitrogen loads on the Italian territory shows, in general, soil sensitivity to nitrogen coming from the depositions and bearing on eutrophication. Alpine soils from the Ligurian Apennine, as well as from Sardegna and from other areas of Central Italy, are the most sensitive to the phenomenon of eutrophication. The most critical areas, where a cutback of nitrogen depositions is required, are particularly concentrated along the Alpine Arc.

However, analysis conducted on data from the 1987-1998 period, collected by the stations of ENEL network that have been sampling humid depositions, gives credit to the assertion that acidification has diminished.

As is well known, air pollution is not an easily solved problem, since it cannot be limited by controls at national scale. Actually, 70% of the nitrogen oxides and 47% of ammonia given off by Italy are transported over national borders, and get deposited on the far side of our frontiers. On the contrary, 30% of the nitrogen oxides and 12% of ammonia interacting with our territory come from other countries (as estimated by EMEP 1997: a co-operation program for the monitoring and the evaluation of long-range transmission of air pollutants in Europe).

Forest health reports carried out by CONECOFOR (see section *Monitoring networks under the National Forest Service*) have pointed out how the foliage of broadleaf trees is more prone to defoliation with respect to conifers. Among less than 60 years old conifers, Scots Pine is the most damaged species, while in the older than 60 years category the worst damage has been reported on Common Silver Fir individuals. Among young broadleaf trees, a large number of Sweet Chestnut and Downy Oak individuals have been found to be suffering from medium defoliation, while European Beech is the most damaged species in the older plants category.

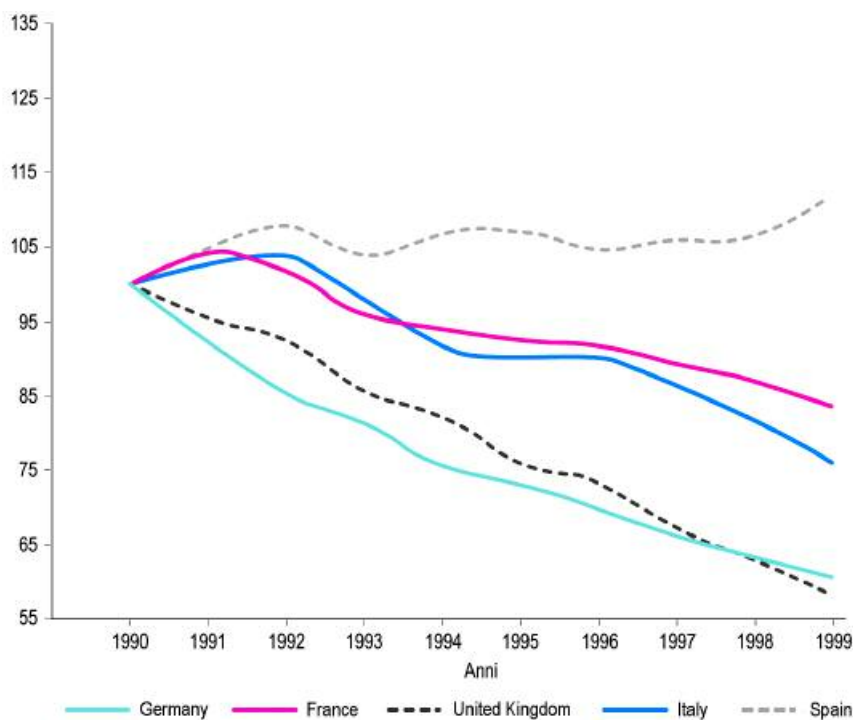


Figure 3.22 - NO_x emissions out of energy processes in a few UE countries (Source: European Environment Agency, 2001) (ENEA, 2001, modified).

ALIEN SPECIES

[Riccardo Scalera, Laura Celesti Grapow]

In many parts of the world, one of the major causes of biodiversity loss is represented by the introduction, by man activity, of an increasing number of species outside of their original range (REJMANEK, 1995). The introduced species, also known as 'exotic' or 'alien' species, are among the main factors responsible for the extinction of many species in Italy. Moreover, they are apt to causing relevant economic, health, social and cultural damage, reflected as a consequence on society as a whole. Not all of the introduced species are harmful, on the contrary many of them are useful, for example the numerous plants standing today as the basic food supply for a large part of the world population (HOYT, 1992). In general, the majority of the species is not successful at overcoming the existing barriers – reproductive, environmental – and settling down in a new territory. Still, a small part of them, singled out by the term 'invasive' (RICHARDSON *et al.*, 2000), manages to assert itself and spread around in such a way as to threaten the persistence of the native *taxa* and, as a result, of biological diversity itself. In spite of all this, the unsettled questions pertaining to the so-said 'biological invasions', as alien species diffusion is commonly referred to, have often been overlooked or underestimated by scientific and academic communities themselves: it may suffice to recall that, not so far back in time, even alien species acclimatization societies existed! It's only in recent years that attention by the entire scientific community and governmental policy makers and practitioners has been mounting perceptibly.

Nowadays invasions are considered to be, right after habitat destruction, one of the chief factors behind the loss of biodiversity over the biosphere (HURKA, 2002). Article 8h of the CBD, devoted to alien species, stresses the importance of a careful evaluation of all introduced entities and states the necessity for prevention, for control, and for removal of those species that are judged detrimental. A high-priority element in the management of invasions therefore resides in the knowledge of the single species, of their present role, and of their invasive potential.

One of the first answers to such an urgent demand was provided in the '80s by the commission 'Scientific Committee on Problems of the Environment' (SCOPE), a network of specialists established in 1969 within the *International Council for Science* (ICSU), with 38 subscribing national scientific institutions and research councils, and 22 international scientific organizations; the com-

mission underlined the impact of invasive species on the ecosystems (DRAKE *et al.*, 1989).

More recently the *Global Invasive Species Program* (GISP), established in 1997 by SCOPE, by the International Centre for Agriculture and Biological sciences (*CAB International* – CABI) and by IUCN, and partially funded by UNEP (GISP PHASE I), has given attention to the identification and control of the most problematic species (Mooney, 1999). In more detail, the programme has the aim of developing a global strategy to meet the threats posed by *Invasive Alien Species* (IAS), and of providing technical and scientific support towards the implementation of the above mentioned article 8. GISP is built around a team of specialists on natural resources conservation – biologists, economists, policy makers and managers among others – who devote themselves to the effort of providing local, national and international agencies and offices with long term strategies and tools for invasions management. At the present time the following are institutional members of the programme (GISP PHASE II): CABI, IUCN, SCOPE, CBD, the *South African National Biodiversity Institute* (SANBI), the programme *Working for Water* (WfW), the firestop campaign *Ukuvuka Fire Stop*, UNEP, the *Invasive Species Specialist Group* (ISSG) from IUCN's *Species Survival Commission* (SSC), the project *DIVERSITAS*, the *International Programme of Biodiversity Science*, and Australia's *Commonwealth Scientific and Industrial Research Organisation* (CSIRO).

Finally, the Council of Europe, on the occasion of the 23rd meeting of the Permanent Committee of the Bern Convention in Strasbourg, on December 2003, has adopted a European Strategy on Invasive Alien Species (Rec. N.99/2003).

Introductions are not recent phenomena; their origins date as far back as human prehistory. For this reason it can be quite hard at times, if not utterly impossible, to determine whether a certain species has reached a particular region driven by natural causes or by man. A typical case is that of the African porcupine (*Hystrix cristata*), a species considered to be native to Italy by some authors, while others believe that it was introduced at the time of the ancient Romans. It is a fact that in recent years continuous species translocation, by now extending to infinite numbers of plant and animal organisms all over the world, is quickly scaling up to quite dramatic proportions, especially as a result of the growing liberalization of the market. Actually, the principal factors lying behind introductions, whether intentional or incidental, can be boiled down to tourism and international trade, them-

selves connected to a series of productive activities, such as agriculture and livestock raising for food and industrial purposes, but also to collecting and pet markets. Moreover, many transportation vehicles represent optimal vectors for species of all different sorts. Just as the rats since many centuries have been using the ships' hulls to colonize every other angle of the planet, a huge number of marine organisms let themselves be carried around from one ocean to the next in the ballast water of ship tanks. And there are also great numbers of vertebrates and invertebrates, which, aside from dimensions, manage to take good advantage of a ride in the cargo hold of an airplane or in a container.

Invasions' ecological implications are of primary importance and engage the entire biosphere, ranging from water habitats to land masses. Already ELTON (1958), one of the founders of Ecology, maintained that the introduction of living organisms outside of the areas where they have evolved can cause permanent alterations at all levels of ecological organization. Even if the presence of new species may seem to increase the biological diversity at local scale, it can jeopardize the equilibria existing within a system and at the world's scale it can lead to the decline and the disappearance of many *taxa*. Allochthonous species may act both directly, through competition, and indirectly, by interfering with interspecific relations within the components of a community and by modifying the equilibria that were preexisting in the ecosystems. A further risk consists in the genetic interactions between the introduced and the native plants (hybridization), which in some cases may go as far as threatening rare species persistence (RHYMER and SIMBERLOFF, 1996).

Not all species that have been introduced are likely to become invasive. Actually, following an empirical rule, only one out of ten manages to settle in permanently, and among these generally not more than one out of ten ends up constituting a problem for the native communities. The fauna and the vegetation components of exotic origin can vary strikingly through time and space, being subjected to the continuous change brought about by the species' success as opposed to other species' failure.

According to recent researches aimed at defining our country's situation, the number of exotic entities present in Italy is quite substantial. The picture of the fauna actually takes into account some hundreds of non native species moving freely about in the natural environment. Among these at least 60 species of vertebrates have been identified, 40% of which are fresh water fish (Table 3.5). Only naturalized entities thereby come into account, that

Mammals
<i>Crocidura russula</i> (White-toothed shrew)
<i>Lepus capensis</i> (Brown hare)
<i>Sylvilagus floridanus</i> (Eastern cottontail)
<i>Oryctolagus cuniculus</i> (European wild rabbit)
<i>Sciurus carolinensis</i> (Eastern grey squirrel)
<i>Tamias sibiricus</i> (Siberian chipmunk)
<i>Callosciurus finlaysonii</i> (Unstriped ground squirrel)
<i>Myocastor coypus</i> (Coypu)
<i>Rattus norvegicus</i> (Norway rat)
<i>Rattus rattus</i> (Black rat)
<i>Mus musculus</i> (Domestic mouse)
<i>Ondatra zibethicus</i> (Common muskrat)
<i>Hystrix cristata</i> (Crested porcupine)
<i>Mustela vison</i> (American mink)
<i>Dama dama</i> (Gazelle)
<i>Ovis ammon musimon</i> (European mouflon)
Birds
<i>Threskiornis aethiopicus</i> (Sacred Ibis)
<i>Cygnus olor</i> (Mute Swan)
<i>Colinus virginianus</i> (Northern bobwhite)
<i>Phasianus colchicus</i> (Common Pheasant)
<i>Alectoris barbara</i> (Barbary partridge)
<i>Alectoris chukar</i> (Oriental partridge)
<i>Francolinus francolinus</i> (Black partridge)
<i>Francolinus erckelii</i> (Erckel partridge)
<i>Amazona aestiva</i> (Amazzone fronte blu)
<i>Myiopsitta monachus</i> (Monk parakeet)
<i>Psittacula krameri</i> (Ring-necked parakeet)
<i>Amandava amandava</i> (Strawberry finch)
<i>Paradoxornis alphonisianus</i> (Becco a cono golacenerina)
Reptiles
<i>Trachemys scripta elegans</i> (Red-eared slider)
<i>Mauremys caspita</i> (Mauremide caspita)
<i>Testudo graeca</i> (Spur-thighed tortoise)
<i>Testudo marginata</i> (Marginated tortoise)
<i>Chamaeleo chamaeleon</i> (Chameleon)
<i>Coluber hippocrepis</i> (Whip snake)
Amphibians
<i>Rana catesbeiana</i> (Bullfrog)
Fishes
<i>Acipenser transmontanus</i> (White sturgeon)
<i>Cyprinus carpio</i> (Carp)
<i>Carassius carassius</i> (Goldfish)
<i>Abramis brama</i> (Abramide)
<i>Pseudorasbora parva</i> (Stone moroko)
<i>Rodeus amarus</i> (Rodeo amaro)
<i>Rutilus rutilus</i> (Roach)
<i>Naso</i> sp. (Nase)
<i>Ictalurus melas</i> (Black bullhead)
<i>Ictalurus punctatus</i> (Channel catfish)
<i>Ictalurus nebulosus</i> (Nebulous catfish)
<i>Silurus glanis</i> (Wels catfish)
<i>Salvelinus fontinalis</i> (Brook trout)
<i>Oncorhynchus mykiss</i> (Trout)
<i>Coregonus</i> sp. (Whitefish)
<i>Coregonus macrophthalmus</i> (Nosed whitefish)
<i>Lota lota</i> (Burbot)
<i>Gambusia affinis</i> (Mosquito fish)
<i>Lampris regius</i> (King fish)
<i>Micropterus salmoides</i> (Largemouth bass)
<i>Lepomis gibbosus</i> (Pumpkinseed sunfish)
<i>Perca fluviatilis</i> (European perch)
<i>Stizostedion lucioperca</i> (Pike-perch)
<i>Gymnocephalus cernuus</i> (Ruffe)

Table 3.5 - List of vertebrate species introduced into Italy.

is, those whose populations are capable of self-sustenance without any support from man. If we were also to consider simply acclimatized species, or even occasionally sighted species – as a consequence of few specimens having escaped that were once bred in captivity (their populations being on the brink of potential naturalization or of local extinction) – the number of alien species in Italy would be much higher: this is the reason for which at times published data are not in accord with each other. Moreover, it is possible that not every author would agree with some entities' presumed allochthonous source, as they could have been introduced in ancient times, and even more especially so when historical or paleontological clues are spare or absent. This also contributes to the diversification of the estimates put forward in different works.

Another long list of species must be added onto introductions in the strict sense of the word: that is, those involved in fauna translocation activities. This is the case of species that have been subjected to insertion from one side of our country to the other. A typical example is that of the Brown Hare (*Lepus europaeus*), a species that was originally confined to the northern and central regions of Italy, and has subsequently been repeatedly inserted for hunting purposes also in central to southern Italy and in Sicilia, where the Italian Hare is present (*Lepus corsicanus*),

an endemism that is particularly vulnerable to such interventions. The islands being exposed to the intromission of species originating in the peninsula represent a particular case of fauna translocations. Sardegna comes to mind, since it is alleged that all species of mammals present there are of allochthonous origin. In such a context, the situation may take on quite alarming proportions, considering that in insular systems all over the world alien species introductions are held to be by far the principal cause of native species extinction.

In most cases unfortunately the grave consequences of the introductions are not readily perceived. Be as it may, when an exotic species has settled in and by then is starting to pose serious threats to the environment, to productive activities, or to man's health, then it may be necessary to take into consideration control or eradication actions; these strategies, however, are by their very nature exposed to public agreement or to public dissent, according to the delicate disputes regarding the ethical and utilitarian issues that come into play. Such a limit has been well portrayed in Italy by the case of tentative eradication of the Eastern Grey Squirrel (*Sciurus carolinensis*), a species deemed to be potentially dangerous to the survival of the Red Squirrel (*Sciurus vulgaris*) and capable of serious damage to the crops.

FAUNA

[Marzio Zapparoli²]

At the present time a reasoned list of non-indigenous animal species in Italy is not available, there being only partial summaries of the data especially relative to arthropods of economic importance, and to vertebrates. The following notes are based on Italian fauna species check-lists (MINELLI *et al.*, 1993-1995), on a few of the above mentioned summaries (PELLIZZARI and DALLA MONTÀ, 1997; ANDREOTTI *et al.*, 2001; SCALERA, 2001), and on single, specific works.

As for terrestrial fauna, considering nematodes, molluscs (gastropods), arthropods and vertebrates, it is possible to provide a rough, low-side estimate of at least 450 species, incidentally or intentionally introduced in our country, which for the major part are members of the class Insecta. Some of them can be referred to as species of ancient introduction, frequently anthropophilic and thus cosmopolitan by now, e.g. rodents commensal of man, or insects infesting food consumables. All in all, they only add up to a small constituent part, albeit interesting in view of practical applications. Instead, the number of more recently introduced species is by far greater. Among phytophagous insects of agricultural and forest interest, for example, 115 species were introduced through trade

between 1945 and 1995; approximately 76% of these are represented by stenorrhynchous Homoptera (Figure 3.23). Almost 80% are acclimatized. Many species are connected to ornamental plants and a few have begun their expansion over Europe from Italian based breeding grounds (*Corythuca ciliata*, *Paractopa robinella*, *Metcalfa pruinosa*). Between 1945 and 1964 the introduced species were 13, on a 0.6 per year ratio. From 1965 to 1974 the ratio grows to 1.8 and in the 1975-95 period it jumps up to 4.2 species per year. The upward tendency is certainly not going to slow down, suffice it to say that over the last three years at least some twenty cases concerning new insect introductions have been published. The major part of the passively settled in phytophagous insects over the 1945-95 period is of palearctic and nearctic origin (17% W-palearctic, 10% E-palearctic, 27% nearctic), 16% neotropical, 14% afrotropical, 8% austroasiatic and 7% oriental.

Many cases of acclimatization are also known among insects employed in biological control, some of which are even specifically bred. Species introductions that are apt to spreading pathogens to the local fauna or to man, or are liable to constitute epidemic reservoirs for otherwise occasional pathogens, are likewise worrisome for their sanitary impact.

The reported problems and examples are mainly concerned with urban and agricultural ecosystems; however, numerous episodes have been documented in natural environments as well. Among others, the South East European ground beetle *Carabus montivagus* (Coleoptera: Carabidae), whose presence in the Central Alps is probably due to the military manoeuvres that took place during World

² With contributions by Gilberto Gandolfi (fresh water fish), Marco Oliverio (marine shellfish), Simona Bussotti, Paolo Guidetti and Marino Vacchi (marine fish).

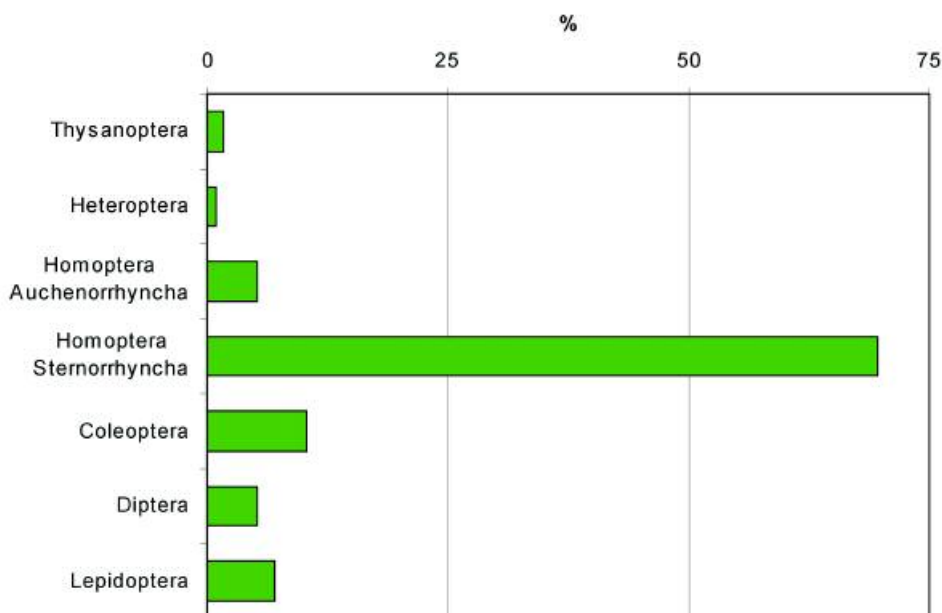


Fig. 3.23 - Division into orders of insects of agriculture and forest importance introduced in Italy from 1945 to 1995 (PELLIZZARI e DALLA MONTÀ, 1997).

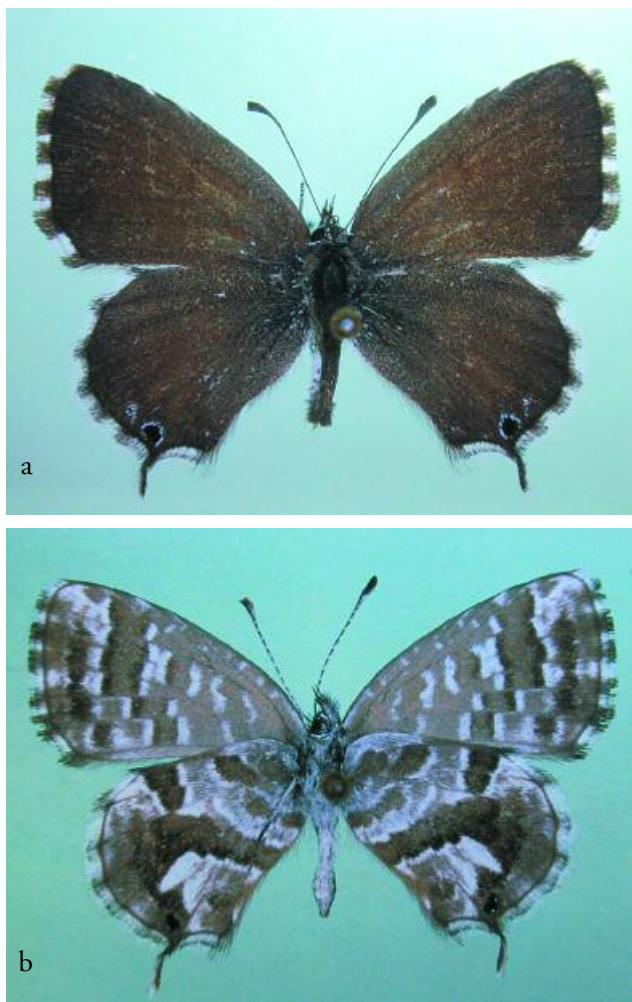


Fig. 3.24 - *Cacyreus marshalli*, a South African lepidopter of the family Lycaenidae, whose caterpillar develops on plants of the genera *Geranium* and *Pelargonium*, introduced in Italy at the end of the '90s (Photo by A. Zilli) (a: front; b: rear).

War I. Since 1965, the West European Pulmonate gastropod *Arion lusitanicus* is present in N Italy, and keeps on expanding. The mud-daubing wasp *Sceliphron curvatum* (Hymenoptera: Sphecidae), of Indian origin, arrived in 1995. Among acclimatized Macrolepidoptera, the Saturniidae *Antheraea yamamai* and *Samia cynthia* are classical examples that deserve to be mentioned, both of Asian origin and deliberately introduced in the second half of the 19th century, as well as the Geranium Bronze *Cacyreus marshalli* (a South African Lycaenidae) (Figure 3.24), which incidentally arrived at the end of the 20th century. A few species have been subjected to transfaunations, especially from the continent to Sardinia, as is the case of the Meloid beetle *Mylabris variabilis*, which was introduced in 1946 for grasshoppers' control and is now present in Corsica as

well. Introductions and transfaunations have also touched upon hypogeous environments, for example in the case of the cave species *Bathysciola derosasi* (Coleoptera: Cholevidae), acclimatized since the mid '50s in a cave in Lazio.

Both fish repopulation projects and the aquarium industry have contributed to the faunistic pollution of our water environments through intentional or occasional release of exotic species of molluscs. Thus, in recent years, in Italy as much as in other European countries, evidence has been provided for the diffusion of various non-indigenous species in natural environments – both gastropods (*Potamopyrgus antipodarum*, *Physa acuta*, *Helisoma duryi*, etc.) and bivalves (*Anodonta woodiana*, *Dreissena polymorpha*, etc.) – as well as for the transfaunation of a few native species (*Viviparus ater*, *Emmericia patula*, etc.) from one geographical district to the other.

Without doubt, the number of non native terrestrial vertebrates is low compared to the invertebrates (36 species), however their impact on local cenoses is just as relevant (Figure 3.25). As for the phytophagous insects, the major part of the introduced terrestrial vertebrates is represented by palearctic and nearctic species (respectively 48% and 19%), followed by oriental species (14%), afrotropical (11%) and neotropical (8%). Among amphibians the only non-indigenous species is certainly nearctic *Rana catesbeiana*, introduced for food purposes during the '30s. In the North this species is perhaps in competition with *Pelobates fuscus*, an indigenous anuran particularly worthy of note.

The introduced reptiles are at least six; among them the most problematic species is *Trachemys scripta*, nearctic, introduced in the '80s. It became quite widespread as a 'pet' and has since then been frequently abandoned in natural environments and in rural areas; it is believed that it could compete with *Emys orbicularis*, the only indigenous Italian turtle, now on a steep decline due to the al-

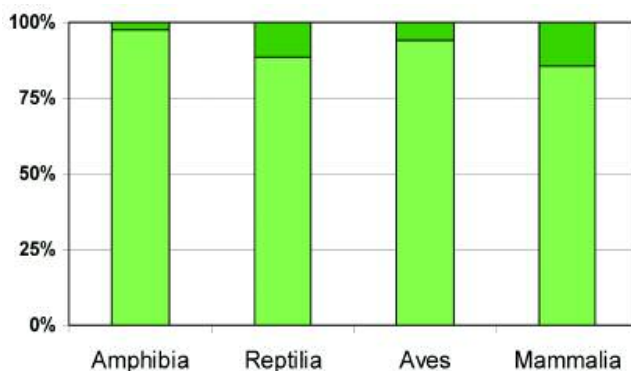


Fig. 3.25 - Percentage composition of non-indigenous component (in green, upper part) in terrestrial vertebrate classes in Italy.

		Decade and origin	Site	No. pairs (year 2000)
Bearded vulture	<i>Gypaetus barbatus</i>	1990 - reintroduction	P.N. Stelvio (Lombardia)	2?
Red-footed falcon	<i>Falco vespertinus</i>	1990 - immigration	Province of Parma	approx. 20
Northern bobwhite	<i>Colinus virginianus</i>	1980 - introduction	Lombardia, Piemonte	4,000-6,000
Lapwing	<i>Vanellus vanellus</i>	1950 - immigration	Province of Venezia	600-1,000
Ring-necked parakeet	<i>Psittacula krameri</i>	1970 - introduction	Genova (Liguria)	30-80
Monk parakeet	<i>Myiopsitta monachus</i>	1980 - introduction	Genova (Liguria)	30-70
Great spotted cuckoo	<i>Clamator glandarius</i>	1960 - immigration	Toscana, Sardegna	less than 10
Ural owl	<i>Strix uralensis</i>	1990 - immigration	Province of Udine	less than 10
Red-rumped swallow	<i>Hirundo daurica</i>	1960 - immigration	Gargano (Puglia)	15-25
Fieldfare	<i>Turdus pilaris</i>	1960 - immigration	Trentino-Alto Adige	5,000-10,000
Strawberry finch	<i>Amandava amandava</i>	1990 - introduction	Molise, Lazio, Veneto ecc.	100-500

Table 3.6 - New nesting bird species in Italy (non-aquatic species that were introduced or reintroduced or immigrated to Italy in the second half of the 20th century).

teration of water bodies. The Marginated Tortoise (*Testudo marginata*) is an endemism from Southern Greece, presenting populations also in Sardegna, which trace back to quite ancient introductions.

The number of species of exotic birds observed in Italy is very high (110), but only a dozen of them are naturalized or acclimatized (Table 3.6). Approximately half of these are Phasianidae, introduced for hunting purposes; the rest are mainly treated as recreational animals. Among the few species that could have a negative effect on the environment are the Mute Swan (*Cygnus olor*), whose feeding activities may alter aquatic phytocenoses, the Common Pheasant (*Phasianus colchicus*), a potential competitor of indigenous Galliformes, and the Psittaciformes *Myiopsitta monachus* and *Psittacula krameri*, which are natural reservoirs of psittacosis.

As far as mammals are concerned, the non native species are 16, for the most part rodents (Table 3.7). In some cases they are considered as ancient introductions, incidental (*Rattus rattus*, *R. norvegicus*, *Mus domesticus*, *Crocidura russula*), or for hunting purposes (*Lepus capensis*, *Oryctolagus*

cuniculus, *Dama dama*, *Ovis orientalis*) (Table 3.8). The presence of the Eastern Grey Squirrel (*Sciurus carolinensis*), a nearctic sciurid, a few couples of which have been released between 1948 and 1994 in NW Italy for amateur purposes, is particularly troubling, given the current propagation of the species especially in the provinces of Turin and Cuneo. From there it is highly probable it will expand towards the Alps, heavily threatening the survival of the Red Squirrel (*S. vulgaris*); moreover, the species causes wide damage to specialized farming cultures – the Hazel – and to forest management assets. Again for amateur purposes, Finlayson's squirrel (*Callosciurus finlaysonii*) was introduced in the '80s; of Indo-Chinese origin, it has locally spread at Acqui Terme (in the province of Alessandria); and the Siberian Chipmunk (*Tamias sibiricus*), E-paleartic, locally found at places in the North and Center. Both species are expanding; there is high risk that *C. finlaysonii* may damage forest cenoses and forest management activities; the chipmunk does not seem to interfere negatively. The Eastern Cottontail (*Sylvilagus floridanus*), an American lagomorph that could enter

SCIURIDS		
Eastern grey squirrel	<i>Sciurus carolinensis</i>	introduced from the United States in the second half of last century, the population of Piemonte is in a phase of rapid expansion
Unstriped ground squirrel	<i>Callosciurus finlaysonii</i>	asiatic species introduced in the 1980s near Acqui Terme
Siberian chipmunk	<i>Tamias sibiricus</i>	Asiatic species introduced into several areas of northern Italy, a population along the Belluno tract of the River Piave shows the greatest potential for expansion
MICROTIDS		
Common muskrat	<i>Ondatra zibethicus</i>	introduced into Europe in the first half of the 20th century, currently in expansion
MYOCASTORIDS		
Coypu	<i>Myocastor corpus</i>	naturalization came about in the second half of last century and has led to a rapid colonization of the hydrographical basins in most of Italy

Table 3.7 - Historical events leading to a few Rodent's introduction or spontaneous migration from other areas of European introduction.

SUIDS		
Wild boar	<i>Sus scrofa</i>	The genetic divergence between the subspecies of supposed origin from the Maremma (<i>S. s. majori</i>) and the European introduced one (<i>S. s. scrofa</i>) is scarce; the Sardinian population seems to have originated from domesticated forms
CERVIDS		
Red deer	<i>Cervus elaphus</i>	Autochthonous populations are only present in the Bosco della Mesola (Ferrara) (<i>C. e. elaphus</i>) and in Sardegna (<i>C. e. corsicanus</i>)
Gazelle	<i>Dama dama</i>	Species already introduced in the Neolithic period, though assumptions have been made indicating the presence of the species in Italy already at the end of the last glaciation
Roe deer	<i>Capreolus capreolus</i>	Autochthonous populations of the ssp. <i>C. c. italicus</i> have survived in isolated geographic habitats (Siena province, Castelporziano, Gargano and Orsomarso in Calabria)
BOVIDS		
European mouflon	<i>Ovis [orientalis] musimon</i>	Probably derived from sheep in the first stages of domestication, today the Sardinian mouflon is considered by several authors as a subspecies of <i>O. orientalis</i>
Wild goat	<i>Capra aegagrus</i>	Population deriving from an ancient introduction of semi-domesticated forms of the Asiatic wild goat, with further introductions of domestic goats

Table 3.8 - Historical events leading to a few Ungulates' introduction or spontaneous migration from other areas of European introduction.

into competition with indigenous lagomorphs, was released during the '60s for hunting purposes.

From the beginning of the 20th century through to the '20s, the Muskrat (*Ondatra zibethicus*), nearctic, and the Coypu (*Myocastor coypus*), neotropical, have been introduced to Europe as fur animals; typical of wet environments, these rodents are by now acclimatized, and expanding. In Italy, the Muskrat has recently established colonies in the North East, moving in from East Europe. The Coypu is present in the Pianura Padana, and along the Tyrrhenian and the Adriatic coasts; isolated populations have been reported in the North East, in the South, in Sicilia and Sardegna. The Coypu is especially responsible of severe alterations to riparian ecosystems, due to the disappearance of vegetation and of its associated fauna; damages to riverbanks stability and to the adjacent agricultural ecosystems have also been accounted for. The introduction in Europe of the American Mink (*Mustela vison*) as a fur animal dates back to the '50s. In Italy the species is restricted to the North East and to the Center, where the only stable nucleus is present. This mustelid can become a competitor of the Otter (*Lutra lutra*) and of the Polecat (*Mustela putorius*), it can threaten birds and micromammals, and damage animal husbandry and fish culture activities. The colonization of our country by the Raccoon-dog (*Nyctereutes procyonoides*) is probably going to take place over the near future; it is an E-palaearctic canid, introduced in East Europe as a fur animal over the '30s-'50s period, and has been actively expanding ever since.

Many fish species coming from different parts of the world are found nowadays to be introduced and acclimatized to a great extent in the total expanse of Italian internal waters. Among them, the Carp was certainly the

earliest one to be introduced. Introduction in medieval times has been supposed, but not proven yet, for a few others, such as the Burbot, the Danube Roach and the Perch. Subsequent introductions have followed suit since the middle of the 19th century up to the year 1970, involving species from Europe, such as the Pollan and the Zander, or from North America, such as the Rainbow trout, the Brook trout, the Black bullhead, the Pumpkinseed, the Largemouth Bass and the Mosquitofish.

At an overwhelming pace, over the past thirty years many other species of diverse origin have shown up in Italy: from East and Central Europe, the European Whitefish, the Wels catfish (*Silurus glanis*), the Ruffe (*Gymnocephalus cernuus*), the Weatherfish (*Misgurnus fossilis*), and a substantial group of Danubian and Illyrian cyprinids; from East Asia, the Stone moroko (*Pseudorasbora parva*), the Grass carp (*Ctenopharyngodon idellus*), the Silver carp (*Hypophthalmichthys molitrix*), and the Bighead carp (*H. nobilis*); from Africa the tilapia (*Tilapia* sp.); from North America the Channel catfish (*Ictalurus punctatus*), from South America the Pejerrey. A few other species have been reported in Italian waters, but no proof of their acclimatization has been supplied as yet. In the basins of the Padano-Venetian district the populations are under constant evolution: the appearance of newly introduced species is met with a reduction of the native species populations, and, on a few occasions, also of the previously widely spread non native species.

The older introductions were based on economic rationale, to foster professional fishing or breeding activities. As time went by other interests – mainly centered on recreational fishing – gradually took the lead, eventually to become preminent at present times.

The inappropriate light-mindedness with which species from other countries have been dumped into our waters has caused irreparable harm. In the great majority of cases the effect of alien species introduction is detrimental to the delicate equilibrium of the ecosystem. Furthermore, as our water ecosystems are generally under rather precarious conditions, the settlement of new species brings about damages that are likely to aggravate them to a greater extent, by triggering competition and increasing the probability of indigenous species extinction.

Approximately twenty species of molluscs living along our coasts are of allochthonous origin, representing 1.4% of Italian mollusc fauna. Three of them are indicated as lessepsian invasors (migrated from the Red Sea to the Mediterranean through the Suez Canal): the small mytilid *Brachidontes pharaonis* and the two nudibranchs *Bursatella leachi* and *Chromodoris quadricolor*. Three species of edible bivalves (*Tapes philippinarum*, *Crassostrea gigas* and *Saccostrea cucullata*) have incidentally escaped out of aquaculture facilities or restricted lagoon areas, inside which they were obviously not to be confined. In the case of the South East Asia clam (*Tapes philippinarum*), its ample introduction in the major part of the Italian lagoons, especially in the North Adriatic, where it has subsequently given rise to natural populations, was based on the high commercial value of the species. The invasiveness of the naturalized populations represents a problem for indigenous biodiversity, in particular to the local Chequered carpet shell (*Tapes decussatus*), which has almost been completely substituted by the alien species by now. The remaining non native species can be clearly qualified as being of incidental anthropic insertion. For example, in the case of the two mytilids *Musculista senhousia* and *Xenostrobus securis* grave alterations of the lagoon communities are to be expected, leading to serious damages inflicted upon biological diversity. In all mentioned cases the risks at all levels have not been ascertained for the indigenous communities, both in terms of having them compete over resources with native species, and of having them introduce pathogens – viruses, bacteria and mycoses – or parasites.

The causes of the introduction of new species of marine fish in the Mediterranean can be anthropic or natural – even though often the border between the two categories is unstable or even difficult to establish. The species that escape out of aquariums and aquaculture facilities fall in the first category. Eggs and larvae of fish species also happen to be carried around in the ballast water of ship tanks. In quite the same way, ships having particularly ‘dirty’ hulls – i.e. covered with copious incrustations – may

constitute a transport vector for samples of small juvenile and adult benthic fish forms. Similar mechanisms of passive introduction have for instance been hypothesized for the Indo-Pacific tropical Pomacentrid (*Abudefduf vaigiensis*; Figure 3.26) which has been reported in the Gulf of Naples, and, more recently, in the Ligurian Sea; or for the lessepsian Grouper *Epinephelus coioides*, spotted in the North Adriatic. The same may be said of the Mugilid *Mugil soini*, introduced in the Black Sea from the oriental Asiatic coasts (Russia, Cina and Corea) for aquaculture purposes and whose access to the Mediterranean is held to be a matter of time, in view of its remarkable adaptive abilities, typical of Mugilids. The latter case calls for attention to an aspect that will have to be taken into account when allochthonous fish species will be proposed for employment in the Mediterranean aquaculture industry.



Fig. 3.26 - Specimens of *Abudefduf vaigiensis* (Photo by R. Fenner).

Up till 1869 the introduction of non native species had essentially been the outcome of incursions from the Atlantic. It was only after the opening of the Suez Canal that invasion of species from the Indo-Pacific became possible. More than a dozen of them have come to be so abundant as to be economically exploited. Among the 90 allochthonous species of fish in the Mediterranean only a

residual number – 3 species – is of Atlantic-Boreal origin (displaying cold-water affinity), while the most part – 87 species – is of Indo-Pacific and Atlantic-Tropical origin (manifesting warm-water affinity).

The so-said ‘tropicalization’ of the Mediterranean, implying the appearance and expansion of thermophile species inside its Basin, could explain the fact that the greater part – more than 90% – of its non native species are thermophile. This hints at the fact that climatic changes, such as the water warming process, could provide the basis for the success of the allochthonous, warm-water related species of fish of the Mediterranean basin.

The discovery of non-indigenous species is becoming an ever more frequent event, even in Italian seas. The number of allochthonous species of fish that have been reported so far in the Italian seas is 17, 3 out of which are elasmobranchs. Among them a few can be found that can be labeled as occasional visitors of our waters – they are ‘tramp species’. For example, the three sharks mentioned later in Table 3.9 belong to this group of allochthonous species. For all three of them, in fact, only single findings are reported in our seas: *Sphyrna mokarran* (Figure 3.27) in the Gulf of Genoa, *Rhizoprionodon acutus* in the Gulf of Taranto and a recent report of *Galeocerdo cuvieri* (Figure 3.28) in the waters of the Strait of Messina. For the Osteichthyes a few examples can be mentioned: *Halosaurus owenii*, of Atlantic origin, first detected along the Algerian coasts, then along those of South Sardegna; *Beryx splendens*, omnipresent in almost all of the oceans, but with a single reliable report in the Mediterranean, along the shores of the Ligurian sea; and the Black marlin *Makaira indica*, probably introduced through Gibilterra and caught in the Ligurian sea. Other recently reported extra-Mediterranean species, instead, have

rapidly constituted reproducing and self-maintaining populations in our waters. The most relevant example is *Spherooides pachygaster* (Order Tetraodontiformes): it comes from the tropical Atlantic and was detected for the first time in the Mediterranean in 1981 in the Balearic Islands waters, then in 1985 in Sardegna and in the Canal of Sicilia. In the following years there have been numerous reports in the Mediterranean, first in the western basin, then in the Adriatic, Ionio, and all the rest of the eastern basin. Today, in the Canal of Sicilia, the species, of no economical value, is frequently captured by trawl boats. Incidentally, scientific references have been recovered, documenting its presence in the Mediterranean as far back as the 16th century. Thus it is possible to speculate about many Atlantic species having found, already in the past, favourable climatic and environmental conditions supporting their penetration in the Mediterranean, and the temporary or definitive maintenance of their enlarged range.

Marine alien species

[Anna Occhipinti]

It's only recently that marine ecologists' interest toward the allochthonous species invasion phenomenon has increased, in relation to a few emblematic cases that have been causing widespread ecological and economical damage: as an example, the invasions of the Mediterranean by tropical algae of the genus *Caulerpa*, and of the Black Sea by *Mnemiopsis leidyi* (Ctenophora) and by gastropod *Rapana venosa* may be mentioned.

The introduction of alien species is an age-old phenomenon, but it has speeded up consistently in recent years; a list of all non-indigenous marine animals report-



Fig. 3.27 - Specimen of *Sphyrna mokarran* (Photo by F. Boero).



Fig. 3.28 - Specimen of *Galeocerdo cuvieri* (Photo by J. Stafford).

CNIDARIA	
<i>Clytia hummelincki</i> (Leloup, 1935)	<i>Scyllarus caparti</i> * Holthuis, 1952
<i>Diadumene cincta</i> Stephenson, 1925	<i>Thalamita gloriensis</i> Crosnier, 1962
<i>Garveia franciscana</i> (Torrey, 1902)	MOLLUSCA, BIVALVIA
ANNELIDA	<i>Anadara inaequalis</i> (Bruguière, 1789)
<i>Amphicorina eimeri</i> (Lagerhans, 1880)	<i>Anadara demiri</i> (Piani, 1981)
<i>Branchiomma luctuosum</i> (Grube, 1869)	<i>Brachidontes pharaonis</i> (Fisher, 1870)
<i>Desdemona ornata</i> Banse, 1957	<i>Crassostrea gigas</i> (Thunberg, 1793)
<i>Dispio uncinata</i> Hartman, 1951	<i>Eastonia rugosa</i> * (Helbling, 1779)
<i>Isolda pulchella</i> Muller, 1858	<i>Musculista senhousia</i> (Benson in Cantor, 1842)
<i>Lumbrineris inflata</i> Moore, 1911	<i>Mya arenaria</i> Linnaeus, 1758
<i>Lysidice collaris</i> Grube, 1870	<i>Perna picta</i> (Born, 1778)
<i>Mediomastus capensis</i> Day, 1961	<i>Pinctada radiata</i> (Leach, 1814)
<i>Metasychis gotoi</i> (Izuka, 1902)	<i>Saccostrea cucullata</i> (Born, 1778)
<i>Monticellina dorsobranchialis</i> (Kirkegaard, 1959)	<i>Tapes philippinarum</i> (Adams et Reeve, 1850)
(= <i>Tharyx heterochaeta</i> Laubier, 1961)	<i>Xenostrobus securis</i> (Lamarck, 1819)
<i>Notomastus aberrans</i> Day, 1963	MOLLUSCA, GASTROPODA
<i>Ophryotrocha japonica</i> nomen nudum	<i>Aeolidiella indica</i> * (Bergh, 1888)
<i>Pileolaria berkeleyana</i> (Rioja, 1942)	<i>Bursatella leachii</i> De Blainville, 1817
<i>Protodorvillea egena</i> (Ehlers, 1913)	<i>Cerithium scabridum</i> Philippi, 1848
<i>Pseudofabriciella filamentosa</i> (Day, 1963)	<i>Chromodoris quadricolor</i> (Rueppell et Leuckart, 1828)
<i>Questa caudicirra</i> Hartman, 1966	<i>Crepidula fornicata</i> (Linnaeus, 1758)
<i>Rhodine gracilior</i> Tauber, 1879 (= <i>Rhodine loveni</i>)	<i>Cuthona perca</i> * (Marcus, 1958)
<i>Rullierinereis anoculata</i> Cantone, 1982	<i>Doris bertheloti</i> * (d'Orbigny, 1839)
<i>Spirorbis marioni</i> Caullery et Mesnil, 1897	<i>Haminoea callidegenita</i> Gibson et Chia, 1989
<i>Streblosoma hesslei</i> (Day, 1955)	<i>Melibe fimbriata</i> Alder e Hancock, 1864
BRYOZOA	<i>Odostomia</i> (<i>Megastomia</i>) cfr. <i>sicula</i> * Philippi, 1851
<i>Arachnoidea protecta</i> (Harmer, 1915)	<i>Polycera hedgepethi</i> Marcus, 1964
<i>Celleporella carolinensis</i> Ryland, 1979	<i>Polycerella emertoni</i> Verrill, 1881
<i>Electra tenella</i> (Hinks, 1880)	<i>Rapana venosa</i> (Valenciennes, 1846)
<i>Tricellaria inopinata</i> (d'Hondt et Occhipinti Ambrogi, 1985)	<i>Rissoina spirata</i> * (Sowerby, 1820)
PYCNOGONIDA	<i>Sabia conica</i> (= <i>Hipponyx conicus</i>)* (Schumacher, 1817)
<i>Ammothea hilgendorfi</i> (Böhm, 1879)	<i>Sclerodoris</i> cfr. <i>tuberculata</i> * Eliot, 1904
<i>Anoplodactylus californicus</i> (Hall, 1912)	TUNICATA
CRUSTACEA, COPEPODA	<i>Botrylloides violaceus</i> Oka, 1927
<i>Acartia grani</i> Sars, 1904	<i>Microcosmus exasperatus</i> Heller, 1978
<i>Acartia tonsa</i> Dana, 1849	PISCES
<i>Pteriacartia josephinae</i> Crisafi, 1974	<i>Abudefduf vaigiensis</i> (Quoy et Gaimard, 1825)
CRUSTACEA, PERACARIDA	<i>Berix splendens</i> Lowe, 1834
<i>Paracerceis sculpta</i> (Holmes, 1904)	<i>Chaunax suttkusi</i> Caruso, 1889
<i>Elasmopus pecteniscrus</i> (Bate, 1842)	<i>Diodon hystrix</i> (Linnaeus, 1758)
<i>Caprella scaura</i> Templeton, 1836	<i>Epinephelus coioides</i> * (Hamilton, 1822)
CRUSTACEA, DECAPODA	<i>Galeocerdo cuvieri</i> (Peron et Le Sueur, 1822)
<i>Callinectes danae</i> * Smith, 1869	<i>Makaira indica</i> (Cuvier, 1832)
<i>Callinectes sapidus</i> Rathbun, 1896	<i>Pinguipes brasilianus</i> Cuvier et Valenciennes, 1829
<i>Calappa pelii</i> Herklots, 1851	<i>Pisodonophis semicinctus</i> (Richardson, 1848)
<i>Dromia</i> (= <i>Sternodromia</i>) <i>spinirostris</i> * (Miers, 1881)	<i>Pomadourys stridens</i> (Forsskal, 1775)
<i>Dyspanopeus sayi</i> (Smith, 1869)	<i>Pristis pectinata</i> Latham, 1794
<i>Herbstia nitida</i> Manning et Holthuis, 1981	<i>Rhizoprionodon acutus</i> (Rüppell, 1837)
<i>Heteropanope laevis</i> * (Dana, 1852)	<i>Seriola fasciata</i> (Bloch, 1793)
<i>Marsupenaeus japonicus</i> (Bate, 1888)	<i>Seriola carpenteri</i> Mather, 1971
<i>Menaethius monoceros</i> * (Latreille, 1825)	<i>Sphoeroides pachygaster</i> (Muller et Troschel, 1848)
<i>Percnon gibbesi</i> (H Milne Edwards, 1853)	<i>Sphyrna mokarran</i> (Rüppell, 1837)
<i>Portunus pelagicus</i> (Linnaeus, 1758)	<i>Stephanolepis</i> cfr. <i>diaspros</i> Fraser-Brunner, 1940
<i>Rhithropanopeus harrisi</i> (Gould, 1841)	<i>Synagrops japonicus</i> (Döderlein, 1884)

Table 3.9 - Updated list (October 2002) of allochthonous marine invertebrates and fishes reported in Italian waters (* = single sightings).

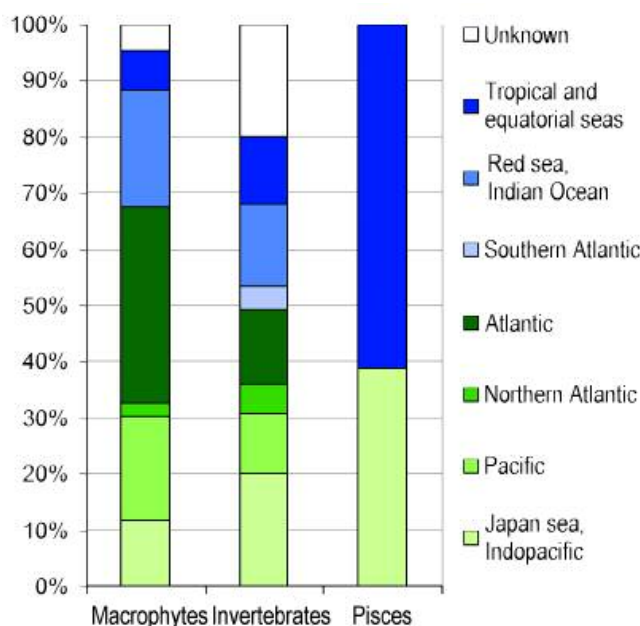


Fig. 3.29 - Original ranges of the allochthonous species reported in Italian seas.

ed by October 2002 in Italian waters contains 79 invertebrates and 18 fish (Table 3.9).

The invertebrates introduced in Italian waters belong to the annelids (20 species), crustaceans (20), molluscs (28) and to other groups (11). For some of the reported species it is the case of single observations that need to be verified and confirmed. The list does not include species that were introduced prior to 1950, such as for example *Ficopomatus enigmaticus*, *Hydroides dianthus*, *H. elegans*, *Balanus eburneus*, *B. improvisus*.

The North Adriatic represents an area with a high incidence of introductions: 17 species have been exclusively reported from this sea, and quite surprisingly 9 belong solely to the Venice lagoon (the hydrozoan *Garveia franciscana*, the bryozoan *Celleporella carolinensis*, the pycnogonid *Ammothoea hilgendorfi*, the peracarid crustaceans *Paracerceis sculpta*, *Elasmopus pecteniscus*, *Caprella scaura* and the decapod *Dyspanopeus sayi*, the nudibranch *Doris bertheloti* and the colonial ascidian *Botrylloides violaceus*).

Of the invertebrate species introduced in the Italian seas, approximately 25% is native to the Atlantic ocean, 18% originates in the Indo-Pacific and Japan seas, 18% is from the Red Sea and the Indian ocean, 11% from tropical and equatorial seas and finally 14% originates in the Pacific ocean. It is not possible to establish the origin of 14% of the allochthonous invertebrates (Figure 3.29).

As far as the methods of introduction are concerned, 29% of the species are thought to have been transported

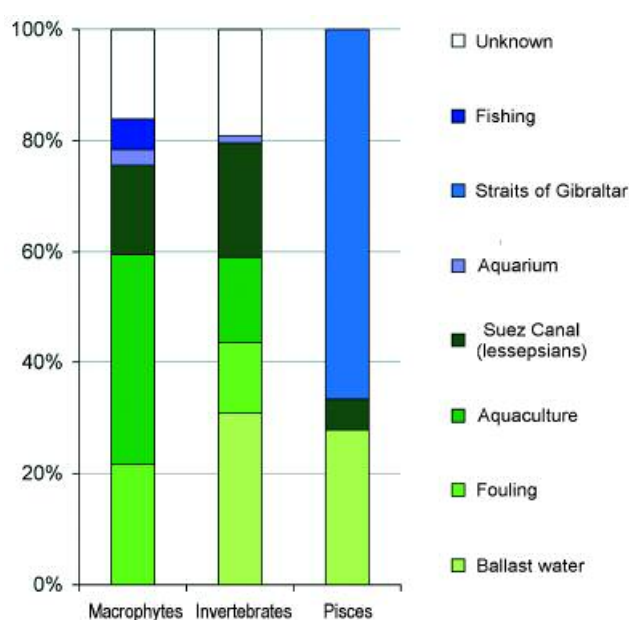


Fig. 3.30 - Likely methods of introduction of allochthonous species reported in Italian seas.

in the ballast water of ship tanks, and a good percentage (19%) are thought to have reached the Italian littoral zone on their own, by way of a slow migration through the Suez Canal (lessepsian species). Aquaculture (14% of introductions), transport on ships's hulls (*fouling*, 16%) and accidental introductions as consequence of aquarium hobby practices (1% of introductions) seem to play a secondary role with respect to ballast water in allochthonous invertebrates transport to our country (Figure 3.30).

A few species intentionally introduced for economic purposes since quite some time have become well acclimatized to the new environment. The oyster *Crassostrea gigas* and the clam *Tapes philippinarum* both support a thriving fishing activity in North Adriatic waters. The Asian gastropod *Rapana venosa* (Figure 3.31), a predator of bivalves, though abundant in a few areas of the Adriatic and on an expansion drive, does not seem to have caused any significant ecological and economic impact, at least for the time being. Recently, in addition to *R. venosa*, the rapid growth of the bivalve *Anadara demiri*, from the Indo-Pacific, has been calling for attention; it was observed in the year 2000, in large numbers, along the littoral zone of central Adriatic. The bryozoan *Tricellaria inopinata* (Figure 3.32) arrived at the beginning of the '80s in the Venice lagoon, probably as a side companion to aquaculture-destined products, and has undergone a rapid initial expansion; it has occupied all the lagoon's sectors, apart from the more salt-deprived areas, quickly becoming the most



Fig. 3.31 - Muricid *Rapana venosa* is present in North Adriatic waters since 1974. This species, originating in the seas of China and Japan, and introduced in the Black Sea (1947) and Adriatic (1973), is a voracious predator of bivalves of economic interest. Its recent involuntary introduction (probably owing to the ballast water of big commercial ships) in areas of particular worth for bivalves' raising and fishing (Chesapeake Bay, USA; Rio de la Plata, Uruguay; Baie de Quiberon, France) has stimulated diverse research initiatives on an international level. The vertical white bar indicates 1 cm (Photo by D. Savini, 2002).

abundant bryozoan of the lagoon. The subtropical crab *Percnon gibbesi*, observed for the first time close to the littoral zone of the island of Linosa, is rapidly growing towards other Sicilian districts, such as Pantelleria, Ustica, and along Catanese and Palermitan coasts.

The major part of the non-indigenous fish detected in Italian waters originates in tropical Atlantic seas (61%), while 39% is from the Indo-Pacific area. No species has been accounted for as being of cold water origin (boreal Atlantic). A single young individual of the Indo-Pacific grouper, *Epinephelus coioides*, was caught alive in the Gulf of Trieste – its taxonomical recognition being deferred until it reached the adult stage. Big size pelagic fish could have reached the Italian coasts through the Strait of Gibraltar (66%), and to a lesser extent through the Suez Canal (6%), while smaller sized fish could have been transported by ships (28%). The data seem to point to an ever increasing flow of immigrants from the Atlantic (Strait of Gibraltar), primarily due to climatic change: the precipitation-evaporation ratio in the Mediterranean basin being deficient, this calls for prevailing currents coming in from Gibraltar; the global warming effect comes in addition, leading to water surface temperature increase, and this al-



Fig. 3.32 - Colony of allocthonous bryozoan *Tricellaria inopinata* on *Mytilus galloprovincialis*. *T. inopinata* is present in the North Adriatic (Venezia lagoon, 1982 and Grado lagoon, 1990). The bryozoan, originating in the North Pacific, was probably introduced in the Venetian lagoon together with products destined to aquaculture and was subsequently distributed along the Atlantic coasts, from Galicia to the English Channel and to the North Sea. The vertical white bar indicates 1 cm (Photo by D. Savini, 2003).

so favours the entrance of species with tropical affinity; finally, the increase in marine traffic plays a not so secondary role in the introduction of marine vertebrates.

Commercial navigation traffic and aquaculture practices are experiencing exponential growth, and it is quite probable that the number of introductions is also going to increase over a relatively brief time span. A fundamental aspect to be taken into account in striving to keep the phenomenon under control is based on the immediate recognition of the newly introduced species; unfortunately, the required highly specialistic taxonomic skills are seldom given solid ground in today's scientific scene.

FLORA

[Laura Celesti Grapow]

In Italy an up to date account of exotic flora distribution and of the impact of invasions at national scale is not available, but already at the beginning of the 20th century numerous species list have been published, census lists at regional or local level, and studies on the appearance and diffusion of single *taxa* (cf. e.g. BÉGUINOT and MAZZA, 1916; VIEGI *et al.*, 1974, 1990; GENTILE, 1991). More recent comprehensive estimates, obtained from the Italian vascular flora database (see section *Vascular Plants*), attest the presence of 751 allochthonous species, representing 11% of Italian flora. These are much lower values than those expressed by other countries, for example of central Europe (CELESTI GRAPOW and BLASI, 1998): in the Czech Republic exotic plant species constitute 33% (PYŠEK, 2002), in Germany 22% (KOWARIK, 2002), in Austria 26% (ESSL and RABITSCH, 2003). Again, on our territory relatively few species succeed in effectively penetrating natural cenoses and in threatening indigenous populations, especially if compared to the situation we are faced with in the New World, particularly in Australia, New Zealand, and the Ocean Islands (e.g. Hawaii). The high biological diversity of the Mediterranean Basin, the constant introduction of new species and the flora's long adaptation to the impact of man have moulded numerous relatively invasion-resistant plant communities (cf. e.g. DI CASTRI, 1990; NAVEH and VERNET, 1991), and the introduced species remain for the most part confined to anthropic habitats and cultures. All the same, species that are causing problems to natural cenoses do exist, just as fast growing *taxa* and particularly painful cases, so in Italy by all means invasions constitute a threat to the conservation of biodiversity.

Following recent terminology, allochthonous (exotic) species are defined as those that have migrated out of their original range since Neolithic or post-Neolithic times, through deliberate or accidental intervention by man (RICHARDSON *et al.*, 2000). Exotic plants are thus defined on the basis of three criteria: immigration methods, degree of naturalization and historic period of introduction. On the basis of the first, the species introduced intentionally by man, for example for food or ornamental purposes, and escaped from culture facilities are to be distinguished from the adventitious, incidentally occurring ones. The latter, mainly herbaceous ones, are among the most widespread pest plants, detrimental to cultures and quickly spreading over ruderal areas. Ama-

ranthaceae, for example, primarily of American origin, rapidly infest cultivated and subsequently abandoned land, on account of their quick vegetative growth and of the production of an enormous number of wind dispersed seeds. A single plant of *Amaranthus retroflexus* can produce up to 120,000 seeds during its short life cycle. Another annual herbaceous plant that is liable of producing very high numbers of seeds is *Conyza canadensis* (Asteraceae), originating in North America. It can shoot up to 3 metres high and invade fields, vineyards and vegetable gardens, as well as irrigation ditches and abandoned land. This species' high resistance constitutes an ecological problem as its control may have to rely heavily on the use of herbicides. Soursob (*Oxalis pes-caprae*, Oxalidaceae), introduced from South Africa to the Mediterranean basin in 1796, infests olive-groves, fruit gardens, and gardens of South Italy, through dispersal of the numerous bulbils produced by the underground rhizomes. Moreover the high concentration of oxalates in its leaves, which look much like clover leaves, can lead to pasture poisoning. Jimson Weed (*Datura stramonium*, Solanaceae), also known as Devil's Weed for its narcotic, hallucinogenic and sedative properties, is also very toxic and dangerous for grazing herbivores.

The degree of naturalization sets up a measure of the species' success over the new territory and an estimate of their 'invasiveness'. By its means, species can be distinguished as being *occasional*, reproducing over few generations without giving rise to stable populations, *naturalized*, capable of settling in the new geographic area independently of the original seed sources, and *invasive*, whose rapid and uncontrolled spreading is at the root of ecological and economic problems (PYŠEK, 1995). The latter are generally a very low percentage of the total introduced species. However, in a few cases, in the absence of the competitors, of the herbivores and of the parasites that hold their populations in check in their original range, some species can reproduce very rapidly and start competing directly with the indigenous species for the environmental resources: light at the epigeal level, water and nutrients at the hypogeal level. In fact, rather than directly interfering, invasive plants more often act indirectly, by altering ecosystems' equilibria, for example by modifying the nutrient cycles. It is the case of the Black locust (*Robinia pseudoacacia*, Fabaceae), the most widespread and well known invasive wood species of Italy. By means of the symbiosis with nitrogen-fixing bacteria located in its root nodules, which is typical of the Leguminosae, this species can alter the nitrogen cycle by soil

enrichment, to the detriment of native species that have adapted to poor soils. The Black locust originates in the North East of the United States, was introduced in Europe at the beginning of the 17th century and has been largely cultivated for various reasons: as an ornamental species, for the display, among other assets, of conspicuous, perfumed flowers; for its rapid growth, hard wood, and solid rhizome system which has led to its employment in the stabilization of road and railroad side escarpments. It quickly escaped from culture; in Italy it represents an example of a species which not only invades anthropogenic areas, but also expands to natural cenoses. It is a ruderal competitive species, the most successful strategy adopted by invasive species, as it joins together strong competitiveness – rapid growth, large development of root and vegetative systems – and pioneer species characteristics – capacity for new habitat colonization, efficient reproduction and dispersion. Particularly because of the latter characteristics, the periodic felling to which it has been subjected in order to limit its spread has on the contrary favoured its propagation. On the other hand, it has been ascertained that populations of Black locust, if not restored by cutting, are destined to lose their dominant trait and regress over time (BERTACCHI *et al.*, 2001).

Together with the Black locust, one of Italy's main invasive wood species is the Tree-of-Heaven (*Ailanthus altissima*), which belongs to the tropical family Simaroubaceae. It is a deciduous tree with compound leaves that has been measured at over 25 m. Native of central China, it was introduced in the entire northern hemisphere around the middle of the 18th century, and primarily set along town avenues, for its tolerance to the urban environment. It is quite a vigorous plant, in terms of both vegetative and seed propagation. It is dioecious – male and female flowers are born on separate individuals – and a single plant can produce up to a million of seeds per year, dispersed by wind and water. As a consequence of its ability to adapt to a wide range of environmental conditions and of its efficient dispersion methods, the Tree-of-Heaven has rapidly spread throughout the temperate warm areas of Europe, the United States and Australia, where it develops monospecific stands competing with native vegetation. In Italy it grows almost exclusively in ruderal and in high anthropogenic impact areas, and generally does not gain access to natural vegetation, but in urban sites it gets to be a problematic species, as its roots cause damage to buildings' foundations and to archaeological remains.

Prunus serotina too, is an expanding woody species. It is a forest plant, native of the eastern regions of North America, introduced in Europe in the 17th century for ornamental purposes. Initially grown only in parks and gardens, towards the end of the 19th century it came to be used in reforestation projects, so that it gradually began to become established in the wild. However, instead of growing into tall-stemmed trees good for logging, *P. serotina* began developing into low thickets and invading different types of forests, thereby modifying the ecological conditions of lower shrub and herbaceous layers and hampering native species rejuvenation by giving rise to extremely dense populations. In present days numerous European countries are involved in this species' expansion; the plant can germinate and grow in a vast range of environmental conditions and displays efficient methods of propagation, it rapidly grows to reproductive maturity and produces large numbers of fruits.

Among rapidly expanding invasive species, *Senecio inaequidens* deserves to be mentioned; it is an aster native of South Africa, which, as a consequence of the efficient dispersion by the wind of the pappus-provided seeds, is spreading all over Italy, mainly along the road sides.

As for the third criterion, namely the immigration period, the species of ancient introduction, known as archeophytes, are often considered to be an integral part of the local flora. The 6 m tall Giant reed (*Arundo donax*, Poaceae), the largest grass of the Mediterranean, serves as a good example. It is of Asian origin and was introduced so as to be employed in the erection of barriers and as a source of the bamboo-like culms. On account of the presence of the underground rhizomes, it constitutes dense populations on the banks of ditches or along roads and railroads, and is currently widespread in the tropical and subtropical areas of the whole world.

Plants that were introduced after 1492 are called neophytes. That date, charged with the discovery of America, represents the beginning of the European period of colonialism, which allowed many species to overcome the biogeographical barriers separating the Eurasiatic continent from the American, the Australian and the farthest lands of the African continents. In fact the worst damages to the biodiversity of the new territories, particularly in the islands, have been caused especially by the species carried over from the Old World by the European colonials (DI CASTRI, 1989), but to a lesser extent the opposite flow took place as well. It should not be overlooked that the allochthonous species import to Europe for the most part has been concerned with plants that were of

great importance to the development of human societies, as represented by the numerous food species of American origin, such as the potato (*Solanum tuberosum*) and the tomato (*Lycopersicon esculentum*). Only in few cases in the new territories have the non native plants taken on characteristics of invasiveness, particularly when landing in biogeographical regions similar to the ones they had left. This correspondence between the climates of the original and of the colonized areas is at the basis of the existence of two distinct groups of alien species in Italy, the more mesophile being solidly established in the phytoclimatic temperate region and the more thermophile in the Mediterranean.

The original entities from temperate regions of North America (e.g. *Ambrosia artemisiifolia*, *Solidago canadensis*, *S. gigantea*) and from Asia (e.g. *Reynoutria japonica*, *Impatiens glandulifera*, *I. parviflora*) prevail in temperate-continental Italy; they tend to be strongly invasive also in central and northern Europe. The presence of *Ambrosia artemisiifolia*, an aster native of North America, was reported in Italy for the first time in 1902 (PIGNATTI, 1982). It is under current intense expansion, widely spread in the urban areas and in the anthropogenic environments of central Europe. The problem elicited by this species consists in the marked allergenicity of its pollen granules, which can also arouse sensibilization phenomena toward other composite plants. *Reynoutria japonica* (Polygonaceae) is a perennial herbaceous plant exhibiting vigorous growth, native of Japan, Taiwan and North China. Outside of its original range it is an aggressive infesting pest, invading riparian and anthropogenic habitats and establishing impenetrable populations along water bodies, road and railroad sides. Introduced in Europe in the middle of the 18th century to be used for fodder, for ornamental purposes and for holding sandy slopes, it has spread in central and northern Europe, in the United States, in Canada, in New Zealand and in portions of Australia. In North Italy it is expanding, often present in West and North-West Pianura Padana and in the Prealpine valleys (FRATTINI, 1987). It is an excellent competitor, as its foliage rapidly gives rise to a dense canopy that blocks the germination of indigenous species in the layer below. It is moreover capable of pioneer habitat colonization. By virtue of its high ecological plasticity it can become adapted to a wide variety of environmental factors, and tolerate extreme pH values, highly salted soils as well as heavy metal-polluted soils. The role of seeds, hydrochorous and anemochorous, in this species dispersion is once again secondary, as the plant spreads primarily through under-

ground rhizomes. Few rhizome fragments in the soil are enough for its growth, and this accounts for its easy spreading out and for its difficult control as a pest. Heavy use of herbicides to keep it in check is an indirect cause of environmental damage, too.

Another Asiatic species in rapid expansion in North Italy is *Impatiens parviflora* (Balsaminaceae). At first distributed as a ruderal species, by the end of the 19th century it had already become one of the most common invasive species of Central European forests. The congeneric *I. glandulifera* also originates in Asia; introduced at the beginning of the 1800s, it is under constant expansion in the riparian habitats of North and West Europe. Its invasive potential relies upon the efficient hydrochorous seed dispersion and upon its capacity to compete with robust native perennials, in spite of it being an annual species.

In the Mediterranean region, on the other hand, thermophile elements of Neotropical origin (e.g. *Agave americana* – Figure 3.33, *Nicotiana glauca* – Figure 3.34, *Opuntia ficus-barbarica*) or from other regions with a Mediterranean climate (*Carpobrotus acinaciformis* – Figure 3.35,



Fig. 3.33 - American agave, Torre Astura - Lazio (Photo by L. Rosati).



Fig. 3.34 - *Nicotiana tabacum* (Photo by L. Rosati).



Fig. 3.35 - *Carpobrotus acinaciformis*, Torre Astura - Lazio (Photo by L. Rosati).

C. edulis, *Oxalis pes-caprae*) are found to be prevalent; they frequently constitute a problem in bioclimatically similar areas such as California or South West Australia. Such is the case with *Carpobrotus* (Aizoaceae), which are native of Cape region in South Africa; their invasion currently makes for one of the worse threats to indigenous cenoses and to coastal ecosystems of the Mediterranean Basin. *C. acinaciformis* and *C. edulis* were introduced in the Mediterranean and in California at the beginning of the 1800s as ornamental species and for dune and slope binding purposes. They reproduce both with seeds and vegetatively, by the stems sprouting new roots from nodes. They are tolerant of a great variety of humid and nutrient-content conditions, and propagate both over the dunes and along the rocky coasts. By means of their prostrate posture, they form dense monospecific beds, and compete directly with other species for the sun, the nutrients, the water and for space. Their rapid expansion can cause local extinctions and can mean danger for biological diversity in the presence of endemisms or of rare species, just as in the Balearic Islands for a few endemic species of the genus *Limonium*. By salt accumulation in their succulent leaves *Carpobrotus* alter soil pH and can diminish nutrient availability. Moreover, by shaping the buildup of organic material on the sandy dunes, they may support the establishment of other foreign species on an otherwise colonization-resistant substrate.

The Indian Fig (*Opuntia ficus-barbarica*) is a cactus crop originating in Mexico and introduced in Europe by Christopher Columbus in 1500. Cultivated for its edible

fruits and as a hedge species, this robust and thorny species invades ruderal and abandoned areas, pastures and scrublands. It is currently a problematic species in California, South Africa, Hawaii and in a few areas of South Europe, where it replaces natural vegetation and restricts access to certain sites, by giving rise to impenetrable barriers.

This brief synthesis on the invasive flora of Italy highlights that for the purpose of biodiversity conservation there exists a fundamental difference between the species that remain confined to anthropic habitats and those that invade natural cenoses. Generally the environments that are mostly involved with invasions are the ones more strongly influenced by man, such as cultivated lands, urban areas, industrial zones and transportation roadways (CELESTI GRAPOW *et al.*, 2004). The anthropogenic disturbance gives rise to empty ecological niches and sets up early succession stages, that are particularly apt to being colonized by new species. The invasion process inside the cities is furthermore enhanced by the greater dispersion chances. It is for these reasons that the exotic component constitutes a relevant percentage of the flora of inhabited areas, standing at approximately 40% in Central Europe and at 20% in Italy (CELESTI GRAPOW *et al.*, 2001; CELESTI GRAPOW and BLASI, 2002).

Among natural environments more prone to invasion a few prevail as being more susceptible, namely riparian, plain, coastal and water habitats. An example is provided by the invasion of the green alga of tropical origin *Caulerpa taxifolia* (Chlorophyta, Ulvophyceae), which constitutes a heavy threat to the biodiversity of the Mediter-

anean sea. *Caulerpa taxifolia* has been used since the mid-70s as a decorative saltwater aquarium species. The first spontaneous settlements were sighted in 1984 over a coast stretch close to Monaco. They occupied a mere one square meter wide patch, and apparently descended from individuals that had escaped from Monaco's Oceanographic Museum. Five years later the colony was more than a hectare wide, and by the end of 2001 the species' infestation spanned over 6 countries (Germany, France, Italy, Spain, Croatia and Tunisia), blanketing more than 130 square kilometers of the seafloor and 190 kilometers of the coastline. In Italy the first confirmed occurrence dates from the year 1992, but since that time the alga has rapidly spread and currently covers around 100 square kilometers. To the contrary of what happens in the Mediterranean, it never forms dense colonies in the original tropical waters. Vegetative reproduction is vigorous and dispersion is facilitated by long distance transport of thallus fragments by means of boat anchors and fishing nets; such fragments tend to sink again, giving birth to new colonies right there where they land. The efficient propagation is also a consequence of the toxin content that makes it less than desirable, and of its capacity to form closely packed settlements over an ample variety of substrates and depths. The introduction of *Caulerpa taxifolia* has posed substantial ecological threats, particularly to the meadows of endemic vascular plant *Posidonia oceanica*, as the alga reduces light penetration and alters the functions of such a fragile and important ecosystem. In addition, it endangers the diversity of numerous marine communities, including cenoses of algae and fish fauna.

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