Nymphalid *Boloria eunomia*

The high moisture content in the soil, a few centimetres (if not millimetres) in depth, is another element which favours populations of *Myrmica* and is also positive for some *Formica*.

Lastly, temperature excursions and strong daily fluctuations in the level of sunlight, due to lack of tree cover, favours colonisation by ants of a continental nature, to the detriment of those typical of meadows and woodlands. There are therefore few species of ants in bog habitats, partly also due to the limited food resources that they can offer.

On the time-scale of these insects, peat bogs are sufficiently stable environments , on the time-scale of these insects, to the point that, in bogs with minimum human impact, the same nests can be found after a period of ten years. This close bond between insect and environment suggests the possibility of using ant populations as an index of peat bog naturalness.

From the zoogeographical point of view, this group of insects also shows a prevalence for species with northern gravitation, including some that are extremely rare all over the Alps. Species which most often nest in peat bogs include *Myrmica laevinodis*, *M. ruginodis*, *M. lobicomis*, *Leptothorax muscorum*, *Formica lemani* and *F. truncorum*. Others may be added, originating from the surrounding meadow or forest habitats, like *Lasius niger*, *Dendrolasius fuliginosus*, *Camponotus herculeanus*, *C. ligniperda*, *Formica fusca* and *F. sanguinea*.

Lepidoptera. The Lepidoptera are also species-poor in Italian mountain peat bogs.

Few butterflies can be considered habitual frequenters of these environments. Those that do include the nymphalid *Boloria eunomia*, the caterpillar of which lives on *Polygonum bistorta* and which is found sporadically on very small sites in the central-eastern Alps.

Coenonympha tullia

Its congener *B. aquilonaris*, which frequents bogs with *Sphagnum magellanicum* in central Europe and feeds on *Vaccinium oxycoccus*, does not venture as far as Italy. Limited in the north-east of Italy to the area around Tarvisio, but more widespread north of the Alps, is the small satyrid *Coenonympha tullia*. It forms small colonies on

Rhyncospora and *Eriophorum*, on which the larvae live; it frequents bogs with *Sphagnum magellanicum* and communities of *Carex davalliana* and *C. lasiocarpa*.

Other species, some of which are more widespread in Italy, are less dependent on the peat bog habitat, such as nymphalids *Brenthis ino* and *Boloria napaea*, or pierid *Colias palaeno*, whose caterpillars live on *Vaccinium myrtillus* and *V. uliginosum*, and the lycaenid *Albulina optilete*, which flies at between 800 and 2100 m, and is associated with heaths of the genus *Myrtillus*.

Another lycaenid with very interesting biology is *Maculinea alcon*. Although more common at lower altitudes, it may also be found in mountain peat bogs. The female of this species scatters her small white eggs on the flower buds of some *Gentiana*, on which the caterpillars later feed. With the coming of autumn, the larvae allow themselves to be carried into the ant-hills of some species of *Myrmica* (*M. ruginodis*, *M. scabrinodis*), with which they begin a symbiotic relationship: they are apparently “accepted” by their hosts, but in fact eat their larvae, especially during the final stage of their larval existence following a winter resting period (diapause). Pupation always takes place in the ant-hill.

Brenthis ino

Peat bog plants are the home to some micro-Lepidoptera, such as the glyphipterigid *Glyphipteryx hawortana*, the larvae of which live on *Eriophorum*, as does the elachistid *Elachista morandinii*, a newly-described species recently found in a peat bog near Tolmezzo (north-east Italy). Instead, the gelechiid *Aristotelia ericinella* feeds on *Calluna*; other species of the same family prefer *Vaccinium* species (*Chionodes viduella*) or other dwarf deciduous shrubs (*Prolita sexpunctella*). *Vaccinium myrtillus* is also the plant that feeds the caterpillars of the geometrid *Jodis putata* (a mesophilous species found on, but not exclusive to, mountain peat bogs). Another moth of the same family, *Carsia sororiata*, lives on *Vaccinium oxycoccus*.

Lastly, the vast family of the noctuids includes some hygrophilous and peat-loving species. They live mainly on heaths of the genera *Vaccinium* and *Arctostaphylos*, as in the case of *Acronycta menyantidis*, *Lithomoia solidaginis*, *Anarta cordigera* and *Protolampra sobrina*. To these species can be added *Eurois occulta*, a large noctuid also living on *Vaccinium*, but not exclusive to peat bog habitats. Another large moth found in mountain peat bogs, but with caterpillars which feed on the leaves of birch and alder, is the notodontid *Furcula bicuspis*. Its caterpillar, similar to the other congener species, has two long posterior appendages and an attractive green livery, with brown markings on its back which make it practically invisible when it remains motionless on the plant. As already mentioned, insect species feeding on bryophytes are very rare. This is also true of the Lepidoptera: among the few exceptions is the small tortricid *Phiaris palustrana*.

Furcula bicuspis caterpillar

Diptera. Almost nothing is known of the Diptera in Italian peat bogs. However, some information may be gained from studies carried out in central European countries. In a study of the Hranièni slaù peat bog in the Czech Republic, 16 families of acalyptrate dipterans were found, for a total of 88 species. The most abundant families were the sphaerocerids, with 30 species, and the chloropids, with 15. Neither of the two species collected there, which are considered tyrphobiont, have been recorded for Italy, but at least two of the six species classified as peat-loving (the sphaerocerids *Pteremis fenestralis* and *Spelobia nana*) are also found in Italy.

Peat bogs and insects in Quaternary

Alessandro Minelli

The importance of peat bogs as historical “archives” has been described in another box (see pp. 18-19). These are not only archives of human pre-history but, more often, ones preserving evidence of the climatic changes in Italian regions in the later stages of the Quaternary.

Pollens are certainly the most abundant and best studied of the organic remains preserved in peat bogs, in Italy too, but there is no lack of both aquatic and terrestrial animal remains, usually consisting of parts of the exoskeleton of arthropods.

The most commonly found aquatic forms are ostracods, minute crustaceans of which the bivalve shell is preserved. Among terrestrial animals, the most abundant remains are generally those of beetles, represented mainly by wing-cases and fragments of thorax (most often the tough prothorax, the body segment immediately behind to the head). However, there are also traces of other groups, for example among the insects (hemipterans) or mites among the arachnids.

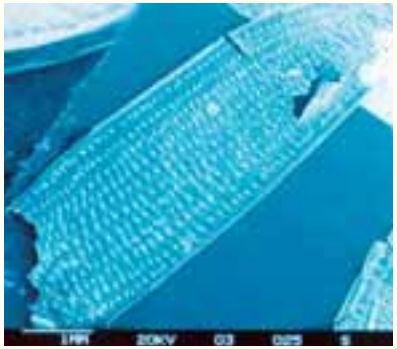
Study of arthropod remains preserved within peat deposits has originated a true scientific discipline, Quaternary entomology, which first developed in the United Kingdom, and then attracted scholars of other countries in both Europe and North America.

These remains can very often be traced to extant species, whose current distribution area does not, however, include the region where evidence was found in peat layers.

The alternating climatic events of the Quaternary probably moved the distribution area towards either warmer southern lands, or colder northern ones, depending on the specific ecological requirements of each species. When interpreting these data, it is generally assumed that insect ecology has not changed a great deal during the past millennia, so that a species may be taken as an indicator of the environmental conditions extant in the peat bog during the time it lived there.

In Italy, unlike the high level of research conducted on pollen preserved in peat bogs, knowledge of Quaternary entomology is practically non-existent.

It is therefore worth describing research carried out at the end of the 1980s on a site in north-eastern Italy, at Ca’ di David (province of Verona). This is a gravel quarry at Bernascone, at about 60 m above sea level, where the peat bog came to light under a layer of about 5.60 m of gravel. Radiocarbon dating attributed an age of 18,870±300 years to this 5-10 cm thick layer, rich in organic material. Pollen analysis revealed the presence of a scattered tree cover of conifers (mountain pine, Swiss pine), with some dwarf birch. In the peat bog areas *Eriophorum* or *Trichophorum* dominated, accompanied by aquatic or marsh plants such as *Potamogeton*, *Lemna*, *Myriophyllum*, *Sparganium* and *Typha*. There are also traces of sedges, willows and green alder (*Alnus viridis*).



Electron microscope photograph of fossil wing-case of *Plateumaris sericea*, found in a peat bog in Veneto and dated to around 19,000 years ago

The plentiful remains of insects are mainly beetles (21 species), flanked by two Hemiptera (an aquatic species of the Corixidae family, and a terrestrial one belonging to the Lygaeidae). Some species of beetles are definitely aquatic, like a small dytiscid of the genus *Hydroporus*, a predator, and an even smaller hydraenid of the genus *Limnebius*, represented by a group feeding on filamentous algae.

The metallic wing-cases of three Chrysomelidae (*Plateumaris sericea*, *Donacia clavipes*, *D. marginata*), phytophagous species living on marsh plants, are extremely well preserved. Nowadays, *P. sericea* feeds on the leaves of some species of sedge and yellow iris (*Iris pseudachorus*), *D. clavipes* on reeds (*Phragmites communis*) and bogbean (*Menyanthes trifoliata*) and *D. marginata* on *Sparganium erectum* and perhaps also some *Carex*.

Example of today’s *Plateumaris sericea* under scanning electron microscope: this leaf beetle still lives in peat bog habitats

Phalacrus substriatus, one of the phalacrids, a family of minute beetles with very shiny backs, was accustomed to eating the *Carex* inflorescences attacked by fungi of the “smut” group (Ustilaginales).

Instead, water-logged plant detritus was eaten by the two genera of hydrophilids found in the peat at Bernascone, *Chaetarthria seminulum* and *Coleostoma orbiculare*. The three staphylinid beetles collected were perhaps less dependent on the bog habitat, whereas the most interesting specimens are among the eight carabid species. These include *Phonias diligens* (described on p.78), and, more especially, *Amara alpina*, which today lives in the Arctic tundra regions of both Eurasia and North America; in Europe it is confined to mountain peat bogs in Scotland and Scandinavia. Significantly, six species of beetles found in the peat at Bernascone today inhabit mountain peat bogs in the Canton Ticino in Switzerland, an area with many glacial relicts.

This paleo-fauna data-set implies an environment fitting that indicated by radiocarbon dating, which sets this peat layer at the peak of the Würm glaciation. It has been estimated that average temperatures were then 8-9 °C lower than they are today, corresponding to a lowering of climatic horizons by approximately 1000 m.

It is to be hoped that this type of research can be carried out systematically, before the delicate, vulnerable remains of this Quaternary fauna are lost forever, or simply burnt with the peat which has preserved them up to now.

Vertebrates

AUGUSTO GENTILLI

Mountain peat bogs are environments where few species of vertebrates are found, although they may sometimes host great numbers of animals. One of the main limitations to high biodiversity is climate: long cold winters with ice and snow, and short summers. These conditions limit the survival of many animals, including many vertebrates. The acidic water and relative scarcity of oxygen both represent further limitations (e.g., for fish). The best represented classes are amphibians and reptiles, which find these habitats ideal for breeding and finding food. These vertebrates hibernate over winter and thus avoid its adversities. Fish are more or less absent from pools, although they sometimes live in streams connected with bogs. There are many small mammals, generally ubiquitous, which can also survive in bogs but only rarely have peat bogs as their habitat of choice. Birds only marginally visit these environments, frequenting rockier areas with shrub cover.

■ Amphibians

Amphibians are vertebrates whose lives are spent on both land and in water. The great majority of European and Italian species frequent aquatic environments during their breeding and larval stages, whereas adults move some distance away, depending on species and season. There are two orders of amphibians in Italy: Urodela (salamanders and newts) and Anura (frogs and toads).

Urodela keep their tails as adults, and are characterised by internal fecundation and reproduction in the form of spawn, or young born as either larvae or already metamorphosed. They feed on small invertebrates and are generally long-lived: newts may live for more than 15 years.

Anura are tail-less as adults, always have external fecundation (in the European species), lay spawn which hatch after some weeks into larvae (tadpoles) and which, after some months, metamorphose and acquire adult characteristics. They do not normally live very long (4-6 years), although some species (e.g., common toad) may live for more than 15 years. They feed on small invertebrates.

Field vole (*Microtus agrestis*), a typical vole of peat bogs and non-grazed meadows

These biological characteristics help us understand why these vertebrates adapt well to life in peat bogs. Available water throughout the year means that they can carry out their full life cycle, and abundant insects and other invertebrates offer a plentiful food supply. Some species also shelter from freezing winter temperatures by hibernating in the mud on the bottom of pools. Their respiration - through the skin - plays a very important metabolic role, allowing them to over-winter in a state of quiescence. Slowed winter metabolism, with reduced oxygen requirement, also helps survival.

Three Urodela are found in Italian peat bogs: Alpine salamander (*Salamandra atra*), Alpine newt (*Triturus alpestris*) and, although rarely, Italian crested newt (*Triturus carnifex*). In some bogs on the south-eastern Alps it is also possible to find common newt (*Triturus vulgaris vulgaris*), which lives together with both the Alpine and Italian crested newts in these habitats.

The Alpine salamander is an amphibian with a very interesting biological cycle. It mates on damp ground at the end of an elaborate courtship, after which the male ejects a spermatophore, which is picked up by the labia of the female's cloaca. After a two-year pregnancy, the female gives birth to two already metamorphosed offspring, which do not depend on water, not even in the first part of their life. The entire life of this species is thereafter spent in terrestrial environments. This may represent an adaptation to a cold mountain environment with short summers, because in this way the female can optimise the development of her offspring by allowing the young larvae to over-winter in her abdomen. Salamanders also inhabit spruce forests and mountain pastures to altitudes of over 2100 metres.

Alpine salamander (*Salamandra atra*)

In peat bog pools in the central-eastern Alps, it is easy to spot Alpine newt, a small urodele approximately 11-12 cm long. The larger Italian crested newt may sometimes be found at lower altitudes (e.g., in the large peat bog at Pian Gembro in the province of Brescia, 1400 m a.s.l.). This species, although not typically montane (it is difficult to find above 1400 m), lives in larger, deeper pools in peat bogs.

The most typical peat bog Anura is common frog (*Rana temporaria*), although other species (e.g., common toad or green frogs) sometimes also frequent

A pair of common toads (*Bufo bufo*)

Alpine newt

Augusto Gentilli

Alpine newt (*Triturus alpestris*) is a medium-sized amphibian, males being up to 11 cm long and females 12 cm. The males are recognisable, especially during the breeding season, by a vertebral crest extending the length of the back, low and straight, which continues to the tail. During the breeding season, the cloaca is also conspicuously swollen in males. The species differs from crested newt by being smaller, by the rectilinear crest and unmarked belly. In the Alpine subspecies (*T. a. alpestris*) both sexes have orange throat and belly, without markings, unlike the Apennine subspecies (*T. a. apuanus*). The dorsal parts are dark, particularly in males where they blend into a silver and light blue lateral stripe. The larvae, 7-8 mm long at hatching, reach 30-50 mm at metamorphosis. They have a yellowish or light brown back and unmarked belly. Cases of neoteny are frequent.

Triturus alpestris is a mainly central European species. There are three subspecies in Italy: *T. a. alpestris* in the Alps, becoming increasingly rare moving from east to west, *T. a. apuanus* in the Maritime Alps and Apennines as far as Monti della Laga, and *T. a. inexpectatus* in northern Calabria. Alpine newt is a typically mountain species in Italy and may reach 3000 m in the Alps; around 80% of breeding grounds in northern Italy are between 900 and 2400 m a.s.l. In some situations, the nominal subspecies is also found at low altitudes, below 200 m, while the Apennine one may also be found on low-lying plains.

Among Italian species, Alpine newt is the one most closely associated with water. Precise information is difficult to provide on the length of stay in these environments, as very different situations have been verified in areas close to one another. At low altitude, the animals enter the water very early in the season, from the beginning of February, and remain there until late November. In favourable situations, where water is present all year, Alpine newts may over-winter in the debris on the bottom. The adults sometimes remain active even under ice, continuing to feed regularly. They frequent water bodies of various types: small-medium pools, Alpine tarns, and small watercourses with slow-moving currents, but also man-made ponds, water-holes and tanks. In Italy, this species has been found in water with a hardness of between 10 and 15. Breeding grounds are generally sited in open areas, but it is also possible to find *T. alpestris* in woods. Population density varies between populations and, within populations, over the years, remaining at between 0.01 and 10 individuals/sq.m. Reproduction in high-altitude populations begins at the age of ten, and older animals may even be over twenty. In these populations, breeding follows a biennial cycle, i.e., not all adults breed every year. The biology of pre-adults, extremely elusive and almost exclusively terrestrial, is largely unknown. The sex ratio varies, although it is usually close to one: cases of ratios strongly in favour of females exist, e.g., 1:3.

The eggs, approximately 150 per female, are laid singly, attached to underwater or emerging straight vegetation and usually not on branched plants. The development of the eggs and larvae differs greatly in its timing according to climate. In some cases, larvae which do not manage to complete metamorphosis by the end of autumn pass the winter in water, completing their development the following spring. Cases of neoteny, i.e., reaching sexual maturity while still having larval characteristics (e.g., gills) have often been recorded.

The aquatic diet of newts is mainly small invertebrates, on the bottom or surface, whereas the terrestrial diet consists mostly of small arthropods found in leaf litter. This is therefore an opportunist diet, since the animals feed on the most abundant prey, with strong seasonal variations.

Young Alpine newt is habitually preyed upon by fish (normally salmonids), other amphibians (e.g., *T. carniflex*), reptiles (snakes of the genus *Natrix*) and birds, as well as some large aquatic invertebrates, including beetles, water bugs and dragonfly larvae. The eggs are the prey of insects (dytiscid beetles and other newts): predation is the major cause of death of eggs.

The main danger to newts is the introduction of salmonids, which may lead to the total extinction of a population within a short time.

Alpine newt (*Triturus alpestris*)

Italian crested newt (*Triturus camiflex*)

Common frog

Augusto Gentilli

Common frog (*Rana temporaria*) is a medium-large species (males may be up to 107 mm long and females 111 mm), with a grey, reddish-brown or yellowish-brown back, usually spotted, dappled or marbled. The underbelly is yellowish-white in males and from pale yellow to orange in females.
Males have a pair of internal vocal sacs at the sides of the throat, which is bluish or purplish during the breeding season. They also have more robust hind legs, wider webbing of the feet, and a large basal pad on the inside of the first digit of the front legs, covered by thick black horny spinules in the mating season. This pad is used to improve the male newt's grip on the female during mating.
The larva (tadpole), with a dark brown back, black belly with metallic spotting, and a round blunt tail, is approximately 45 mm long at metamorphosis.
The species is widespread throughout Europe, excluding the far south. In Italy it lives in the Alps and Apennines as far south as Tuscany and Emilia-Romagna, and there is also an isolated population on the Monti della Laga (in Latium, province of Rome).
In Italy, *R. temporanea* is a typical mountain and hill species, although it may also live in some areas on the plain. The minimum altitudes recorded are circa 20 m a.s.l. near Final Ligure (Savona), the highest on the Alps are around 2800 m.
Activity generally begins in spring, with variations depending on local temperature and rainfall. In some areas, a water temperature of 7 °C has been recorded when the eggs (spawn) begin to be laid, although it may later occur at even lower temperatures.
The influence of weather conditions on the ongoing activity is highly variable.
The males arrive at the breeding grounds earlier than the females and remain there until the end of the breeding season. Instead, females usually migrate immediately after spawing, although they sometimes remain where they are for a few days.
The males stay in the water for an average of 15 days (minimum 4, maximum 26).
They usually leave the breeding grounds when weather conditions are favourable, mainly during rainy nights, and these migrations are often along preferential routes which depend on the terrain.
The species has many different habitats, such as broad-leaved or conifer forests, pastures and peaty areas. Either natural or man-made ponds, small lakes, peat bogs, stream-side pools, animal watering-places or tanks are all used for breeding. These breeding sites must have little vegetation, warm water during summer, and no fish.
Spawn is mainly deposited close to the edges. Clutches are often laid one next to the other and intermingle, covering whole areas of ponds. In one population in Piedmont, the number of spawn per clutch was counted at between 580 and 3,410.
After the breeding season, the animals leave the water, usually moving when there is high humidity. In the post-breeding season they usually move between 2 and 10 metres a day.
The males, when possible, move along small watercourses and less on the ground.

Depending on the area, it is possible to find specimens active by day, or only at night during rain.
The relatively unspecialised diet is based on small invertebrates, mainly spiders, beetles, flies and ants, which are captured on the ground.
Hibernation is either in water or on land, and lasts longer in adults; individuals of different sex and age may be found in the same hibernating sites.
Spawn hatches after 3-4 weeks, and larval development lasts two or three months, although cases of hibernating tadpoles have been recorded. The development rate is greatly influenced by both weather and availability of phytoplankton. Tadpoles tend to gather close to the banks where the water is shallower, to favour heat absorption, and they form dark compact masses.
There seems to be no preferential association between closely related individuals.
The predators of these amphibians include many mammals and birds, as well as fish (mainly salmonids), snakes (*Natrix natrix*, *Vipera berus* and, more rarely, *Vipera aspis*) and aquatic invertebrates.

these environments. They belong to the group of red frogs, which use water only for breeding in early spring and pass the rest of the summer on land. Green frogs are much more aquatic and pass much of the year, usually including winter, in water.

In Europe, these frogs are still of uncertain classification and nomenclature because of their widespread and extraordinary hybridisation phenomena. They do not love high altitudes, but may occasionally be found in mountain peat bogs, e.g., Pian Gembro, mentioned above. Larger sunlit peat bog pools may be home to common toad (*Bufo bufo*), a species which adapts well to the mountain environment, even living above 2000 m. It is a poorly aquatic species which, after breeding, frequents woods and pastures in search of the small invertebrates on which it feeds, and usually over-winters on land. In the central-southern Alps, yellow-bellied toad (*Bombina variegata*) may also be spotted in wet environments, sometimes accompanied by green toad (*Bufo viridis*).

In the Dolomiti Bellunese National Park, there are large breeding populations of green toad at 1800 m above sea level.

Yellow-bellied toad (*Bombina variegata*)

■ Reptiles

Unlike amphibians, reptiles are strictly terrestrial throughout their life-cycle. They generally lay eggs with hard shells, affording protection to the developing embryo. The young which hatch from these eggs are identical to the adults. Fecundation is consequently internal. Moreover, the skin, covered by horny scales, protects them against dehydration, so that they can also live in very arid environments.

There are species which have subsequently gone back to the water - in some cases (e.g. turtle) living in the sea permanently, except when the females crawl up beaches in order to lay their eggs.

Only two species of reptile are generally to be found in mountain peat bogs: adder or European viper (*Viperus berus*) and green lizard (*Zootoca vivipara*). Both species have developed viviparity as an adaptation to the cold climates in which they live. The adder is the only poisonous snake regularly frequenting mountain peat bogs. The hazard it represents is commonly exaggerated; it is

Water snake (*Natrix n. natrix*), example of striped phenotype, typical of north-eastern Italy

Adder (*Vipera berus*) about to slough its skin, on the edge of a peat bog in the Dolomites

European viper

Augusto Gentilli

The adder or European viper is a generally small, poisonous, viviparous snake: males reach 55-60 cm, females are usually 5-10 cm longer. Their background colour is reddish-brown or grey; the markings are a sort of black central fret with dark patches along the side. Melanic (black) individuals are also locally common. The head is less distinctly triangular than that of other species of viper.
In Italy, European viper lives in the central-eastern Alps, usually above 1000 m, in many different environments (pastures, screes, peat bogs, woodland glades) up to at least 2500 m a.s.l..
Until the end of the 19th century, it could also be found in wetland areas of the central-eastern Po Valley, as far as the province of Pavia. It is a terrestrial reptile with the largest distribution world-wide, reaching the Arctic Circle, Siberia and North Korea.
Adders leave their winter refuge during April and May (depending on altitude) in order to regulate their body temperature; males generally precede females by a couple of weeks. During May-June, the males begin sexual activity, which consists of travelling in search of a partner, ritualised fights, and mating. The females give birth in late summer to 5-15 self-sufficient young, about 18 cm long. Because of the short season, females which have just given birth are unable to reconstitute the fat reserves necessary for breeding the following year. Parturition therefore takes place every two years, or even longer.
Adders mainly feed on small mammals, but also prey on birds' nests on the ground and on amphibians, which may form a large part of their diet in some areas. Green lizards are the main prey of the young.
Hibernation starts during the latter half of October, inside a hole in the ground, often at a depth of more than one metre.

Green lizard

Augusto Gentilli

Green lizard (*Zootoca vivipara*) is a small saurian which, in Italy, lives almost exclusively in the central-eastern Alps, with isolated relict populations in the western Alps and central-eastern Veneto plain. It has a wide distribution, which extends from Ireland in Europe to the island of Sakhalin in Asia; it is also found on the island of Hokkaido in Japan.
Southwards, it reaches northern Spain, the Veneto plain and the Rodopi mountains in Bulgaria; the northern limit is marked by the 70° N parallel.
The species is characterised by a short head and legs and brown back with darker vertebral stripe: this stripe is usually continuous in females. Both sexes often also have dark lateral bands and small black markings.
On the Alps, green lizard lives in various environments, such as pastures, stony ground, low scrub, and the banks of streams and peat bogs, from valley bottoms up to 3000 m a.s.l. On the plain, relict populations are limited to marshes and spring wetlands.
The start of the year's activity generally coincides with the first days of May, finishing towards the end of September. This period may be longer where conditions are favourable, e.g., on plains. Green lizard is a mainly diurnal species, although at low altitudes during summer activity is mainly nocturnal. Mating is between April and May, or in June at high altitudes. Females are sexually receptive from the age of three years, and give birth towards the end of August, when 3-12 autonomous, completely black young are born.
A new subspecies (*Zootoca vivipara carniolica*) has recently been described, living on the Veneto plain, in Slovenia, Carinthia and north-west Croatia. It lays eggs (5 or 6) with perfectly calcified shells. Some Pyrenean populations, while being genetically closer to *Z. v. vivipara* than *Z. v. carniolica*, also have oviparous reproduction. There are two other known subspecies: *Z. v. sachalinensis*, on east Asian coasts, and *Z. v. pannonica*, in south-eastern areas of Central Europe.
Hibernation is briefer than in other species but is never interrupted, not even in warm weather. Its duration is related to both altitude and latitude: in colder climates, the active season is obviously shorter. During hibernation, ice crystals may form inside the body and quite literally freeze part of the lizard or even its whole body. At the end of winter, even these individuals resume normal activity.
The diet of green lizard includes insects, gastropods, spiders, millipedes and other small invertebrates. The most common prey, although there may be great seasonal differences, are Heteroptera and spiders as well as woodlice and caterpillars. If it feels threatened green lizard often hides under water, where it can remain for many minutes.

in fact a shy and not very aggressive snake, and its bite can usually be treated.
The green lizard is a small saurian limited in Italy to the Alps (to over 2500 m a.s.l.) and some relict sites on the Veneto plain.
In peat bogs, these two species generally frequent drier areas, although both are extremely good swimmers and may also be found in flooded parts. Green lizard, in fact, often escapes danger by diving into the water and hiding in the mud on the bottom where it may remain concealed for many minutes.
In lower mountain bogs (up to 1500-1600 m a.s.l.) water-snake (*Natrix natrix*) may also be found. They are more common in the wetlands of low-lying plains and hills, preying mainly on amphibians and fish.

■ Birds

Birds are vertebrates which have conquered the air and therefore enjoy, with some rare exceptions, maximum freedom of movement. The down and feathers covering their bodies give optimal thermal insulation, which allows birds to live in extremely cold environments.
On mountains, birds are generally well-represented both in terms of number of

Black grouse (*Tetrao tetrix*) on communal display ground on edges of an Alpine peat bog (Julian Alps)

A peat bog surrounded by mlown meadows (Carnian Alps, Friuli Venezia Giulia)

species and numbers of individuals. Despite this, the peat bog environment is little used, and even then almost exclusively marginal areas tempered by the surrounding environment.

The communal display grounds (*leks*) of black grouse (*Tetrao tetrix*) are often situated on the edges of Alpine peat bogs, which ring with their noisy ritualised mating duels between April and May.

Stony, rocky and scrub areas, often found at the edges of peat bogs, are the elected habitat of many species which sometimes wander into the bogs themselves. Amongst these occasional visitors are fieldfare (*Oenanthe oenanthe*), black redstart (*Phoenicurus ochruros*) and hedge sparrow (*Prunella modularis*). A species much more closely associated with peat bogs is water pipit (*Anthus spinoletta*), a small bird (17 cm) with pale pink underparts streaked only on the sides of the breast, white outer tail feathers, long beak and dark legs. It is ground-nesting, laying 4-5 white eggs with dense grey and brown markings. Incubation, always done by the female, lasts 14 days. Water pipit over-winters on the plains, along rivers and lakes.

Mountain peat bogs are also resting places for some species of birds which pause during migration, so, in late summer, very varied sightings are possible.

Wheatear (*Oenanthe oenanthe*)

Yellow-necked mouse (*Apodemus flavicollis*)

■ Mammals

Mammals, thanks to the fur covering their bodies, can also survive in cold inhospitable climates. Many species also hibernate.

Mountain peat bogs are not environments much used by large mammals, although they sometimes serve as watering-holes for red and roe deer.

In some high-altitude areas of the Alps, bogs are the only available source of water, and so are regularly visited by chamois (*Rupicapra rupicapra*), quite large herds of which seek them out in some parts of the Dolomites (Livinallongo, Col di Lana).

Small mammals are much more representative of mountain peat bogs: insectivores (shrews), rodents (mice and voles) and bats. The latter are not very widespread at high altitudes, but some species do visit these habitats.

Pygmy shrew (*Sorex minutus*)

Alpine shrew (*Sorex alpinus*)

Many species of terrestrial (*Sorex*) and water shrews (*Neomys*) (*Sorex alpinus*, *S. araneus*, *S. minutus*, *Neomys fodiens*, *N. anomalus*) are quite common.

Among terrestrial shrews, pygmy shrew (Sorex minutus) is the one best adapted to waterlogged soils, where it hunts small invertebrates (spiders, beetles, isopods, bugs) on the soil surface; in the search for prey a fundamental role is played by its sense of smell.

Instead, the prey of aquatic species (genera *Neomys*) are located mostly by the long, extremely sensitive whiskers. Water shrews are able to produce a neurotoxic enzyme which, injected with the saliva, immobilises larger prey like spiders.

Water shrew (*Neomys fodiens*) and Miller's water shrew (*N. anomalus*) are distinguishable from terrestrial species by their larger size and, especially, their black upper parts contrasting with silvery-white beneath. Miller's water shrew is

Water shrew (*Neomys fodiens*)

generally to be found at lower altitudes than its congener, rarely living higher than 1500 m. Recent eco-ethological investigations have clarified how these two aquatic shrews divide resources where they co-habit. *Neomys fodiens* swims very well and mainly seeks out benthic invertebrates, which are to be found up to half a metre deep. *Neomys anomalus* is a very poor swimmer and collects small animals on the ground at the edges of pools and peat bogs. Among bats, which form a relatively thermophilous group (and are therefore to be found more often in valleys), a typical species in Alpine peat bogs is Nilsson's bat (*Amblyotus nilssonii*). This species, which may reach an altitude of 2300 m, begins hunting at dusk or sometimes even late at night. It is medium-sized, with a brown back and lighter, shinier hairs on its head. It has a swift, agile flight and hunts above open ground, over water, and also round tree-tops, where it may rest on the

Common shrew (*Sorex araneus*) attacking an earthworm

branches. During the day it hides in cracks; breeding sites are usually on buildings. It over-winters in caves, tunnels and cellars.

Another species found near peat bogs, although extremely rare in Italy, is parti-coloured bat (*Vespertilio murinis*). This is a migratory species of medium size, which reaches 1900 m on the Alps. It starts hunting late at night, continuing until dawn. Its flight is very swift and straight, 10-20 m above the ground. It does not breed on the Italian Alps and captured specimens are nearly always migrating males. Sexual segregation during the breeding season is the rule for this species, and males move much further south than females.

Other species which visit mountain peat bogs more rarely are whiskered bat (*Myotis mystacinus*) and common pipistrelle (*Pipistrellus pipistrellus*).

Rodents represent the last order of mammals living regularly in mountain peat bogs. These small animals belong to few genera, mainly the vole group (genera *Microtus*, *Chionomys* and *Clethrionomys*), but there are also wild mice (genus *Apodemus*) and hazel dormice (*Muscardinus avellanarius*), which build their hanging nests on bushes.

Voles (Microtidae family) are small rodents with short tails, rounded bodies and heads not very distinct from the body. They live in tunnels, which they dig

Male parti-coloured bat (*Vespertilio murinus*) at Passo Pramollo peat bog (Friuli)

immediately below the soil surface. In rocky areas they may use gaps and fissures between rocks, which in some cases (*Chionomys nivalis*) become their preferred habitat.

One of the most diffuse species in Italy, and well represented in peat bogs, is bank vole (*Clethrionomys glareolus*). Living up to altitudes sometimes exceeding 2000 m, this species feeds mainly on leaves, bark, stalks and seeds. It integrates its diet with animal protein by preying on insect larvae.

Unlike other voles, bank vole tends to move around less under leaf litter or in the soil, and it is not unusual to see one jump or climb bushes. Bank voles build their nests in thick vegetation, between roots or in fallen trunks. They store food (e.g., seeds) in their nests, thus aiding dissemination. Breeding continues throughout summer: gestation lasts around 20 days, and the babies, from one to six, are weaned after about a month.

Other Microtidae to be found in high-altitude peat bogs on the central-eastern Alps, although more occasionally, are common vole (*Microtus arvalis*), field vole (*Microtus agrestis*) and common pine vole (*Microtus subterraneus*). Of these, field vole shows a strong preference for water-meadows and peat bogs.

Common pipistrelle (*Pipistrellus pipistrellus*), one of the smallest European bats

Bank vole (*Clethrionomys glareolus*)

Common vole (*Microtus arvalis*)

In lower-altitude peat bogs, it is also possible to find alpine pine vole (*Microtus multiplex*), Liechtensteins's pine vole (*Microtus liechtensteini*) and Savi's pine vole (*Microtus savii*).

Among rodents belonging to the Muridae family (rats and mice), only three species of wood mice (*Apodemus sylvaticus*, *A. alpicola*, *A. flavicollis*) are present, if the bog contains woody vegetation.

These rodents, with long tails and large ears, are mainly nocturnal, although they may occasionally be spotted during the day. They are mainly granivorous, but do not disdain fruit and insects. Wood mouse (*A. sylvaticus*) has decidedly more terrestrial habits than yellow-necked mouse (*A. flavicollis*), which happily climbs trees. Breeding takes place two or three times a year, the mothers giving birth to five or six young each time.

In peat bogs with an abundance of trees, hazel dormouse (*Muscardinus avellanarius*) may also be found occasionally: this rodent, belonging to the same family as fat dormouse, is a nocturnal species which is particularly active at dusk and dawn. It is an agile climber and feeds on fruit, seeds and buds, but also eggs and nestlings.

Common pine vole (*Microtus subterraneus*)

Liechtenstein's pine vole (*Microtus liechtensteini*)

Hazel dormouse mates in spring, three or four young being born after about 20 days. It builds summer nests of leaves, blades of grass and moss on bushes, but winter nests are on the ground between the roots of trees and are made mostly of moss. Hibernation begins at the end of October and lasts until mid-March. Contrary to what might be expected, imperfect homoiothermy, with daytime or winter hibernation, is an energy-saving strategy widespread mainly in temperate zones of the world. It is advantageous only where the winter is not too long, with low temperatures and food crises which do not last for more than six months.

Carnivores which frequent mountain and valley peat bogs include western polecat (*Mustela putorius putorius*). This species lives mainly in forests, but also visits marshlands to prey on many amphibians which, in spring and autumn, may constitute 90% of its diet.

The relative biological richness of high-altitude peat bogs also attracts other carnivores which are able to capture varied prey in them. On the edges of Alpine peat bogs, it is common to find the tracks of fox (*Vulpes vulpes*) and badger (*Meles meles*), attracted by the abundance of both small mammals and invertebrates.

Wood mouse (*Apodemus sylvaticus*)

Conservation and management

FRANCESCO BRACCO · FABIO STOCH · ALESSANDRO MINELLI · ROBERTO VENANZONI

■ Peat bogs as “islands”

With their form and characteristics, it is easy to associate the biogeographical concept of “island” with peat bogs

For an ecologist (or a biogeographer), the concept of an island has wider connotations than a geographer would accept.
An island in the strict sense is a piece of emerging land entirely surrounded by water, which separates it from other islands or the nearest continent. In the same way, a peat bog, small wood or high-altitude pasture may be viewed as an “island”, because of its well-defined environmental characteristics, and separated from other similar “islands” by a “sea” dominated by completely different environmental conditions. The comparison goes a great deal further than a simple metaphor, because the same descriptive and interpretative models, in relation to the fauna and flora, may be applied to all these situations.
In particular, a problem common to all “island” situations is that of colonisation and extinction. The more remote an island is from areas producing “propagules” of species which are not already present, the less probability there is of colonisation. This is valid both for an island lost in the ocean, such as Easter Island in the middle of the Pacific, and for a relict mountain peat bog, like those often found in Italy, especially in the Apennines.
The size and environmental heterogeneity of an island are decisive for the lasting success of colonisation: the smaller the island, the greater the risk of rapid extinction. Combining the various factors, a small remote island tends to preserve a limited population, whereas a large one close to the continent, or one already inhabited, quickly becomes enriched with species, until it attains the maximum level of biodiversity compatible with its size and type. In the absence of external factors, these species then tend to be maintained, by the

Drainage channel crossing a peat bog near Madonna di Campiglio (Trentino)

effect of a reciprocal balance between new immigrations and new extinctions. This does not mean that populations must always remain unchanged. In addition to species well-adapted to local conditions and therefore in less danger of extinction, there are others, especially amongst more recent immigrants, the presence of which is less durable, so that they more easily leave space for new arrivals. This numerical equilibrium represents a somewhat idealised situation. However, it is a useful reference in order to highlight, and attempt to interpret, conditions found in individual island populations.

These observations are the nucleus of the *island biogeography theory* proposed forty years ago by Robert MacArthur and Edward O. Wilson. Above and beyond their obvious theoretical and interpretative interest, models of island biogeography are sources of valuable suggestions for conservation, which are particularly applicable to Italian mountain peat bogs.

On small, very remote islands, the probabilities of extinction, for any one of the species living there, are always high, for the simple reason that there is no room for the growth of very numerous populations; equally, colonisation probabilities are extremely low, given the distance from the possible "stores" of propagules. It is therefore easy to see how dramatic are the prospects for survival of animal and plant populations in a small peat bog far away from

An example of peat production

other biotopes of the same kind. In this case, the strictness of conservation measures and how rigorously they are applied are of little importance: against all the very best of human intentions, sooner or later the fate of that peat bog will be sealed. In other words, little is gained by saving one tiny peat bog as a "small model" of a valuable environment, if this model is cut off from any reasonable hope of population interchange, and thereby (re-)colonisation, with other similar biotopes.

For environments such as peat bogs, which are by their very nature small "islands" surrounded by an inhospitable "sea" for all the more specialised organisms living in them, a detailed and far-sighted environmental policy is a essential factor in safeguarding an entire "archipelago" of similar sites of special natural interest.

It is not merely by chance that some of the most prestigious forms of insect fauna of Italian mountain peat bogs, such as *Agonum ericeti* or *Chrysochraon dispar*, are known only on the basis of single finds a century or more ago. Although there is still some hope that these species are not in fact extinct in Italy, their disappearance is more than possible, and any prospects for their returning from bogs on the northern slopes of the Alps are much more tenuous.

Following peat extraction, large areas of the bog become filled with water

Highly degraded peat bog with drainage system of water accumulating in peat diggings

■ Problems and risks

A peat bog is characterised ecologically by some extremely limiting conditions, such as abundant water, low availability of nutrients, and the possibility of evolving its own surface morphology consistent with the ecology of the different species of sphagnum growing in it. Any modification that implies variations in water quality and nutrient levels can endanger its existence.

In the past, subsistence farming and the need for cheap fuel meant that removal of peat was common, even from small bogs. Later, in an attempt to achieve industrial production, peat extraction was extended and seriously threatened larger peat bogs with high natural value. In Italy, the exploitation of peat in this way now represents much less of a threat.

Nowadays, the main threats to peat bog survival are mainly represented by the reduction in water availability following drainage for changes in land use, for such bogs are considered, like other areas of natural vegetation, entirely non-productive and therefore suitable for transformation into forests or farmland. Other dangers include operations to fill in the hollows and cover the peat bogs with rubble, in order to create new construction sites near towns or smaller isolated buildings (lodges, refuge huts, etc.).

The draining or reclamation of a peat bog, if it does not lead to the total disappearance of the vegetation, is usually followed by colonising of new species. After drainage, in the most optimistic of hypotheses, hygrophilous meadows may develop with some level of floral originality; however, the appearance of synanthropic vegetation is more frequent, due to the presence of crops or, to a greater or lesser extent, built-up areas. The destruction of peat bogs affects floral biodiversity, which is impoverished after the disappearance of typical peat-loving species and the appearance of ordinary species favoured by human settlements and activities.

In several cases, peat bogs have been irredeemably ruined by excavation of their sides or hollows to enlarge pools or create artificial basins for the most disparate reasons -, fishing, tourism, reservoirs of water for fighting forest fires or even making artificial snow in winter. Extreme cases, such as the Campotosto bog in central Italy, are represented by peat bogs on the bottom or sides of valleys which have been flooded by the building of dams for hydroelectric power.

The most insidious effect of these transformations is that the casual observer does not perceive the disappearance of the wetland area of the bog, but just its substitution by water, which may even be assumed to be natural because of the subsequent appearance of cosmopolitan species (such as cattatil,

common reed, some sedges and willows) which confer an apparently acceptable aspect. Once again, the loss of biodiversity in terms of rare plant species and types of vegetation is irreversible.

Another type of risk to which peat bog environments are exposed is caused by the dispersion of nitrogen and phosphate nutrients released by human activities. These substances are contained in wastewater coming from towns, even small ones, and from farmland where intensive agriculture and livestock rearing are practised. When wastewater flows into the peat bog, it increases the trophic level of the circulating water, causing grave damage to most species, both bryophytes and flowering plants, which cannot tolerate even slight nutrient increases in nutrients. Eutrophication is therefore a very real threat.

In the traditional mountain landscape, livestock rearing and forestry have often coexisted with peat bogs and their vegetation, with alternating results, often affecting floral composition through management practices (drainage, burn-off, etc.) which tended indirectly to transform the area substantially without endangering its survival. Grazing is a risk especially where there are many animals - and this is not infrequent, as peaty areas often correspond to more or less flat surfaces and are therefore easily accessible to livestock. In this case,

Grazing can affect floral composition of peat bogs

excessive trampling can cause erosion, which destroys the cover and hummocks of sphagnum and mosses and also the few vascular plants present. Secondary damage is caused by progressive compaction of the substrate by grazing animals.

Tourism produces extremely diversified direct and indirect effects, which give rise to all the risk conditions described so far. These days, tourism is often the greatest threat to peat bogs, because of the current lack of importance of agriculture in the mountain economy.

It should also be remembered that, in Italy, peat bogs are located in marginal situations with respect to their principal phytogeographical distribution, associated with cooler, oceanic climates. They are thus more fragile from the ecological point of view and have even greater natural and biological value than in areas where they are more frequently found. Peat bogs, from all aspects, have relict significance, as their formation and colonisation by different plant species is related to the Quaternary Ice Ages rather than to current climatic conditions. The disappearance of these environments in Italy is thus in most cases irreversible, as spontaneous reconstitution could only occur with enormous difficulty over tiny surface areas.

Peat bog on the edge of an Alpine tarn in a highly degraded area

■ Management and conservation

The many threats of human origin and, in Italy, the very specific condition of phytogeographical and relict marginality, renders the future of peat bog environments precarious, and botanists and naturalists have long been campaigning for their inclusion in conservation programmes.
The management and conservation of these environments is in itself a problem, to which an answer has only been sought in recent decades.
No specific national laws exist for peat bog conservation - nor for wetland biotopes at large, and much of the jurisdiction is currently the concern of local agencies operating at different levels. Very often recourse is made to protecting particular biotopes which contain environments of this type. An example of this is Lombardy, a region where protected areas (botanical reserves or specially "oriented" reserves) have been set up for the conservation of Alpine peat bogs (e.g., Pian di Gembro and Paluaccio di Oga). Many peat bogs are in regional parks - for example, Parco dell'Adamello and Parco delle Orobie in Valtellina, or the Stelvio National Park. Some peat bog plant species, such as cotton grasses, are protected.
The situation is similar in the autonomous Valle d'Aosta, where peat bogs are managed in reserves (Lago del Lozon, Lolair) and regional parks (Parco Naturale di Mont Avic) and in the Gran Paradiso National Park. A well-developed model of this type of protection also exists in Emilia-Romagna, which protects mountain peat bog environments, examples being the Regional Parks of Alta Val Nure, Alta Val Parma and Cedra, and in the Apennines around Modena.

Area exploited for peat production

Tofield's asphodel (*Tofieldia calyculata*) is included in the Red List of italian plants considered to be at risk

In this case, the identification of environments of natural interest is associated with very circumstantial knowledge of the qualifying species of peat bog flora, their rarity on a regional scale, and the types of risk to which they are subject. Less often, conservation takes the form of drawing up more general, integrated regulations for the protection of peat bogs in terms of habitat, as happens for example in Trentino-Alto Adige (South Tyrol). Here, regulations differ between the two autonomous provinces. The autonomous province of Bolzano-Alto Adige has tackled this subject with its "*Tutela del paesaggio" - Landesgesetz vom 25 Juli 1970, Nr. 16 "Landschaftsschutz*" (provincial law no. 16 of 25 July 25 1970 "Landscape Protection"). In 1991, Bolzano also published a register of peat bogs and wetland areas in its province.
In the autonomous province of Trento, the subject is regulated by Provincial Law 14 of 23 June 23 1986, "*Norme per la salvaguardia dei biotopi di rilevante interesse ambientale, culturale e scientifico*" ("Regulations for the protection of biotopes of environmental, cultural and scientific importance"). With its application, a Scientific Co-ordinating Commission was established, and inter-disciplinary scientific studies were set up for each biotope.
On a national level, after the historical two volumes devoted to the "census of biotopes of national interest worthy of conservation" published at the end of the 1970s, in recent times many initiatives have flourished, promoted by the Nature Conservancy Service of the Italian Ministry of the Environment. These have led to the publication of the national Red List, regional lists of rare and endangered species in Italy and, in collaboration with the Italian Botanical Society, a census of habitats of European interest, in application of the EC Directive 92/43 ("Habitat Directive").

Peat bog with *Eriophorum vaginatum* (Julian Alps, Friuli)

■ Peat bogs and the Habitat Directive

The census of priority habitats for the European Community, as defined in Annex I of Directive 92/43/EC, better known as the Habitat Directive, and its integration 97/62/EC, gave new impulse to the production of a full botanical description of peat bogs, their distribution and state of conservation.
Collaboration between the Nature Conservancy Service of the Ministry of the Environment and the Italian Botanical Society led to a nation-wide census of priority habitats, which included mountain peat bogs (habitat 7110, 51.1), calcareous marshes with *Cladium mariscus* and *Carex davalliana* (habitat 7210, 53.3), and wooded peat bogs (habitat 91D0, 44A1, 44A4).
Unfortunately, these botanical studies have never been followed up by equally detailed zoological research, but only dealt with restricted areas (north-eastern Italy, in particular): our knowledge of mountain peat bog fauna is therefore only in its initial stages, and a complete census of species, not updated, exists for very few environments.
Very little is known about the frequency of species of European interest in peat bogs, or the species in Annex IV, which are considered as deserving particular protection, and also important for the purposes of Italian DPR 357 of September 8 1997, which bans not only the collection, possession and sale of

Campagnaccia peat bog (Val Malenco, Lombardy)

Fen orchid (*Liparis loeseli*)

Miniature snail *Vertigo angustior*

specimens, but also damage to or destruction of resting areas which animals use for resting and breeding. Italian peat bogs include only a small part of these, despite the fact that many of the species mentioned in this volume are today under serious threat in Italy. This is due to the concept inherent in the definition of “species of European interest”, which signifies species in danger, vulnerable, rare or threatened throughout the European Union.

The boreo-alpine distribution of most species endemic to peat bogs, the lack of specificity of their fauna, together with the great number of peat bogs in central and northern Europe, are the reasons for this scarcity of species of European interest. Even so, some species of exceptional conservation value listed in Annex II are to be found in peat bogs: examples are the orchid *Liparis loeselii*, gastropods *Vertigo angustior*, *V. genesii* and *V. geyeri*, and the dragonfly *Leucorrhinia pectoralis*.

The rarity of Italian peat bogs and some of the species living in them, the fragmentary nature of these biotopes, particularly those in the Apennines, in addition to their vulnerable state, all means that areas as yet unprotected by the European Directive should also be considered as “sites of national interest”. Although they lack legal protection, a serious conservation effort may be enacted by all local authorities within whose jurisdiction the peat bogs lie.

■ The Red List and peat bog flora

The flora of mountain peat bogs is not rich - predictably, given the selectivity of their environmental conditions, their fragmentary nature, and the small areas they cover.

However, an examination of this flora is significant in the light of the conditions of risk for the plants, expressed with reference to the categories included in the international list of the I.U.C.N. (International Union for the Conservation of Nature).

The status of these species can be found in the “Red List of Italian Plants”, published in 1992, and the “Regional Red List of Italian Plants” (1997).

Statuses and conventional acronyms are:

EX (extinct): species no longer in existence.

EW (extinct in the wild): species which survives only in cultivated form.

CR (critical risk): species exposed to a critical risk of extinction in the wild in the

Creta di Aip peat bog (Julian Alps, Friuli Venezia Giulia)

Fiavè peat bog (Trentino) shows clear signs of past peat digging

near future, due to small area of distribution, low population level, and negative trends already observed in the evolution of that population.

EN (endangered): species exposed to serious risk of extinction in the wild in the near future; the criteria are the same as those used to define CR, but with wider distribution thresholds and more numerous populations, with a less pronounced negative trend in population size.

VU (vulnerable): species exposed to a marked risk of extinction in the wild in the near future; the criteria are the same as those used to define CR and EN, but with even wider distribution, higher population numbers, and less pronounced negative trend.

LR (low risk): species not included in one of the preceding three categories but which may be in the near future, because they are currently very close to the quantitative parameters which would mean their attribution to VU status, or which would come into it if the protection measures covering them at present were rescinded.

DD (insufficient data): species for which no documentation exists on distribution area or population size. Although this status does not constitute a

Marsh felwort (*Swertia perennis*)

Tofield's asphodel (*Tofieldia calyculata*)

Red List for peat bogs

	Italy	V. d'A	Piedm	Lomb	S.Tyr	Ven	FVG	Lig	E-R	Tusc	Mar	Umb	Lat	Abr	Mol	Apu	Bas	Cal	Sic
Bryophytes																			
sphagnum (*Sphagnum cuspidatum*)	EN																		
Pteridophytes																			
marsh clubmoss (*Lepidotis inundata*)	VU		VU	VU	CR	VU	VU	CR											
Angiosperms																			
Dicotyledons																			
common sundew (*Drosera rotundifolia*)			VU	VU		CR	EN	EN	CR										
long-leaved sundew (*Drosera anglica*)	VU		VU	VU	VU	CR	VU		EW	CR									
marsh cinquefoil (*Potentilla palustris*)	VU		CR	VU	VU	CR													
marsh violet (*Viola palustris*)							VU											VU	
hether (*Calluna vulgaris*)											VU	LR	VU						
marsh andromeda (*Andromeda polifolia*)	VU			VU	VU	CR													
cranberry (*Vaccinium oxycoccos*)	VU			VU	VU	VU				EW									
small cranberry (*Vaccinium microcarpum*)	LR				LR														
Vaccinium gaultherioides													LR	LR					
marsh felwort (*Swertia perennis*)	VU		VU	VU	VU	CR			CR	VU									
marsh gentian (*Gentiana pneumonanthe*)	EN		VU	VU	VU	EN		EN	CR	CR				EW					
bogbean (*Menyanthes trifoliata*)						EN		EN	VU			CR	EW	EN	CR				
common lousewort (*Pedicularis sylvatica*)	VU			EN	VU	EN													
lesser bladderwort (*Utricularia minor*)	EN			VU	VU	EN				CR		CR		EW					
Monocotyledons																			
rannoch rush (*Scheuchzeria palustris*)	VU		VU	VU	VU		EN												
marsh arrow-grass (*Triglochin palustre*)						EN	VU	CR	CR	EN		CR		VU					
Tofield's asphodel (*Tofieldia calyculata*)									CR					LR					
little false asphodel (*Tofieldia pusilla*)	LR	LR	LR	VU	LR	EN													
heath rush (*Juncus squarrosus*)	VU		VU	VU															
small bur-reed (*Sparganium minimum*)	LR			LR	LR	CR	VU		EN	CR									
few-flowered sedge (*Carex pauciflora*)	VU	VU	LR	VU	EN	VU													
flea sedge (*Carex pulicaris*)	VU			VU	LR	DD	LR												
capitate sedge (*Carex capitata*)	VU				VU														
Davall's sedge (*Carex davalliana*)											CR			VU					
dioecious sedge (*Carex dioica*)					LR	VU													
lesser tussock sedge (*Carex diandra*)	VU	LR	VU	VU	VU	EN	EN												
peat sedge (*Carex heleonastes*)	VU		VU	VU	VU														
tufted sedge (*Carex elata*)											EN	EN	LR	VU					
Carex fusca													LR	VU					
club sedge (*Carex buxbaumii*)	LR		DD		LR		EN					VU		VU					
yellow sedge (*Carex flava*)													VU	VU					
bottle sedge (*Carex rostrata*)													VU	VU					
slender sedge (*Carex lasiocarpa*)			LR	LR	EN	LR													
flat sedge (*Blysmus compressus*)													LR						
few-flowered spike-rush (*Eleocharis quinqueflora*)											LR	LR		LR					
alpine bulrush (*Trichophorum alpinum*)			LR																
tufted bulrush (*Trichophorum caespitosum*)								VU											
harestail cotton grass (*Eriophorum vaginatum*)			LR	LR				VU											
broad-leaved cotton grass (*Eriophorum latifolium*)									EN	VU	EN	EN	EW	EN					
narrow-leaved cotton grass (*Eriophorum angustifolium*)									EN		EW			EW					
brown bog-rush (*Schoenus ferrugineus*)	VU	CR	VU	VU	LR	VU													
black bog-rush (*Schoenus nigricans*)					VU							EN							
white beak-sedge (*Rhyncospora alba*)	CR		VU	VU	EN	CR	VU	DD		EN			EW						
brown beak-sedge (*Rhyncospora fusca*)	CR		CR	CR	CR		VU			EN									
marsh elelborine (*Epipactis palustris*)		VU				EN			EN	VU		EN		VU	CR	CR	VU	VU	CR
summer lady's tresses (*Spiranthes aestivalis*)	EN		VU	EN	EW	EN		EN	EW	VU	EW		VU						
bog orchid (*Hammarbya paludosa*)	CR				CR														
fen orchid (*Liparis loeseli*)	EN		EW	EN	EN	CR	VU												

EX = extinct EW = extinct in the wild CR = critical risk EN = endangered VU = vulnerable LR = low risk DD = insufficient data

Marsh clubmoss (*Lepidotis inundata*) with typical prostrate bearing

declaration of effectively existing risk, which might be hypothesised - for example, on the basis of the ecological preferences or reproduction problems of the species - it does, however, indicate the need for more extensive studies on the distribution and population characteristics of that species.

The table on page 130 lists the species representative of mountain peat bog flora, with their status at Italian national level, and in individual regions. The regions where none of these species have been reported (Campania and Sardinia) are excluded.

Marsh arrow-grass (*Triglochin palustris*)

The table allows some important considerations to be drawn. In the first place, the list of species (definitely incomplete, and one which requires constant monitoring) is quite long, reflecting the general conditions of overall precariousness of the peat bog environment, and reflecting on the conservation status of the individual species.

This is stressed by the second observation: a risk status at national level has been attributed to many species (such as marsh cinquefoil, lesser tussock sedge and white beak-sedge), and is associated with risk conditions in most of the regions where the species are found.

Some of these species, for example, bog orchid, have extremely restricted distribution. Many species also exist, such as common sundew and marsh arrow-grass, which are not endangered in Italy, and therefore lack conservation status on a national level, but which are at widespread risk in many of the different regions in which they are to be found. This fact emerges from the table.

The table also lists species with distributions which often include territories outside peat bog areas, to which a risk status is given only for central-southern regions, since they are in an extreme position in relation to the normally European or boreal distribution area. In these cases, the species grow in Italy in environments different from those of true peat bogs, which are non-existent in the regions in question.

Teaching suggestions

MARGHERITA SOLARI

■ Sphagnum mosses

- Aims: to understand the main elements useful for classifying the plant kingdom; to develop capacity for analysis and comparison of varying plant morphologies.
- Level: schoolchildren between 12 and 15 years: with some simplifications, the course can be adapted for children 9-10 years of age.
- Possible collaboration: an expert botanist.
- Tools: photographs of peat bog environments; photos and drawings of sphagnum mosses and other plants (e.g., herbaceous plants); flex cam microscope (if available); literature.

PRELIMINARY STAGE

1. Select a peat bog for an excursion, taking photographs.
2. Introduce the work in class: present the peat bog environment, describe the itinerary, show pupils how to use a topographical map, and describe the route to be taken.

FIELD EXCURSION

3. Group excursion, observation of peat bog morphology (profile, edges, presence of open water); identification of cardinal points and orientation of topographical map; observation of local geomorphology, stressing salient points (basins and slopes, hydrographical elements, footpaths, man-made elements, etc.).
4. Describe the peculiarities of the peat bog environment; low water temperature, lack of nutrients, acidity, accumulation of undecomposed plant material, etc..
5. Guided observation, by teachers or experts, of the main plants growing in the bog and surrounding area, particularly sphagnum mosses.

ONGOING CLASSWORK

6. Analyse morphological characteristics of sphagnum mosses, enlarging on

Peat bog at Lake Pratignano (Emilia Romagna): one of the few examples of this habitat in the Apennines

rhizoids, stems, leaves, capsules, spores, etc., comparing the structures with those (only partly corresponding) of herbaceous plants which the pupils know: observations with the naked eye.

7. Examine these structures under low magnification, if possible using a flex cam: guide observations and debate, in order to verify pupils' understanding.

8. Draw diagrams of the stem and leaf structures of sphagnum mosses, with special reference to hyalocysts, adapted for water absorption and storage by the plant. Explain the absence of an efficient water transport system and consequent reliance on diffusion and osmosis mechanisms which, together with some previously observed morphological aspects, constitute primitive characteristics.

9. Describe the way in which sphagnum moss grows, its accumulation in overlapping layers and water-purifying capacity.

10. Ask pupils for final considerations on the characteristics of peat bogs and the need to safeguard these specific habitats.

Detail of a sphagnum carpet

■ Archaeology and peat bogs

- Aims: awareness of territorial development in terms of vegetation and human colonisation during the various pre-historic and proto-historic eras; development of capacity for analysis and data interpretation in the chronological reconstruction of events. Reference is made specifically to the colonisation of areas surrounding mountain tarns of glacial origin in the Mesolithic period, not in preceding times.
- Level: schoolchildren between 12 and 15 years: with some simplifications, the course can be adapted for children 9-10 years old.
- Possible collaboration: an archaeologist.
- Tools: bibliographical material, topographical and archaeological maps, pictures of differing peat bog environments.

PRELIMINARY STAGE

1. Locate regional or local archaeological maps, particularly those which show

Peat bogs are interesting biotopes, which are also increasingly exploited for tourism

Flooded area at edge of an Alpine peat bog (Julian Alps, Friuli)

the most ancient sites (Paleolithic, Mesolithic, Neolithic), and topographical maps on a suitable scale (to compare with the preceding ones), which show peat bogs and wetland areas in general.

CLASSWORK

2. Introduce class work: discuss the characteristics of peat bogs, particularly the origin of mountain peat bogs by the burial of Alpine tarns, interpreted as glacial relicts of the Quaternary era.
3. Study pictures of peat bog environments, preferably in the region, analyse their morphology and the geomorphology of the surrounding area.
4. Group work: compare archaeological and topographical maps, perhaps subdividing the work by geographical area; identify archaeological sites close to peat bogs.
5. Share group work, process and write up research group conclusions; identify the most significant historical period for continuing work.
6. Illustrate archaeological evidence found in European peat bogs and the physico-chemical factors which make these environments particularly preservative (anoxia, acidity, sterility of deeper layers, low temperature, etc.).

Example of a simple system for sampling and data collection in a peat bog

Pool at edge of Cima Corso bog (Friuli)

7. Further study, using textbook, of the civilisations in the sites identified; particularly types of settlement.
8. Group discussion of the data and reconstruction of a hypotethical settlement: with respect to the criteria of historical reconstruction, draw up a plan reproducing the landscape at the time of its settlement near one of the peat bogs.
9. Draw conclusions about the importance of peat bogs as environments of fundamental importance for the reconstruction of the history of a territory, thanks to their peculiar capacity for preservation.

■ Palynology and peat bogs

- Aims: to develop capacity for analysis, comparison and interpretation of data acquired from various sources; to understand the evolution of the vegetation in a certain area.
- Level: schoolchildren 14 to 15 years old, perhaps also 12 to 13 years old.
- Possible collaboration: an expert botanist.
- Tools: pictures of various peat bogs and a cross-section of one of them,

Alpine peat bog

High peat bog near Creta d'Aip (Friuli Venezia Giulia)

photographs of pollen grains, bibliographical material (illustrated guides to trees and shrubs); pollen diagrams relating to three or four sites, preferably local.

PRELIMINARY STAGE

1. Locate iconographic material, prepare teaching cards on the trees and shrubs in the diagrams: for each one, provide a brief description, draw the leaves, and/or photograph the plant, and its pollen grains.

Common toad tadpoles

CLASSWORK

2. Introduce classwork: study reproduction in higher plants and their modes of pollination (autogamy, anemogamy, entomogamy).
3. Study pictures of various pollen grains; analyse the structure of a pollen grain (exine, intine, etc.).
4. Verify if concepts are understood, by a discussion on the methods of pollen diffusion of species which use varying strategies in the study area.
5. Describe a peat bog and the characteristics which make it a preserving environment, particularly its physico-chemical parameters: anoxia, acidity, sterility of deeper layers, low temperature, etc.; explain the way plant remains accumulate to form the peat bog.
6. Describe the evolution of the vegetation in relation to climatic or human factors; explain the concepts with reference to variations associated with alternating cold and warm periods during the Quaternary era.
7. Illustrate a pollen diagram: describe why its parameters (sample depth, percentage of pollen grains in the layer, etc.) are significant.
8. Group work: interpret various pollen diagrams and draw up a written report (to verify correct interpretation).
9. Further group work may continue with processing of thematic geographical maps (small-scale) showing the tree cover as identified by the pollen diagrams, with an approximate percentage of cover, during two or three significant phases (if available pollen diagrams illustrate the various depths from which core samples were taken without specifying the age of the layers, it is sufficient to refer to successive stages, without precise time references).

10. Share group work.
11. Describe palynology research techniques and the importance of peat bogs in the discovery of scientific data; discuss the need for conservation.

■ The nitrogen cycle and carnivorous plants

- Aims: to understand the importance of recycling of chemicals in the biosphere; knowledge of the cycles of some elements in ecosystems; knowledge of the peculiar adaptations of carnivorous plants.
- Level: schoolchildren 14 to 15 years old, perhaps also 12 to 13 years old.
- Tools: textbooks, pictures of carnivorous plants in the area, extra literature.

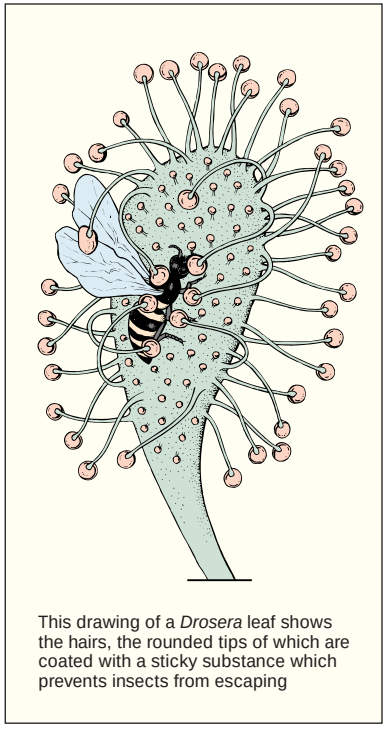
CLASSWORK

1.Study energy and material fluxes in ecosystems; analyse the various components (primary producers, primary and secondary consumers, decomposers, etc.) with suitable examples taken from the local situation;

Water passing around a grassy hummock

analyse the peculiarities of autotrophic and heterotrophic organisms.
2. Study the cycles of some elements: e.g., carbon, phosphorus and, especially, nitrogen.
3. Analyse the ways in which plants take up nitrogen (symbiotic nitrogen-fixing bacteria, etc.).
4. Analyse and compare the ways used by carnivorous plants to integrate traditional nitrogen sources; examine the various types of traps (falling, sticky, triggered, sucking) and accessory substances (enzymes, secretions, etc.), and the mechanisms which permit movement (cell turgor, etc.); study pictures of the most significant carnivorous plants in the area (Droseraceae, Lentibulariaceae).
5. Draw up descriptive cards for each species analysed, study further the relative distribution areas on regional and national levels.
6. Discuss the “cost/benefit ratio” of the capturing mechanisms, which shows that these plants are not very competitive; however, their responses to the problems of survival may be efficient in environments with minimal competition like peat bogs.

Lesser bladderwort (*Utricularia minor*)



This drawing of a *Drosera* leaf shows the hairs, the rounded tips of which are coated with a sticky substance which prevents insects from escaping

Cross-section of peaty soil

7. Draw conclusions about the need for conservation of peat bogs and protection of the peculiar species, such as carnivorous plants, which live in them.

■ Comparison of fossil fuels

Differing substrate characteristics can make great difference to vegetation cover

- Aims: to understand the extremely slow process leading to the formation of fossil fuels; to develop capacity for analysis and comparison.
- Level: primary school pupils and 12-13-year-olds.
- Tools: textbooks, bibliographical aids, laboratory with Bunsen burner, pictures of peat and regional peat bogs, pictures documenting the phases of peat extraction; coal and peat samples.

CLASS WORK

1. Analyse the characteristics of a peat bog, particularly the accumulation of undecomposed plant material; guide study of pictures of mountain peat bogs in the area.
2. Illustrate the process of carbonisation by anaerobic micro-organisms.
3. Study the complete process leading to the formation of bituminous coal and anthracite.
4. Compare coal and peat samples, describe their colour and consistency.
5. If possible, conduct flame sampling (using a Bunsen burner) of equal amounts (e.g., about $1cm^3$) of four types of carbon (anthracite, lignite, bituminous coal, peat) until complete combustion; observe the flame colour and heat developed, analyse data on calorific power found in the literature.
6. Organise individual or group research on the use of peat as a fuel in the past and nowadays within the region or elsewhere (guide pupils in research on areas of northern Europe, particularly Ireland); further study of extraction and drying methods.
7. Discuss the economy of peat extraction in Italy today, comparing extraction costs, calorific power and environmental impact with those of other resources, especially renewable ones.

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A series of guide-books for identifying some Italian aquatic fauna. Unfortunately incomplete, but still today an indispensable working tool.

The fauna and vegetation of peat bogs present peculiar aspects, and further detailed information can only be found in scientific journals, mainly available for consultation in Natural History museums and university libraries.

Glossary

> Acidophile: organism which prefers acidic environments, i.e., pH below 7.
> Anoxia: lack of oxygen
> Distribution area: in biogeography, that part of the territory in which a species is present.
> Bacteriophage: organism which feeds on bacteria.
> Bioclimatic plane: each of the environments or groups of environments which follow each other according to a gradient of altitude or latitude, are defined according to climatic factors of temperature and precipitation, to each of which corresponds a certain vegetal community. Each biogeographic region possesses peculiar bioclimatic planes, in which complexes of vegetal communities with their own structures and floristic compositions develop, called “vegetation planes”.
> Boreo-alpine: disjointed geographical distribution which includes a northern part centred on Scandinavia and a southern one located on the Alps.
> Brachypterous: (insect) with abnormally small wings, incapable of flight; compare macropterous.
> Climax: final stable equilibrium stage in vegetation succession which persists unless environmental conditions vary.
> Edaphic: referring to soil. Edaphic factors are the physical and chemical conditions of the soil which influence plant growth.
> Helophyte: an aquatic plant in which the lower portion of the stem, submerged and anchored to the bottom, carries perennial buds, while the upper, emerging portion bears flowers and fruit.
> Eutrophic: nutrient-rich environments.
> Floating mat, or trembling bog: a layer of soft, grassy soil which floats on marsh water.
> Frigostenotherm: an organism with ecological requirements which restrict its distribution to cold environments.
> Frustule: siliceous covering, composed of two valves with dense and regular external sculpturing, which protect the single cell forming the body of a diatom.
> Halophile: organism which tolerates or prefers high salt content in soil.
> Holarctic: organism distributed over part or most of the Holarctic region, embracing the cold and temperate lands of Europe, Asia and North America.
> Hydrophyte: partly or wholly submerged aquatic plant, with buds located in submerged organs which ensure survival over winter. May float, or be anchored to the bottom.
> Macropterous: insect with normally developed wings and generally capable of flight; compare brachypterous.
> Mesotrophic: environment with average and fairly constant mineral salt contents.
> Microclimate: local climate associated with the habitat.
> Oligotrophic: environment poor in basic salts and therefore nutrients.
> Phytophage: organism which feeds on plants.
> Primary succession: plant community succession which initiates in an environment as yet uncolonised and lacking soil (e.g., rock or recent fluvial-glacial sediments).
> Pseudopod: locomotor appendices, of constantly changing shape, issuing from the cell body of an amoeba.
> Secondary succession: plant community succession which develops on more or less degraded pre-existing soils.
> Tyrphobiont: organism exclusive to peaty environments.
> Tyrphophilous: an organism which prefers peaty habitats, although it is not exclusive to them.
> Topoclimate: local climate, referring to a small geographic area or environment.

List of species

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