European Environment Agency

Europe’s biodiversity

— biogeographical regions and seas

Biogeographical regions in Europe

The Pannonian region

— the remains of the Pannonian Sea

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Summary

- The Pannonian region is dominated by the Great Hungarian Plain.
- Former extensive forests are replaced by grasslands and steppes. Sandy grasslands, i. e. the Hungarian Puszta, is now the dominating type of habitat.
- Agriculture, drainage, eutrophication and salinisation are major threats to biodiversity.
- River regulation and effluents in river are imposing threats to biodiversity in water bodies.
- A few large lakes are heavily influenced by eutrophication and tourist activities.

1. What are the main characteristics and trends of the Pannonian biogeographical region?

1.1 General characteristics

1.1.1 Extent and boundaries

The Pannonian biogeographic region, also known as the central Danubian basin, is completely surrounded by mountains. It is enclosed by the Alps in the west and the Dinarics in the south. The Carpathians encircle the north and east. As regards the main features of relief, alluvial plains dominate with sparse isolated low hills in the interior and low mountain ranges along the boundaries. The main feature of the region is the Great Hungarian plain. Other plains include the Danube plain in Slovakia and the Sava and Drava plains in Croatia and Slovenia. The hilly landscape west of the Danube includes several small mountain ranges as the Bakony and Mecsek hills in Hungary, Frushka Gora hills in Serbia, Papuk and Bilo Gora hills in Croatia. The northern rim is composed of volcanic mountains (Berecse, Pilis, Cserhát, Bukk and Zemplín hills). The fluvial network is an important feature of the region. The Danube, which flows from north to south, has numerous tributaries. The Pannonian region is very rich in underground water.

1.1.2 Geomorphological history

Having developed in the late Tertiary, the Pannonian basin is of recent origin. The area previously hosted a massif, the Tisia, being a remnant of an ancient European mountain system. From late Miocene, the area began to develop into a basin. At the time of powerful emergence of the surrounding mountain ranges, the Tisia broke up, and gradually began to subside. The basin was the inundated Pannonian Sea; the main features of it were formed at the end of the Tertiary. Erosive activity during the course of the Quaternary remodelled the topography to its present state. The fluvial activity was important in this period. Rivers filled up basins and cut terraced valleys. During the periods of Quaternary glaciation, the intense action of frost accelerated the decomposition of rocks in the mountains. Low precipitation with subsequent low flow of rivers caused river valleys to fill up with sediments. The flood plains dried up, after having been covered with sand and silt. Easterly winds were dominant, sand and silt of the flood plains was carried considerable distances. In places where the dust was bound by vegetation deposits of loess were formed.

Table 1. Statistics for the Pannonian biogeographical region

Surface area (km^2)	Number of countries in region	National composition by area	Population (inhabitants/km^2, entire country)
133 000	6	Hungary 70 %	109
		Czech Republic 9%	130
		Serbia 9 %	106
		Croatia 6 %	81
		Romania 4 %	91
		Slovak Republic 1 %	111
		Slovenia 1 %	99

Sources*: various sources compiled by ETC/NPB and EEA.*

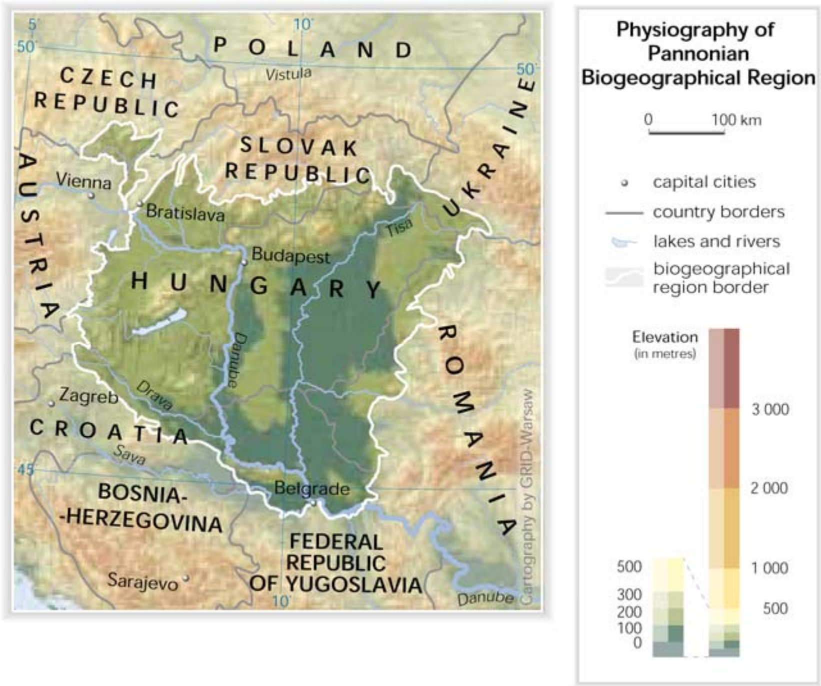
1.1.3 Climate

The climate is an important factor determining the biodiversity of the region. The most important climatic boundary of the Pannonian region separates humid from semi-arid areas, and represents a boundary between two vegetation belts — deciduous forests and forest-steppes. Four climatic types influence the area:

- The west-European climate, rich in precipitation (also during summer), is found in north-western parts of the region which is dominated by forests.
- A continental climate, with lower precipitation, in the eastern part.
- A Mediterranean climate type with warm summers and temperate winters in the south.
- The western part of the region is strongly influenced by an Atlantic-alpine climate.

The average temperature in the central part of the Pannonian region is ca 11 °C, the average temperature in January – 0.7 °C, in July 22 °C. In the western part, the yearly average precipitation is 700–800 mm, while it is ca 500 mm in the central and southern parts. The main feature of the Mediterranean influence in the south is the occurrence of two maxima of precipitation: the first in May and the second in October. Westerly and northerly winds are most frequent and the strongest.

Map 1. The Pannonian biogeographical region. In south is the Federal Republic of Serbia (Capital: Belgrade)



1.1.4 Soils

The wide-spread soils of the plains are chernozems and phaeozems. Chernozems, black soils rich in humus, are found in plains with (windblown) loess sediments. Phaeozems, soils with a thick, dark topsoil rich in organic matter, occur in dryer areas of flood plains where underground water influence the hydrological regime only in the depth of soil profile. Along rivers, where underground water influences hydrological regime of the whole soil profile, fluvisols have developed. The presence of underground water near the surface and its evaporation provided a basis for the development of salty soils (solonchaks and solonetzs). Hilly regions are covered by orthic luvisols and cambisols. In volcanic mountains, andosols and cambisols are pre-dominant.

1.2 Present biodiversity status and trends: habitats, fauna and flora

1.2.1 Habitats, richness and trends

In the period following the latest ice age, the Pannonian basin was covered with dense oak forests, with limes *Tilia* spp., elms *Ulmus* spp., ashes *Fraxinus* spp., and hazel *Corylus avellana*. During a relatively humid phase, species of beech *Fagus* and hornbeam *Carpinus* forests dominated. The natural wood vegetation has now been almost entirely destroyed and has been replaced by an extensive steppe landscape called Puszta. Much of the climazonal vegetation of the lowlands has been transformed into arable land and pastures. Significant habitats with high biodiversity of native species mainly occur on sites not suitable for intensive cultivation and agricultural production, especially on sandy, salty, or wetland sites or in hilly areas.

The present principle habitats include forests, forest-steppe formations, salt and sandy habitats, vegetation on rocks and screes. Natural potential vegetation is dominant in very restricted areas. Agriculture, forestry, urbanisation and water management have had profound influences on the distribution, structure and quality of habitats and species. Many areas that have been modified by centuries of human activities are important for biodiversity and are nevertheless of great conservation value. Traditional agriculture and forest management was sustainable, and biological diversity remained relatively high.

The situation has changed dramatically since the 19th century. Natural habitats have diminished as a result of forest clearance, drainage, the ploughing of meadows and the use of pesticides. Habitat destruction has been the main cause for endangering the existence of particular species as well as the extinction of others. Populations of animal and plant species are increasingly fragmented and isolated from one another.

Table 2. Main habitat types in the Pannonian biogeographical region, as defined by EUNIS (European Nature Information System) habitat classification

Habitat type	Proportion
Regularly or recently cultivated habitats and gardens	67 %
Woodland and forest habitats and other wooded lands	17 %
Grassland habitats	8 %
Constructed industrial and other artificial habitats	5 %
Heathland and scrub habitats	2 %
Freshwater aquatic habitats	1 %
Bogs, fens and mires habitats	0.5 %
Inland sparsely vegetated or unvegetated habitats	< 0.1 %

***Source**: ETC/NPB.*

1.2.1.1 Forests

Seventeen percent of the Pannonian region is covered by forests. Earlier, most of the region was covered by forests, with willow-poplar woods on floodplains, oak-hornbeam forests and oak-dominated thermophilous woods in other areas, and at higher altitudes beech forests. Deforestation began many centuries ago, resulting in agricultural and pastoral land. Forest management practices in the latest decades have led to the planting of large areas of fast-growing tree species like the introduced black locust *Robinia pseudoacacia*, willows *Salix* spp. and poplars *Populus* spp. Only sparse undergrowth vegetation can survive in these plantations. Oak forests on loess are very important for biodiversity. They are floristically extremely rich but today mainly occur in small fragments. Today only in the northern Hungarian region relatively extensive areas of oak forest can be found (e.g. in the vicinity of the village of Kerecsend). For example around 1 000 plant species has been recorded in a 106 ha oak forest — almost half of the total number of species known in Hungary.

The decreasing swamp woods have significant natural values in Hungary. Oxbow and adjacent swamp woods close to the Tisza river.
WWF Hungary/Ferenc Kis.

1.2.1.2 Grasslands

Grasslands of major conservation importance represent 8 % of the region. It harbours numerous rare and threatened taxa, including, *Crambe tatarica* and *Adonis transsylvanica*. Dry plain-grasses and rock-grasses are found in both mountains and plains. In recent decades, disappearance and fast deterioration of the flowery meadows in mountainous and hilly regions are the most striking signs of the decrease in biological diversity in the region. Loess steppe vegetation only remains in very few patches where agriculture has not been possible. Alkaline steppes form about 30 % of grasslands in Hungary and within grazed areas the proportion is even higher. Both the botanical and zoological importance of these areas is significant. Some protected bird species have their nesting sites there. Dolomite steppe habitats occur on the hard soils of the mountains.

Crambe tatarica, a threatened species in the grasslands of the Pannonian biogeographic region.
***Source**: <http://rostliny.nikde.cz>.*

Sandy grasslands were once common in the region, but over recent years they have become restricted, largely because of human activities and drier climatic conditions. Only remnants of sandy habitats can be found, but they have a high natural biodiversity and are rich in endangered and rare species. Four types of sandy habitats can be distinguished, each one representing a successional stage:

- The first stage is characterised by a sparse cover of early-blooming plants, mostly ephemeral, colonising sand, and in particularly dunes. Typical species of this stage are: *Kochia laniflora* and bugseed *Coriospermum nitidum.*
- Open sandy habitats which constitute the second stage of succession in colonisation are very rich in species. Characteristic examples are: dyer's alkanet *Alkanna tinctoria* and spurge *Euphorbia seguieriana.* The important species on

acid sands of this stage are grey hair-grass *Corynephorus canescens*, rat's-tail fescue *Vulpia myuros* and shepherd's cress *Teesdalia nudicaulis*.

- Semi-closed sand steppes of the Hungarian Plains represent the third stage and are developed on calcareous sands with a degree of cover reaching 70–80 %. They are dominated by fescue species *Festuca wagneri*, and accompanied by a species assemblage partly constituted of elements of the open perennial grasslands, but mainly of steppic grasslands, with for example cinquefoil *Potentilla prenaria* and white mullein *Verbascum lychnitis*.
- Closed sandy habitats represent the final stage and are typified by species such as fescue species *Festuca rupicola* and pink species *Dianthus diutinus*, with endemic taxa like some iris e.g. *Iris arenaria* and some flax species e.g. *Linum hirsutum*.

Only about 20 % of the salty habitats are of natural, ancient origin. The rest are secondary, and originated mainly as a result of river regulation at the end of the 19th century. Species richness of the salty habitats is not high, but it is characterised by a rich mosaic of ca 50 plant communities. Typical species of salty habitats include mugwort *Artemisia santonicum* and glasswort *Salicornia europaea.* Unique communities of oaks on salty soils are specific to the region. The fescue *Festuca pseudovina* represents a typical grass of salty communities.

1.2.1.3 Wetlands

Two main wetland types can be distinguished in the Pannonian region, depending on whether they are continuously or temporarily waterlogged. Continuously waterlogged meadows are found in certain climatic zones. They remain stable and are formed by plant communities with high natural values. They are protected in the total range of their distribution. A number of glacial relict species occur, for example: the globe flower *Trollius altissimus* and the alpine butterwort *Pinguicula alpina.* A number of rare species are typical such as *Allium suaveolens* and great fen ragwort *Senecio paludosus*. These areas are also rich in orchids, 10–12 species can be found in some sites.

Pinguicula alpina, *the alpine butterwort is a glacial relict species in waterlogged meadows in parts of the Pannonian region.* ***Source****: <http://rostliny.nikde.cz>.*

Temporarily waterlogged meadows need management for persistence. Several types of *Molinia*-meadows form this group. The plant communities here are of particular interest in late summer, when many of the more typical species are flowering: devil's-bit scabious *Succisa pratensis* and superb pink *Dianthus superbus.* These habitats have to a large extent deteriorated, especially over the last 25 years.

There are a very limited number of raised peat bogs, transition bogs and spring swamps. Bogs can be found in the mountains of Hungary near small springs and streams on acidic soils. Two real raised peat bogs which can be found in the northern region and in northern Great Plain region of Hungary (at the villages Kelemér and Csaroda, respectively) are remnants of the glacial period. Being unique to the Pannonian region, they are of great importance for nature conservation.

1.2.1.4 Water habitats

The whole Pannonian region lies within the watershed of the Danube. Most of the water comes from surrounding areas. All the main rivers (Danube, Tisza, Drava, Rába, Váh, Tamis, and Mures) flow from mountains around the region. Streams and springs represent important habitats for particular fish and invertebrate fauna. Lowering the ground water table level and the embankments of the spring beds has, in some cases, very seriously damaged these habitats. The region is relatively rich in lakes. Two of the biggest — Lake Balaton and Lake Velence — have been considerably modified in recent years. Both are relatively shallow — e.g. the average depth of the almost 600 km^2 large Lake Balaton is 3.2 m — and much of their water evaporates during the summer. As a result, they are particularly sensitive to changes, and are easily influenced by nutrient input and resulting algal blooms. Salt lakes in the lowlands are a particular feature of the region. During the last 15 years, however, most of these lakes have dried out.

1.2.2 Fauna and flora

Species composition and biodiversity of the Pannonian region has largely been determined by the postglacial history of the territory (especially climatic changes), the diversity of habitats and human influence. Thermo- and xerophilous species are dominant in the region. Nevertheless, species of wet habitats form an important part of taxonomical diversity. In the region, a relatively high amount of species is concentrated in a small area. Except for typical Pannonian species, which are mainly endemic or sub-endemic, there are other important groups of thermophilic- and xerophilous species, belonging mainly to sub-Mediterranean and Pontic geo-elements. Carpathian species are found in the north, especially in mountains of northern Hungary and southern Slovakia and, to a smaller extent, in Romania. Specific flora and fauna elements inhabit the Mecsek Mts., with a noticeable Mediterranean influence. The western parts of the Pannonian region are influenced by the Alpine region.

Table 3. The number of vertebrate species (excluding fishes) found in the Pannonian biogeographic region and the number of species threatened at the European level

	Total	Mammals	Breeding birds	Amphibians	Reptiles
Number of species	332	78	222	16	16
Number of threatened species at European level	79	13	66	0	0

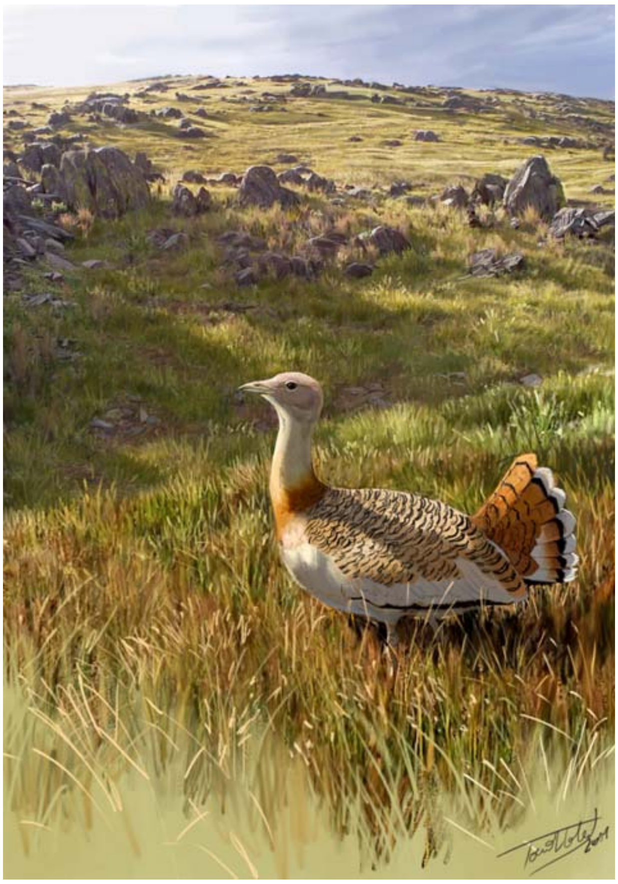
***Source**: ETC/NPB.*

1.2.2.1 Fauna

The number of animal species in the Pannonian region is estimated to 42 000–45 000. Invertebrate species constitute 99 % of total fauna species. Some unique communities of Pannonian animals inhabit grasslands, salt grasslands, wetlands, forest, river valleys and karst terrains. The region hosts a significant population of the great bustard *Otis tarda*, measures for securing the species existence is of importance for the survival of this large European bird species (Kollar, 1996). Pannonian endemic taxa belong to various different animal groups: Reptiles (*Lacerta vivipara pannonica* and *Vipera ursinii rakosiensi*), Arachnids (*Dictyna szaboi*), Orthoptera (*Chortippus acroleucus* and *Miramella irena*), Gasteropods (*Paladilhia hungarica* and *Sadleriana pannonica*). The steppe and meadow viper (*Vipera ursinii* complex) nowadays occur in scattered, and — due to habitat loss decreasing — populations across Europe (cf. Nilsson and Andrén, 2001). The population of the Hungarian (nowadays extinct in Austria and Romania) subspecies of the meadow viper (*Vipera ursinii rakosiensi)* is now classified by IUCN as 'endangered' and listed as a 'priority species' in the Annex II of the EU Habitats Directive (EC, 1992).

The Birds Directive Annex 1, species and subspecies

A total of 70 bird species in the region are included in the Birds Directive Annex 1.



Source: *ETC/NC. Please note that the estimate is limited to breeding species.*
Great bustard, *Otis tarda.*
Drawing : Toni Llobert, Catalonia.

1.2.2.2 Flora

Around 2 500 species of higher plants have been recorded in the Pannonian region. Habitats on sands and salty soils host important vegetation types which are more common in the Pannonian region than anywhere else in Europe. Important vegetation types also inhabit wet meadows, marshy meadows and swamps. Endemic taxa are found mainly in grassland, for instance *Suaeda pannonica*, *Syringa josikae*, *Vincetoxicum pannonicum*. There are about 50 relict species, mostly from interglacial periods. Only one species, oriental hornbeam *Carpinus orientalis* is a relict of the Tertiary period. Around 36 plant species have recently disappeared from the region, including one endemic saltmarsh grass *Puccinellia pannonica*.

2. What is happening to biodiversity in the Pannonian biogeographic region

2.1 Main pressures on biodiversity

Grasslands in the region represent semi-natural habitats where biological diversity is maintained in conjunction with human activities. Their existence depends on specific types of management that are used both for mowing and grazing. Grasslands on salty and sandy soils are relatively fragile and can only stand extensive grazing. There are many local breeds of cattle in the Pannonian region, as well as ancient local types of fruit trees. Native tree species form a basis for forestry, although alien tree species and cultivars are used as well. Wetlands are used in several ways, for instance reed *Phragmites australis* is traditionally used for thatching houses. Almost all water habitat types are used for fishing, which is a relatively common leisure activity. Fish are bred in special ponds and some used for the strengthening of natural populations in rivers and lakes. A number of alien fish species have been introduced, which sometimes causes a negative influence on the original fish biodiversity. Several mammal and bird species are hunted. For example as regards Hungary only 50 000 (0.5 %) of the population are registered hunters, but additionally this is one of the most important European countries for hunting tourism (FACE Europe, 2007, Hungarian Hunters' National Association, 2007).

Changes during recent years have been characterised by continued industrialisation, urbanisation, as well as pressure on arable land, forests and wetlands. Regularly or recently cultivated habitats represent ca 67 % of the Pannonian region. Land cover has changed considerably. For example, over the last 150 years the area of the floodplains in a natural state in Hungary has decreased from 23 000 to 1 528 km², a decrease by 93 %. Nearly all floodplains are today used for agricultural crop production or grazing. Waterways have been modified, for instance the length of Tisza River alone has been shortened by 134 km. Traditional management of wet meadows and mowed areas virtually disappeared during recent centuries in line with the decline of traditional farming. All these changes have induced pressure on species and habitats. Political change and economic transition during the 1990s have implied significant modification of landscape structure. The consequences on biodiversity of this ongoing process cannot yet be fully evaluated.

2.1.1 Agriculture intensification and extensification

Agricultural practice has been intensive in recent years with high use of artificial fertilisers. Agriculture has mostly influenced loess grasslands, since the soil is particularly suited for cultivation practices. In Hungary, for example, even poor or remote lands were cultivated for barley, wheat and maize because the state used to guarantee the purchase of these crops. Before privatisation, the average area cultivated by collective farms was 3 500 hectares and 7 000 hectares by state farms. The ploughland consisted of vast contiguous areas of tableland. The differences in micro-relief were evened up in 20-30 years. The smaller watercourses were eliminated and large areas were drained, in some places the dense network of irrigation canals developed into key landscape elements. The earlier pattern of small plots, hedgerows of trees, dividing balks and smaller erosional rills disappeared. The landscape structure was simplified and its ecological network was weakened.

The political change has resulted in a new property structure by the end of 1994, which has caused or will cause remarkable changes in landscape ecology. Obvious is the large-scale appearance of 3–5 ha plots even in the plain lowland areas. New plot boundaries, alleys and dirt roads appeared which have begun to function as landscape ecological corridors. In the first years of privatisation, the amount of fallow lands increased. 5–8 % of arable land remained uncultivated. The newly established areal patterns have not been better adapted to finer ecological differences or the quality of the soil. Easily accessible land is used for growing cereals; irrespective of soil quality whereas even fertile out-lands in unfavourable positions have been abandoned. The level of mechanisation has drastically decreased and some farmers have reverted to using horse drawn ploughs. The consumption of artificial fertilisers has declined to an average of 50–100 kg of active ingredients/ha, with no use at all in many farms. In certain areas the tendency towards intensification continues, especially in terms of water-management measures undertaken on agricultural land, particularly on meadows and pastures in waterlogged areas of alluvial plains.

2.1.2 Drainage, irrigation and salinisation

In the past, wetlands covered much larger areas in the Pannonian region than today. The process of creating arable land through drainage of large areas of marshy meadows and river regulation started at the end of 19th and beginning of 20th centuries. The main rivers have been shortened. Only small remnants of wet meadows persist, in some areas they have disappeared completely. Large areas of marshy meadows in the regions of Kiskunság and Turjan have been destroyed by drainage and channel construction. Although many marshy meadows are protected now, they are continuing to dry out, often unintentionally. Drainage systems are effective and the climatic conditions are becoming warmer and drier.

The white stork, Ciconia ciconia, *use wetlands and marshy meadows to search for the main prey, frogs and toads.*
Photo and copyright: Linus Svensson, ZooBoTech.

The relatively dry climate of the central and eastern areas of the Great Hungarian Plain has led to the construction of large-scale irrigation systems, mostly in the Tisza River basin. The irrigation of the Hungarian plain has caused salinisation and alkalisation in more than 20 % of the area. In Romania, irrigation has increased since 1965 and is used on more than 20 % of the agricultural land. About 200 000 ha have been salinised, which represents around 6 % of total irrigated land. Salinisation is reversible but reclamation of saline and alkaline soils is expensive and requires complex amelioration techniques.

2.1.3 Eutrophication

In the past the ecological equilibrium of large lakes such as Balaton and Velence has been disturbed. Intensive use by tourists, lack of sewage handling systems, as well as the use of fertilisers and livestock breeding in the surrounding agriculture areas have led to eutrophication, with the annual appearance of algal blooms and the death of fish. Another consequence of eutrophication has been the establishment and spread of reed *Phragmites australis* in the marshy meadows, which has reduced the specialised native vegetation.

In summer, the resident human population on the shores of Lake Balaton jumps from 250 000 to 860 000. During the 1950–1975 periods, eutrophication of the lake became a serious problem. This was the result of the growing use of fertilisers and the inflow of phosphorus from sewage discharges originating from lakeside towns and tourist facilities. Algal blooms became particularly frequent in the most polluted western part of the lake. A new pollution control programme has been established. Sewage treatment has improved. Agricultural pollutants in the Zala River at the southwest end of the lake are now retained in a newly constructed series of reservoirs comprising a wetland complex of almost 15 000 ha, composed of open water, reedbeds and *Salix* scrub. Ten per cent of the area has been designated as a Ramsar site.

In the Neusiedler See, a large shallow lake in the northwest of the region with an average depth of 1.5 metres and a reed bed of 178 km², substantial changes of the indigenous fish communities have been caused by artificial stocking of eel *Anguilla anguilla* and the alien grass carp *Ctenopharyngodon idella*. This has led to a decrease in populations of pike *Esox lucius*, pike-perch *Sander lucioperca*, crucian carp *Carassius carassius* and tench *Tinca tinca*. Other species such as *Leucaspius delineatus*, *Misgurnus fossilis* or *Cobitis taenia* have altogether disappeared. There exists a strong food competition between the eel and other species such as carp, crucian carp and tench in the transition zones between open water and reed beds.

Strong correlations have been observed between eutrophication, regulation of the water level, stocking – also with alien fish species — and increase of herbivorous fish species as well as the decrease of the diversity of the natural fish species. High abundance of fish has led to an accelerated internal nutrient loading in the lake, which has further been increased by stocking of the grass carp. Moreover the proportionally low abundance of predators (pike and perch *Perca fluviatilis*) has led to an uncontrolled increase in herbivorous species.

2.1.4 River regulation

Water regulation and alteration to make rivers navigable for large ships have affected radically their wildlife and biological diversity. Embankment has changed the physical and chemical characteristics of water bodies, leading to deeper ground water levels. Dams, for example on the Romanian and Slovakian part of the Danube River, have made it impossible for fish to migrate. The river regulations have affected forests on floodplain areas, which have been experiencing a slow degradation as a result.

Alteration to make rivers and waterways navigable is decreasing the physical complexity and results in a lower biological diversity. Flooding is controlled and the water table is lowered.
***Photo**: Chris Steenmans.*

2.1.5 Forestry

Native forests of the Pannonian region are under pressure from several factors. The alien tree black locust *Robinia pseudoacacia* has shown to thrive on the extensively drained sandy grasslands. There thus are larger plantations (292 000 ha) of black locust in the region than anywhere else in Europe. The invasive behaviour of this species, spreading uncontrollably, is a threat to native vegetation. Non-native conifer species such as Scots pine *Pinus sylvestris* are also widely distributed (243 000 ha) particularly on higher land, as well as non-natural poplar *Populus* spp. clones in floodplain areas. Valuable indigenous oak and beech tree stands have been replaced. Deforestation of the forest steppe vegetation occurred at the end of the 1900s, particularly in Romania. This process stemmed from forest management, air pollution and natural disturbances accelerated by an ongoing lowering of the soil water level. Although not so pronounced now, dry conditions still damage the lowland forests.

2.1.6 Defoliation

Forests have been damaged by air pollution and drought for years. The health status of forests is being monitored using defoliation as an indicator of tree health. The reasons for defoliation are not completely known: climatic reasons, as well as insect and fungal attacks, which follow mild winters, could contribute to the problem. However, defoliation is primarily monitored because of the link to long-range air pollution (UNECE/ICP Forests, 2005). Results show that forests in the Pannonian region belong to the moderately damaged category in terms of defoliation. The situation degraded progressively between 1988 and 1992, however, since then, no significant change has been recorded. In 1996, defoliation in Hungary was registered as: 37.5 % slightly damaged, 14.1 % with medium level defoliation and 2.4 % severely damaged. 2.8 % of the trees did not survive. Species like oak *Quercus robur* and *Q. petraea* were particularly affected, more than 25 % of the trees died. Others like black locust *Robinia pseudoacacia*, beech *Fagus sylvatica* and hornbeam *Carpinus betulus* were not so heavily affected.

2.1.7 Mining

Economic interests come into conflict with the conservation of wetland vegetation in the Pannonian region. An example is bauxite mines established after the World War II. The technology used required vast quantities of water and by the end of the 1980s it becomes apparent that the water supply of adjacent marshes was lowered. When the mining was closed (possibly not only because of this) water was converted back to the area. A strictly protected species in Hungary, the Birdseye primrose, *Primula farinosa subsp. alpigena*, almost went extinct but this was halted as a result of the restoration activity.

Cyanide and heavy metals pollution of the rivers Szamos, Tisza and Danube

Accidents and the resulting water pollution represent serious threats for living organisms in the rivers. A big accident, which has been termed 'the worst environmental disaster in Europe since Chernobyl', occurred in January and February 2000 in the Szamos and Tisza rivers.

The cyanide pollution of the rivers Szamos and Tisza was caused by the AURUL (an Australian-Romanian venture) located in Baia Mare (Romania). The company extracts non-ferrous metals from the waste rock piles of the mines, using extraction with cyanide. The environmental damage was the result of bursting of a tailings dam containing cyanide. As a consequence, almost 100 000 m^3 waste water with high concentrations of cyanide was spilled into the Zazar and Lapos water courses that belong to the catchment area of river Szamos. The pollution consists mainly of metal complexes of cyanide. Measurements detected in addition to cyanide a significant amount of cooper and zinc. The maximum values measured in the Szamos river were 300 times higher that the limit values of the 'heavily polluted water' category, 100 times higher in the upper section of the river Tisza, and 20–30 times higher in the lower section of the river Tisza. In addition to cyanide pollution the concentration of dissolved heavy metals — primarily copper and zinc — increased significantly, for example in the river Szamos, the peak value of the cooper was 160 times higher than the limit value for heavily polluted water, the concentration of zinc also exceeded the limit value set by this category.

The flow of the polluted water through the rivers caused ecological damages at a magnitude that at present only can be estimated. Both in Szamos and Tisza the transport of the polluted water body was followed by massive death of fish. An overall death of invertebrates was recorded as well. Only few living organisms could be found after the accident. Biologists stated that the level of death in terms of phyto-and zooplankton is almost 100 % in the Szamos and the affected upper Tisza section, whereas in the lower Tisza section, due to dilution, the impact was lower. The effect of the pollution spread to more distant ecosystem parts through food chains. The pollution affected several protected and strictly protected nature protection areas such as part of the Hortobágy National Park, areas designated in the Ramsar Convention, and biosphere reserves that are parts of the MAB programme of UNESCO. Another area at threat, Lake Tisza area was saved by closing a dam before the polluted water arrived. The Danube River in Hungary and former Yugoslavia was also seriously affected.

A second accident that occurred shortly afterwards, further polluted the Tisza river with heavy metals. These elements persist in food webs and will have a long-term impact on biodiversity. Accidental pollution by oil products due to damaged pipelines in Ukraine have occurred several times in recent years. International cooperation is urgently needed in order to prevent similar accidents.

3. Policies at work in the Pannonic biogeographic region

3.1 Biodiversity policy initiatives

3.1.1 Sofia initiative

At the conference of European Environment Ministers in Sofia, held in October 1995, the central and eastern European (CEE) countries agreed to work together on four main initiatives: local air pollution, economic instruments, environmental impact assessment and biological diversity. The main purpose for establishing the biodiversity initiative was to link the environmental action plan for the CEE countries with the pan-European biological and the landscape diversity strategy.

3.1.2 WWF Danube-Carpathian Programme

The WWF Danube-Carpathian Programme has worked in the region since 1998 to promote the conservation, restoration and sustainable management of nature for the benefit of both people and environment (WWF, 2006). The work is primarily focused on freshwater and forest resources in the Danube River basin and Carpathian Mountains. A main objective is thus to re-establish the Danube river natural floodplain ecosystems. Projects have been set up to reduce water pollution, protect animal, plant species and their habitats. It also aims to show the economic and social benefits of protecting and restoring the functions of natural floodplains. On-going projects are located in the border area of Gemenc-Beda-Karapancsa (Hungary) and Kopacki Rit (Croatia), as well as the Morava River (Slovakia, Austria, Czech Republic).

3.1.3 The Regional Environmental Centre for Central and Eastern Europe

The Regional Environmental Centre for Central and Eastern Europe (REC) is a non-profit making organisation whose mission is to help solve environmental problems in Central and Eastern Europe (CEE). REC encourages cooperation among non-governmental organisations, governments and businesses, supporting the free exchange of information and promoting public participation in environmental decision-making. The REC has its headquarters in Hungary and 17 country offices as well as two field offices. Biodiversity aspects are to some extent covered within several REC activities, e.g. the Environmental Law programme (REC, 2006).

3.1.4 International cooperation for the water management of the Tisza River basin

The aim of this project is to develop a technical basis for cooperation between the five sharing territory in the Tisza River basin, the largest sub-basin of the Danube River basin states: Hungary, Romania, Serbia and Montenegro, Slovakia and Ukraine. It was financed in the framework of the European Union PHARE Regional Environment Programme's contribution to the Environmental Programme for the Danube River basin. The Tisza countries are currently developing a Tisza River Basin Management Plan to meet requirements of the EU Water Framework Directive. The first step towards this objective is the preparation by 2007 of the Tisza analysis report — including an overall characterisation of the basin, an analysis of anthropogenic pressures and impacts, and flood risk mapping (ICPDR, 2007).

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