Conservation of Mediterranean Wetlands
A MedWet publication

Characteristics of Mediterranean Wetlands

F. Pearce & A. J. Crivelli

The Tour du Valat would like to thank all those
who have been involved in the production of this publication.

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MedWet

The MedWet action

The Mediterranean basin is rich in wetlands of great ecological, social and economic value. Yet these important natural assets have been considerably degraded or destroyed, mainly during the 20th Century. To stop and reverse this loss, and to ensure the wise use of wetlands throughout the Mediterranean, a concerted long-term collaborative action has been initiated under the name of MedWet.

A three year preparatory project was launched in late 1992 by the European Commission, the Ramsar Convention on Wetlands of International Importance, the governments of Spain, France, Greece, Italy and Portugal, the World Wide Fund for Nature, the International Waterfowl and Wetlands Research Bureau (IWRB) and the Station Biologique de la Tour du Valat.

This project focuses on that part of the Mediterranean included within the European Union, with pilot activities in other countries such as Morocco and Tunisia. Two thirds of the funds are provided by the European Union under the ACNAT programme and the remainder by the other partners.

The concept of MedWet and its importance for the wise use of Mediterranean wetlands was unanimously endorsed by the Kushiro Conference of the Contracting Parties to the Ramsar Convention in june 1993.

The MedWet publication series

Wetlands are complex ecosystems which increasingly require to be managed in order to maintain their wide range of functions and values. The central aim of the MedWet publication series is to improve the understanding of Mediterranean wetlands and to make sound scientific and technical information available to those involved in their management.

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F. Pearce & A.J. Crivelli

Number 1

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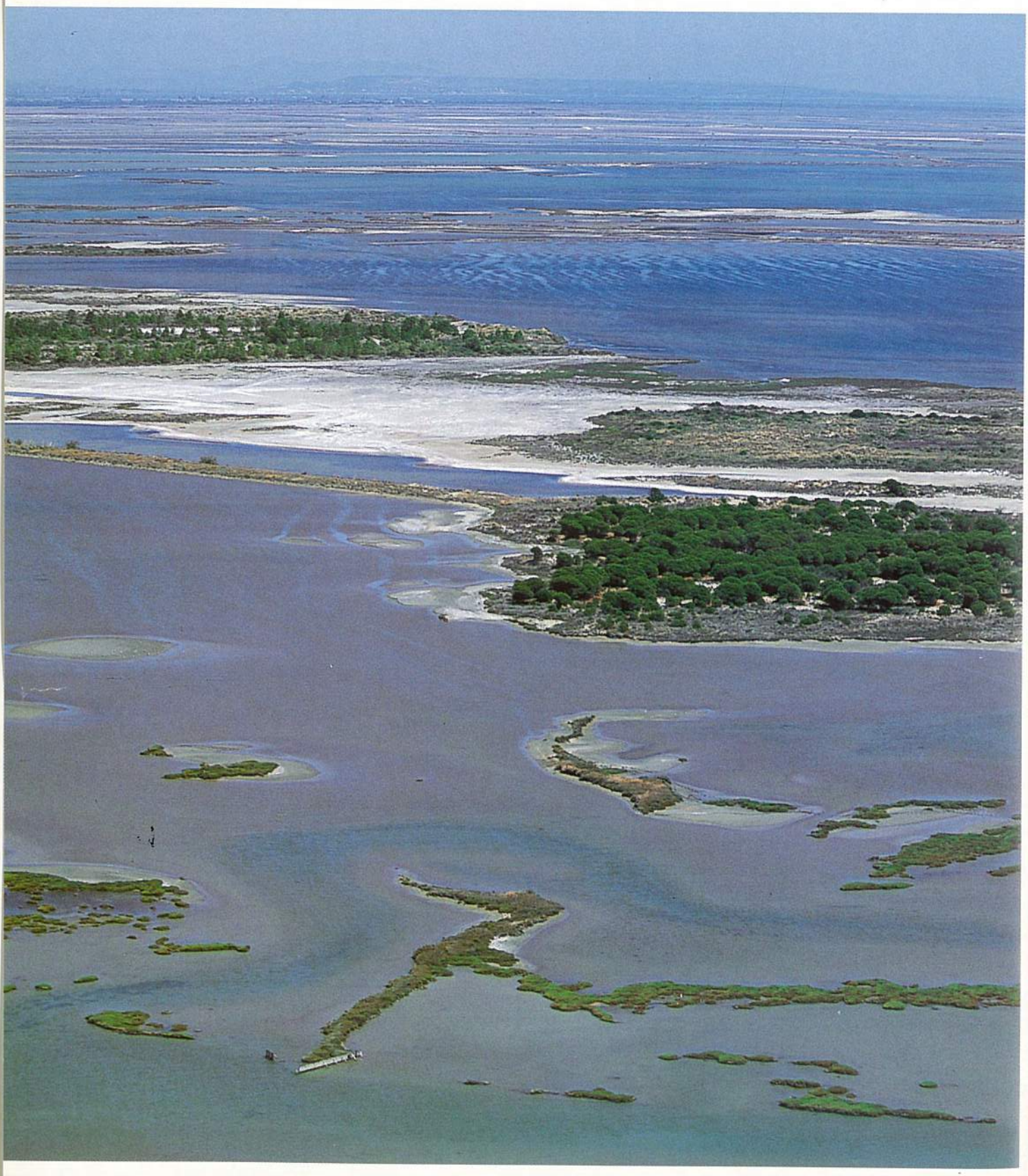

A. Johnson / Tour du Valat

Preface

The importance of wetlands for the future of our living world becomes increasingly recognised. Not only are wetlands areas of exceptional biodiversity, they play also a key role for the conservation and management of freshwater resources. Moreover, they are intimately connected with the livelihood of people living in and around them.

Wetlands are complex ecosystems. Small changes may have strong impacts not only on the wetlands themselves, but on large parts of the catchment where they belong.

This means that those who are in charge of wetland management, in national or local government agencies and in NGO's, bear a high degree of responsibility. Are they fit to assume this ? Do they have enough understanding of the functioning of the ecosystems of their socio-economic importance and of the techniques available for their management ?

Much research has been done on those matters in the past decades. Most of the results are published in scientific journals unavailable for wetland managers and in an often esoteric style. There is an urgent need to make all this information easily accessible to wetland managers.

This is the purpose of this booklet and of the others which will follow in this series in the next three years.

Luc Hoffmann
President
Tour du Valat Fondation

Lagoons of the Camargue : an "untamed wilderness" of flamingoes and white horses

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Introduction

Wetlands are one of our planet's most precious resources. They are second only to rainforests as reservoirs of biodiversity and natural productivity. Furthermore they play important roles in vital planetary processes such as the hydrological cycle and the servicing of migratory fish and birds.
Yet, like rainforests, they are being destroyed at an unprecedented rate, often with the help of development banks and, in the Mediterranean region, the European Community.

F. Mercay / W W F / BIOS

Ichkeul : Tunisia's greatest surviving inland lake

Today, few in Europe would argue that tropical rainforests are wastelands, their resources free for anyone to plunder. Yet many Europeans continue to regard their own wetlands in this way. Marshes, they say, are for draining and clearing and, once reclaimed from nature, for bringing into private ownership and "developing" — as rice paddies or shrimp farms, marinas or leisure complexes, ports or waste dumps.

Wetlands face many other threats. Their water is siphoned off, either using pumps sunk into the wetland or when rivers draining into them are dammed far upstream. Nutrients from sewage and agricultural fertilisers feed explosive growths of algae in lagoons that remove all oxygen. Even the most remote and pristine wetland is under threat. They contain the most extensive wildlife, and so become magnets for tourists.

As with rainforests, modern forms of economic development damage nature and natural processes, and undermine traditional methods of harvesting the abundance of the wetlands. Tragically, many of these development schemes also fail to meet their own objectives — overwhelmed by natural processes, from flooding and silt accumulation, to a build-up of salt in fields or the unforeseen arrival of some weed or predator.

Much development of wetlands to date has proved unsustainable in the longterm. For wetlands are the most dynamic of environments, and their shifting sands and waters, their constantly changing biology, are hard to predict.

Part of the unpredictability arises because wetlands exist at an interface between terrestrial and aquatic environments, changing their character with the seasons. Sometimes they are land and sometimes water, sometimes saline and sometimes fresh, sometimes eroding and sometimes accreting. Their wildlife is similarly transitory.
Migrating birds will arrive in their tens of thousands one year but,

Faced with declining yields from their traditional sources of income, such as fisheries, many rural communities demand ever greater public expenditure on equipment and infrastructure, in a frequently-doomed effort to reap yet more from the over-exploited wetlands.

sensing a drought perhaps, or better conditions elsewhere, keep away the next. Fish, too, migrate in and out of the lagoons, and plants may "bloom" one year, yet be absent the next.

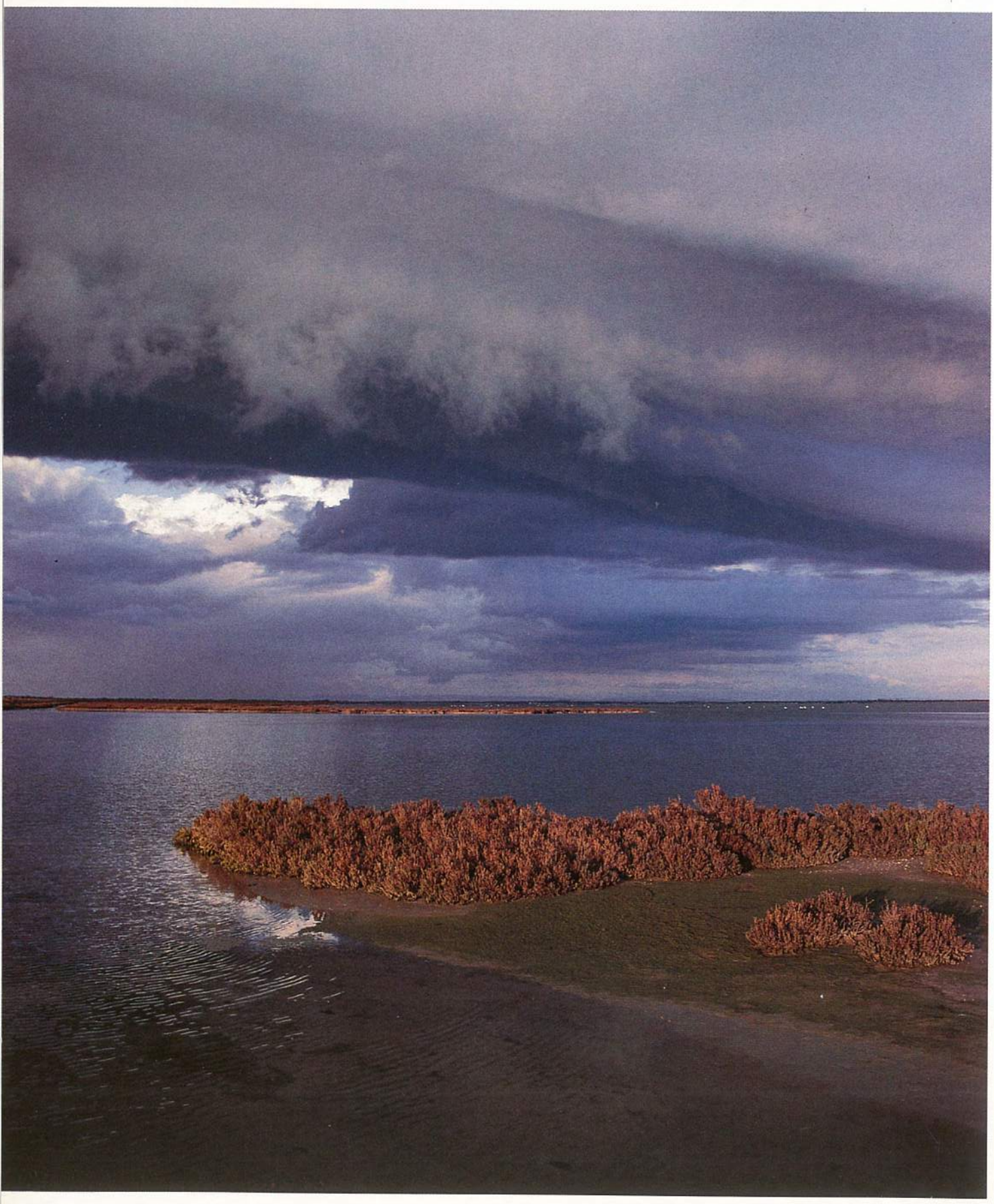
Being at the dynamic boundary of physical as well as ecological systems, wetlands often respond dramatically to change, both natural and anthropogenic. A dam hundreds of miles away can send a growing delta into full-scale retreat overnight, turn lagoons saline and expose its marshes to the open ocean. Few doubt that the changes in climate and sea levels predicted for coming decades will have some of their most dramatic and unpredictable consequences in coastal wetlands.

But, there is a fight-back in progress. The rise of the environmental lobby has coincided with a growing awareness among scientists and economists of the value of wetlands in maintaining fisheries, preventing flooding, attracting tourists and underpinning local economies. Governments are increasingly willing to regard what they previously saw as "wastelands" as resources that require conserving for the greater public good.

The Prespa National Park (Greece) is an important centre of biological diversity, containing more than a thousand plant species. Each spring, fish spawn in the flooded meadows around the lakes and provide food for water birds and people. Lake Mikri Prespa is an important breeding ground for Dalmatian (*Pelecanus crispus*) and White Pelicans (*Pelecanus onocrotalus*). The lake and flooded meadows also support an endemic population of invertebrates and fish (e.g. *Barbus prespensis*).

However, these changes are patchy. Protection of the environment has yet to capture the public imagination in southern Europe, let alone in north Africa, in the way that it has further north.

The call now is for an integrated strategy for conservation of wetland resources. Some want to erect barricades around surviving wetlands, keeping out all but a few people. But any successful strategy in the modern world must be based around the needs of both nature and the communities that live and depend on the surviving wetlands. Conservation in the increasingly crowded Mediterranean basin must depend on the sustainable management and exploitation of the available resources.



B. Pambour / BIOS

Wetland types

The Ramsar Convention on Wetlands of International Importance defines wetlands as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine waters, the depth of which at low tide does not exceed six metres".

In the Mediterranean region, the most prominent coastal wetland formations are river deltas, such as the Rhone in France, Po in Italy and Nile in Egypt, along with regions of salty coastal lagoons and marshes such as the Languedoc-Roussillon region in southern France. There are few inter-tidal mud banks of the kind found in northern Europe, because the almost entirely enclosed Mediterranean Sea is virtually tideless.

Most of the coastal deltas and lagoons form because of the accumulation in tideless coastal waters of sand and silt, brought down by rivers. Because of the region's high rates of evaporation compared to rainfall, wetlands only form elsewhere if there are depressions where water from a surrounding catchment accumulates.

Once, these wet depressions were mostly river valley bottoms, where marshes and flooded forests were the norm in what must have been a much greener Mediterranean landscape. But most of these riverine wetlands have long since been drained.

In arid North Africa, there are huge, salty depressions known as chotts and sebkhets that fill with waters from flash floods. But with evaporation rates more than eight times average precipitation, the water rarely lasts longer than a few weeks.

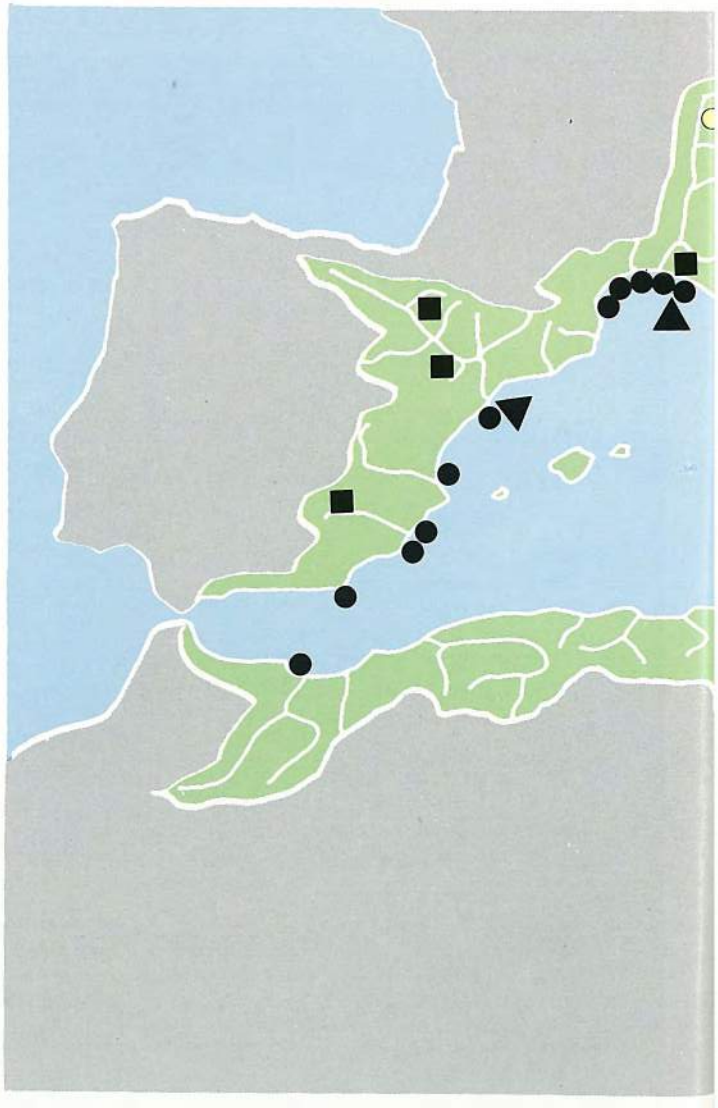
Inland today, most natural wetlands are lakes and their surrounding marshes and pastures. Most are in uplands, from the Atlas mountains of Morocco to the Balkans and the central plateau of Turkey. Increasingly, there are also artificial wetlands in reservoirs on major rivers, often created at the expense of natural formations downstream.

Salt marshes are a habitat under threat

How much wet land ?

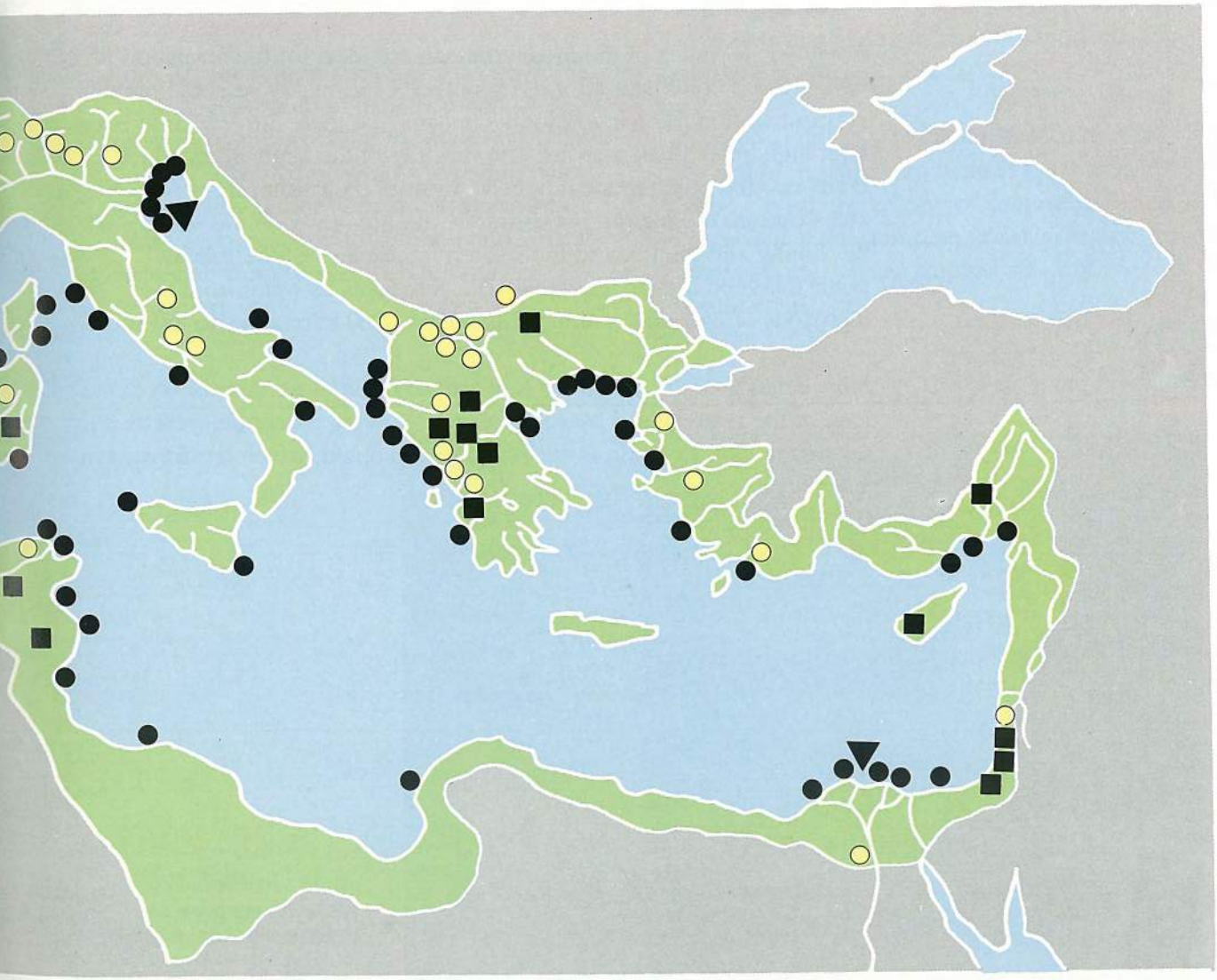
There are no accepted estimates for the area of surviving wetland in the Mediterranean region. The various definitions of wetlands give plenty of room for interpretation, especially over how much of North Africa might be covered by flooded chotts and sebkhets in any one year. Only an average area can be given.

But the main problem is the lack of credible national inventories. There are virtually no data for former Yugoslavia, for instance, and official figures for Italy and North Africa are sketchy. Several studies have been based on maps, rather than surveys. And others, reflecting the interests of the first people to take a serious interest in the conservation of wetlands, assess the sites only according to their value to birds. There are virtually no data on possible surviving wetlands in Libya. Despite these shortcomings, one reasonable estimate for the region concludes that there



○ **Lakes**
● **Lagoons**
■ **Reservoirs**
▼ **Large deltas**

are around 6,500 square kilometres of coastal lagoons, 12,000 square kilometres of natural lakes and marshes and up to 10,000 square kilometres of artificial wetlands, mostly inland reservoirs — a total of 28,500 square kilometres, an area the size of Sicily or Albania.



rincipal wetlands in the Mediterranean basin (excluding those of the upper Nile).

River deltas

The most frequent place to find coastal wetlands is at the mouths of major rivers, where silt and sand brought down to the sea are deposited as the rivers reach the calm, tide-free waters, creating dunes, marshes and new wedges of land into the sea, known as deltas.

Within the delta, the river divides into channels that shift and meander amidst a maze of sand and shingle banks, marshes and pools, created over millennia by the river itself. The main route of the river to the sea may itself change suddenly every few centuries, creating distinctive wetlands in former river beds and backwaters. Thus a typical natural delta will contain a range of different types of wetlands, usually becoming more saline the nearer they are to the sea.

The tideless waters of the Mediterranean are ideal for the formation of deltas. But a combination of steep hillsides and highly seasonal rainfall, concentrated in the winter months, means that there are few large rivers with high flows in all seasons. The majority of the large rivers which drain into the Mediterranean receive most of their water from wetter areas outside the region. For example, the Alps provide the sources of the Rhone and the Po, and the western mountains of the Iberian peninsula feed the Guadalquivir. The Nile takes its water from the highlands of East and central Africa, some 2000 kilometres to the south.

Most deltas are very old, but a few are the result of an increase in the silt load of the river caused by soil erosion following recent deforestation upstream. One example is the Ebro delta in Spain, which has formed in a bay area over the past thousand years.

White horses and flamingoes

The largest and most famous delta wetland in the European Mediterranean is the Camargue at the mouth of the Rhone in southern France. It covers some 800 square kilometres, and has a romantic, almost mystical reputation as a great untamed wilderness, wind swept home of wild white horses and a vast colony of flamingoes.
It is indeed a large area, 400 times the size of Monaco, twice the size of Andorra.
The alluvium of the Rhone delta on which it sits is 60 metres thick. But a wilderness it is not.

Only 40 per cent of the Camargue could be considered as natural habitat, much of it preserved and managed for duck and boar hunting. The hydrology of the region has been largely under human management for many centuries, and today the entire area is protected from the sea behind artificial embankments.

Tourists flock to the Camargue. They ride horses, camp on the wide sandy dunes, watch birds (more than 300 species have been recorded here), and breathe the salty air. But, almost imperceptibly, the former chaotic mosaic of wild habitats has been replaced by standardised "landuses", whether hunting marshes, irrigated rice fields, pastures or the salt lagoons, with their salinity carefully graded and maintained for the production of salt. The introduction of rice cultivation during the 1950s required the digging of some 800 kilometres of irrigation channels that captured much of the wetland's water.

Conservationists warn that if the salina, the largest in the Mediterranean (11,000 ha), were closed, the colony of flamingoes could disappear if the pumping of saline water between the salinas' lagoons was not maintained.

M. Gunther / BIOS

The introduction of rice cultivation required the digging of 800 kilometres of irrigation canals in the Camargue

Coastal lagoons and salt marshes

Most shores round the Mediterranean are rocky and steep. But wherever there are low coastal plains or deltas, there are likely to be coastal lagoons. They form because river sand and silt normally settle a few hundred metres offshore, once sea currents have slowed the river's flow. The currents then mould the deposited sand, often into spits that run parallel to the coastline. Behind the spits, lagoons form. Usually the lagoons are connected to the sea by a channel, and may also be fed by the river.

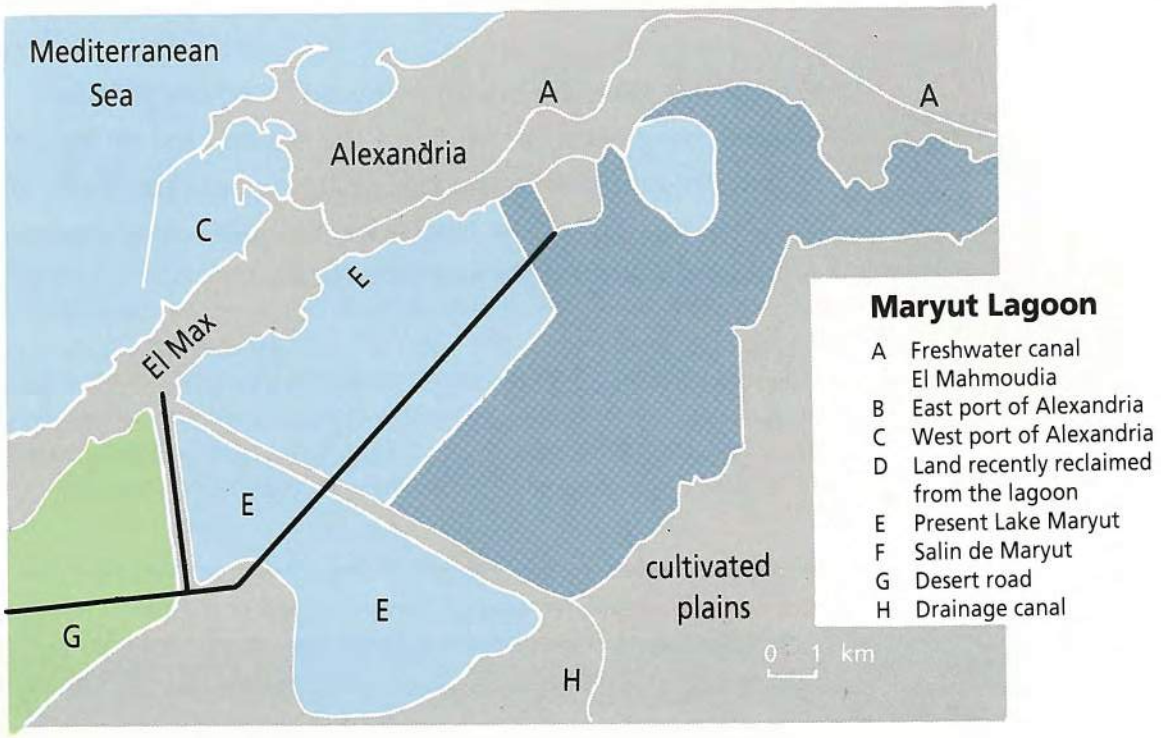
The sea's largest areas of lagoons and salt marshes are along the 200 kilometres of low Languedoc-Roussillon coastline of southern France, in northern Italy from Venice to Trieste and on the Tunisian coast. There are also extensive lagoon areas within the Po and Nile deltas.

In practice, salt marshes often merge gradually into brackish and then freshwater marshes, with vegetation types changing as the marsh salinity falls.

Eventually, as the sand spits extend, some lagoons are cut off and become fresh. This has happened in Languedoc, for instance. Some lagoons, such as the Drana in the Evros delta in Greece, have been separated from the sea by engineers, in preparation for draining for agriculture. But such efforts are not always successful. Saline water may continue to seep into the former lagoon through sand dunes or from salty groundwaters below.

The Agoulinitsa lagoon in southern Greece and a saltmarsh near Neockrori in northern Greece have defied all efforts to drain and freshen them and there are proposals to re-convert them to their initial state.

Salt marshes generally surround lagoons, or occur immediately behind coastal sand dunes. But they can extend far inland, well away from standing salt water, if they are supplied with water from springs that are fed from saline groundwaters. Sea water frequently infiltrates porous rocks, penetrating far inland, especially beneath deltas. This process can be extended when fresh groundwaters are pumped out for irrigation farming, lowering the water table and allowing salt water to replace them.



Nile's lagoon lament

By some counts, a quarter of the surviving Mediterranean coastal wetlands are in Egypt, much of it as lagoons near the outer edge of the large delta region of the Nile.
These lagoons are brackish or fresh, being cut off from the sea by sand spits formed by the action of a strong west-to-east sea current on silt emerging from the river mouth.

But over the past 150 years an extensive system of barrages and drains in lakeside marshes and canals, built with the aim of providing year-round irrigation for millions of farmers, has reformed the hydrology of the delta, changing water and silt flows. As a result, the marshes are almost gone and the four main lagoons — Maryut, Edku, Burullus and Manzalah — have shrunk. Lake Burullus has decreased in size from 588 to 462 square kilometres in recent years, and Lake Manzalah has lost 30 per cent of its open water.
Since the completion of the High Aswan dam far upstream in 1964, the entire delta has also been deprived of more than 95 per cent of its supply of silt, which once amounted to more than 100 million tonnes per year. Today, the silt is trapped behind the dam. This has accelerated the physical retreat of the delta due to erosion. The loss of silt has also dramatically reduced the quantity of natural nutrients that reach the lagoons. This, coupled with inputs of sewage and agricultural drainage water — containing pesticides, fertilisers and salt — has damaged the formerly productive fisheries in the lagoons.

Freshwater lakes

Freshwater lakes form either inland or where marine lagoons have been cut off from the sea and fed by inflowing rivers. Pre-eminent in the latter category are the fresh and brackish lagoons of the Nile delta. But there are others in the deltas of the Rhone, Po and elsewhere.

M. Gunther / BIOS

Lake Tsilit, high in the Atlas Mountains of Morocco...

The Mediterranean was not covered during the Ice Ages by glaciers and ice sheets of the kind that gouged out depressions for thousands of lakes in northern Europe. Most of the region's glacial lakes are among the region's highest peaks, in the Atlas Mountains of Morocco.

Most upland lakes in the region are either volcanic, formed in the cones of volcanoes, or "karstic" formed as water dissolved limestone rock. There are a cluster of volcanic lakes in central Italy, including the Lago di Bolsena, and many more in the central uplands of Turkey.

The often ancient karstic lakes are most evident in the Balkan region of Albania, former Yugoslavia and northeastern Greece. A few, such as Lake Ohrid, are deep. Others, such as Lakes Mikri Prespa and Skadar, are shallow and surrounded by extensive marshes.

In North Africa, there are few permanent lakes other than marine and delta lagoons. Because rates of evaporation are so high, open water soon disappears. Exceptions are Lake Ichkeul in Tunisia, and Lakes Oubeira and Tonga, two of the three lakes that form part of El Kala complex in northern Algeria (the third is Lake Mellah, a marine lagoon).

In the Atlas Mountains, there are more than 100 freshwater lakes, many of glacial origin and some of which still freeze over in winter. The largest is the 250-hectare Aguelmann Sidi Ali. Most lakes in the Atlas Mountains are relatively deep, calcareous and contain abundant submerged vegetation.

On the fringes of the eastern Mediterranean, there is also Lake Kinneret (Sea of Galilee) on the River Jordan and, upstream on the same river, Lake Hula. But Hula and its surrounding marshes, having been largely drained to provide agricultural land, may now be returned to wetland because farm yields have been poor. And Kinneret, though still a very productive fishery, is managed today principally as a holding reservoir for Israel's National Water Carrier.

Balkan retreat

Lake Skadar, on the border between Montenegro and Albania, is the largest of the many lakes in the Balkans and, with the decline of competitors, the open water and marshes make it one of the most important wetlands for birds in southeast Europe. Skadar was formed in a fold in the limestone mountains close to the Adriatic coast. It was probably a bay of the Adriatic until geological forces closed it off about a million years ago. Today, it receives water from both rivers and underground flows, through funnel-shaped solution holes in the bed of the lake. The lake varies in size from 37,000 to 60,000 hectares, flooding meadows and sustaining extensive reed beds along the plain formed where rivers flow into the lake.

A. J. Crivelli / Tour du Valat

... another mountain wetland : the Prespa National Park on the borders between Greece, Albania and former Yugoslavia

Freshwater marshes

Very few of the hundreds of freshwater marshes that once fringed the Mediterranean have survived. And where they have, flooding is almost always at least partly controlled by man. Freshwater marshes range from reed swamps around lakes to grazed wet meadows in deltas or along river floodplains.

H. Hafner / Tour du Valat

Freshwater marshes : a lush legacy from a greener Mediterranean (lake Tonga)

Many form where two rivers meet: for example, the Mekhada marsh in the El Kala wetlands complex of northeast Algeria. Mekhada covers some 9000 hectares and is the largest freshwater marsh in the region. Another is the 1800-hectare Daimiel marsh in central Spain, formed where the Ciguela and Guadiana rivers meet.

Among the largest of the surviving freshwater marshes in the eastern Mediterranean are those around the linked lakes Mikri Prespa and Megali Prespa in Greece's Prespa National Park on the high borders with Albania and former Yugoslavia. The lakes, formed in a natural enclosed depression in the hills at around 850 metres, fluctuate considerably in size, flooding wide expanses of surrounding land during the spring — particularly in May, when snow melts in the surrounding mountains.

These flooded margins contain wide expanses of reed beds and meadows. The reeds have spread further as a result of a ban on traditional reed burning within the Greek National Park, becoming so thick in places that they cut off access by fish to their meadow spawning areas.

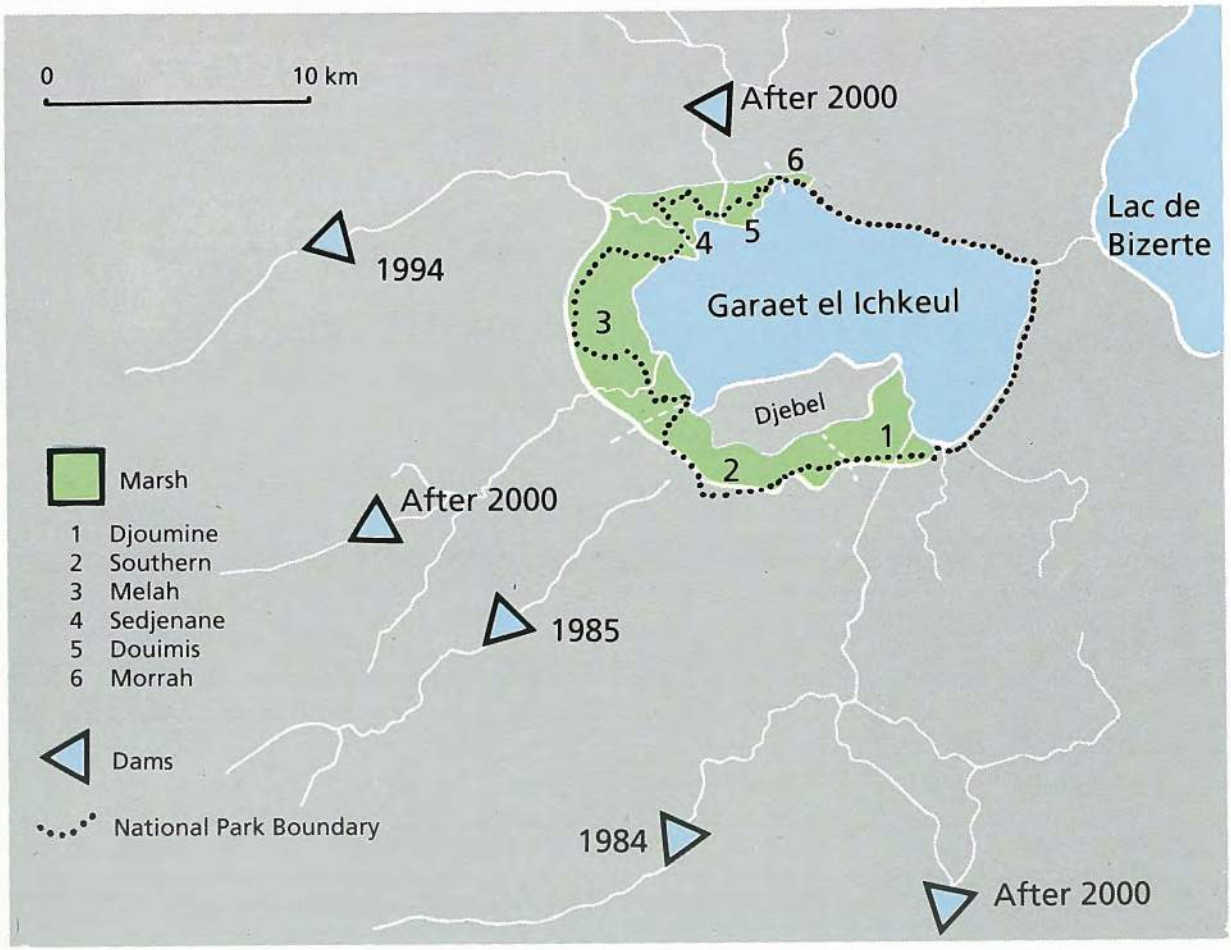
Here, as in other karstic lakes, the hydrology of the lake and its marshes depends as much on the amount of water flowing out from the lakes into underground fissures in the limestone bedrock as on the river inflows. In this potholers' paradise, underground "rivers" draining Lake Megali Prespa are so substantial that fish such as eels (*Anguilla anguilla*) from Lake Ohrid, into which the rivers drain, can swim upstream into the higher lake.

Tunisia's jewel

Frequently, freshwater marshes surround saline lakes. This is the case with the 800 hectares of marshes around Garaet El Ichkeul. Once one of many freshwater or brackish lakes along the North African coast, it is now among the last, and has become among the most important waterfowl sites in the world.

The lagoon's salinity varies by a factor of at least ten through the year. When it rains inland in winter, the lagoon becomes largely fresh. But during the summer dry season, the main body of water is dominated by saline inflows from the sea. However, the chemical character of the surrounding marshes depends largely on the rivers and the groundwaters which seep into the marshes, providing their main source of water.

A series of dams in the mountains have disrupted this balance, turning the lagoon and eventually much of the marsh permanently saline. However, management measures such as the building of sluices might partly offset the negative effects of the dams.



Floodplains and forests

Most of the wetlands that once filled river floodplains have been systematically drained during the past two thousand years. At the same time, the extensive riverine forests (*Salix* spp., *Populus* spp.) which at one time lined the lower reaches of almost all the region's rivers, especially in deltas, have been reduced to small isolated stands, often now under the protection of conservation groups, such as the World Wide Fund for Nature (WWF). The rest have been either cut down, or drained — and frequently both.

There are a few oxbow lakes (abandoned meanders of rivers) along the lower Rhone, and occasional freshwater marshes along the floodplains of the Po, the Tejo in Portugal and in France's Languedoc region. A few flooded forests remain around Lake Skadar in Montenegro, in Pinios and Nestos deltas and in Lake Kerkini in Greece, and in Kizilirmak delta and at Lake Manyas in Turkey.

Most surviving, seasonally-flooded, natural stands of trees are on islands in the middle of braided river channels. But even these are increasingly under threat as river engineers straighten and dredge channels and combine their flows into deep shipping lanes. What were once the most extensive wetlands in the Mediterranean region have now all but gone.

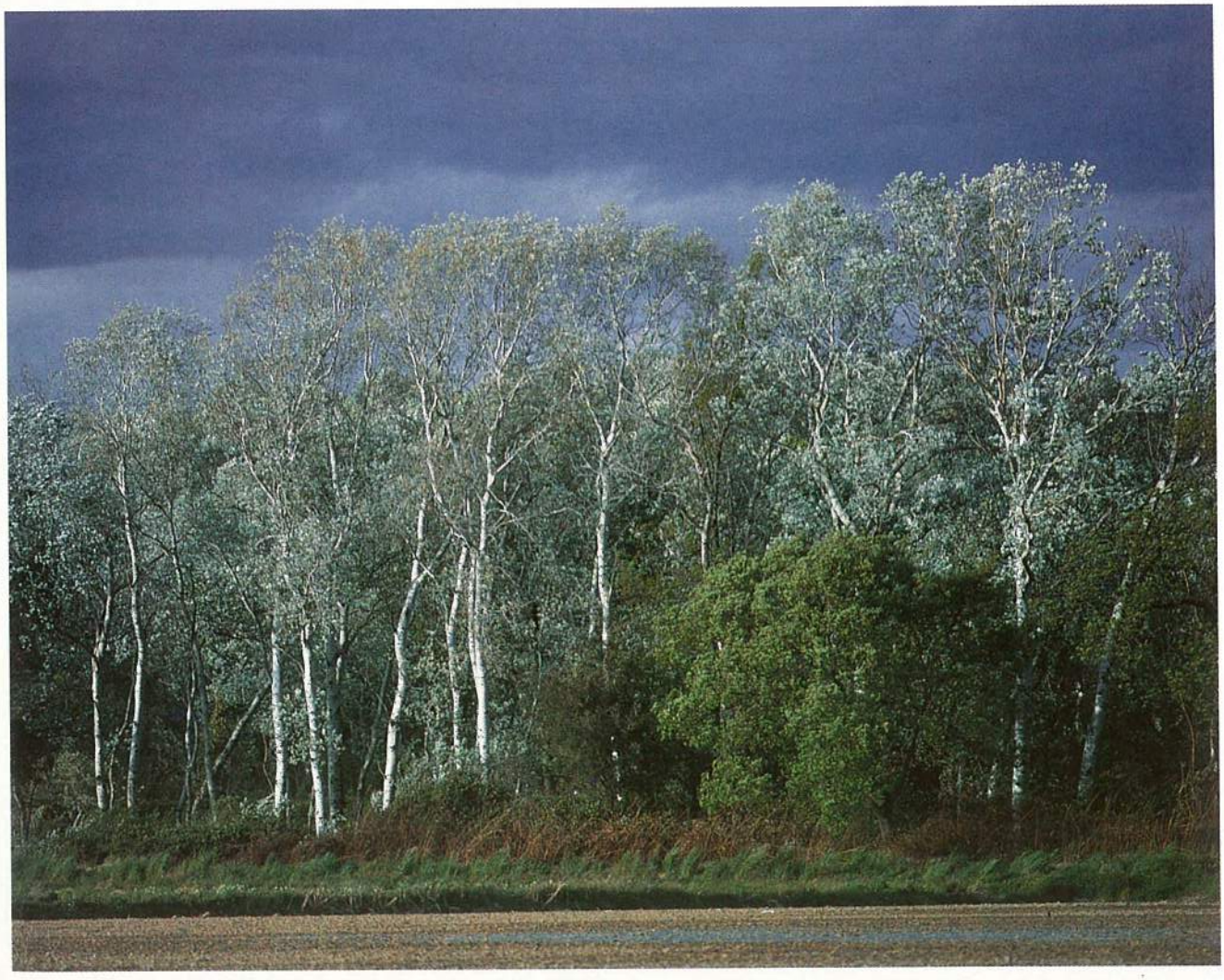
Riverine forest of *Populus alba* bordering a Camargue wetland

Inter-tidal wetlands

The lack of a tide in most of the Mediterranean ensures that there are few large areas of mudflats between high and low tides.

The main exceptions are the estuaries of southern Portugal (included within the scope of this study, though they border the Atlantic Ocean) and, within the Mediterranean basin proper, an area of the Gulf of Gabès between the coast of southern Tunisia and the Kneiss Islands. Here, at the boundary between the eastern and western basins of the Mediterranean, there is a one-metre tidal range, the highest in the Mediterranean and enough to create inter-tidal mud flats covering 200 square kilometres. Along the coasts of the Adriatic Sea significant tides are also observed.

In the mud flats of the Gulf of Gabès, a landscape more redolent of the coasts of the North Sea, vast populations of mud-dwelling invertebrates and molluscs draw 100,000 wintering waders, such as dunlin, grey plover and curlew, each year.



B. Pambour / BIOS

Inland salt lakes

Salt lakes provide some of the largest surviving wetlands in the region. The largest are in North Africa, where the "flash" nature of storms, combined with fast run-off in near-desert landscapes, occasionally create large expanses of water in inland depressions.

The largest chott is Djerid in Tunisia. It covers 4600 square kilometres in all, but a detailed examination of satellite images of Djerid in the late 1970s showed that no more than 5 per cent of the chott was ever covered with water at any one time. It never had water for longer than two months but was rarely without water for longer than seven months.

The high rates of evaporation, which exceed precipitation on an annual basis by eight to one, ensure that the water does not last long. The lakes frequently dry up altogether between rainstorms that may occur only once a year.

During past eras, most recently during the Holocene (some 6000 years ago), much more rain fell over north Africa. The Sahara itself was a grassland crossed by wide rivers and these lakes were probably permanent, sustaining massive wetland habitats. Today, they may be dry for years at a time. Their beds comprise thick deposits of salt, left behind as the water has evaporated.

The drier depressions, most of which stretch east-west along the northern edge of the Sahara, are known as chotts. They rarely hold water for longer than four months at a time, usually in winter. Permanent vegetation is sparse, though a mass of greenery will appear whenever there is rain. Invertebrates are limited to a handful of species that can cope with the desiccated conditions, and visits by water birds are rare.

Spain has a number of small saline lakes in the basins of the Ebro, Guadalquivir and Tagus rivers, which occur on salty rock strata. They are geologically unique in Europe and one, the Fuente de Piedra in Andalusia, is an important breeding ground for flamingoes.

Shallow depressions that hold water for longer — typically drying out only at the height of summer — are called sebkhets. One of the most important of these for wildlife is Sebkhet Sidi El Hani in central Tunisia. It sometimes holds water continually for more than two years, partly because it is also supplied by an oasis. Some years, greater flamingoes (*Phoenicopterus ruber*) visit here to breed. Around 10,000 pairs came in 1972.

Vegetated sebkhets are typically much smaller than unvegetated versions. They concentrate and contain water better, and are less saline. Some appear amid agricultural areas and may be tapped for irrigation water or used as rubbish dumps.

Chott el Djerid, the largest salt lake in North Africa. While never entirely filling, it is rarely without water

M. Breuil / BIOS

Turkey's salt lake

The arid centre of Turkey, a region with less than 400 millimetres of rain a year, drains into a giant salt lake, 90 kilometres long and 32 kilometres wide, but even in winter no more than 1.5 metres deep. Lake Tuz is at the centre of a closed basin with a huge catchment area, and is extremely saline, especially in summer when evaporation turns much of it into a salt pan.

As a result, vegetation is sparse round the lake and almost non-existent within it. Despite this, and increasing industrial pollution, the lake is a major collecting point for birds, with a large breeding population of flamingoes in two large colonies in the centre of the lake and a large wintering population that includes several tens of thousands of white-fronted geese (*Anser albifrons*). The lake's two large salt pans supply two-thirds of Turkey's salt.

Oases

Underground water is plentiful beneath the Sahara and much of the Levant, a product of infiltration during wetter eras in the region's history.

S. Zalewski / BIOS

Oases are desert wetlands supplied by underground springs (Azraq, Jordan)

It is being tapped on a large scale by Libya's "Great Man-made River Project" which, at a cost of several billion dollars in pumps and pipes, is taking water from well fields in the desert to coastal farms. Elsewhere, the fresh underground water reaches the surface under its own pressure at oases, around which important wetlands can form.

Sometimes oases and saline lakes are linked. An oasis directly feeds the Sebkhet Sidi El Hani in central Tunisia. One of the most important oases for wildlife, and one of the most threatened, is the Azraq oasis in Jordan, which has been designated under the Ramsar Convention. This lush freshwater oasis is at the centre of a basin that also receives occasional run-off from a wide region of desert wadis covering more than 12,000 square kilometres. After storms, a huge saline lake forms. But the oasis, fed by the large underground store of water beneath the basin, is the only source of fresh water.

Azraq harbours rare Jordanian reptiles and is an important stopping-off point for migrating birds. But in the past decade the discharge of the two Azraq springs has been reduced to a fifth of its former level by widespread pumping from the aquifer beneath, to provide desperately needed drinking water for the Jordanian capital, Amman.

M. Gunther / BIOS

Salinas : valuable industrial wetlands

Salinas

Salinas, modern industrial salt pans, are highly engineered but extremely valuable wetland habitats. Most have been established on the sites of natural salt lagoons. In the past, their construction caused great disruption, particularly to the birds using the lagoons; but today they offer havens of relative tranquillity. Conservationists have come to regard the construction of these industrial facilities as a change of wetland use rather than a loss of wetland.

The largest salina in Europe is the Salin de Giraud, covering 11,000 hectares of lagoons and salt pans at the seaward extremity of the Camargue in France. It was first built in the late 19th century to meet the demand for sodium chloride created by the invention of the Solvay process for converting salt to soda, and the subsequent demand for soda as a raw material in the production of detergents, plastics and many other products.

Today, it has more than 100 basins, each with its own stable level of salinity. They range from 37 grams of salt per litre where the water is pumped in from the sea, increasing gradually as the water is pumped into each succeeding lagoon for further evaporation up to 320 grams per litre, where the salt itself is harvested.

In the lower lagoons some salt-tolerant plants and fish thrive; but by the end there are only brine shrimp. These engineered basins have none of the dynamic unpredictability of natural lagoons. But they do have a regular seasonal cycle that creates a predictable food supply and, as a result, an abundant bird life.

Current and former salinas are almost the only regular habitat for flamingoes in the Mediterranean, and there is increasing interest in managing habitats on other active or abandoned salinas to make them more attractive for the birds. Malta's Ghadira wetland reserve, for instance, is a former salina. But there are competing uses. Several abandoned salt works in Portugal and elsewhere have been converted with EC funds into shrimp farms.

A study of former salinas on the Tejo river in Portugal has found that the density of black-winged stilts (*Himantopus himantopus*) on those salinas converted to shrimp farms is, at one pair per 10 hectares, only a third of the density on abandoned salinas and half that on still-active salinas. Whatever their industrial past, salinas are an increasingly important wetland resource for birds and, after their closure, must be managed for the benefit of wildlife.

Artificial reservoirs

An increasingly important form of Mediterranean wetland is the man-made reservoir.
As governments capture ever more water from rivers for diversion to irrigation projects, industry and cities, upland reservoirs are to some extent replacing the downstream wetlands.

In Tunisia, for instance, an estimated 19,000 hectares of natural wetlands lost in the past century have been replaced by 22,000 hectares of artificial reservoirs. The Doñana wetlands at the mouth of the River Guadalquivir in Spain suffer largely because of 30 high dams built upstream, which between them retain a total of 4.7 cubic kilometres of water.

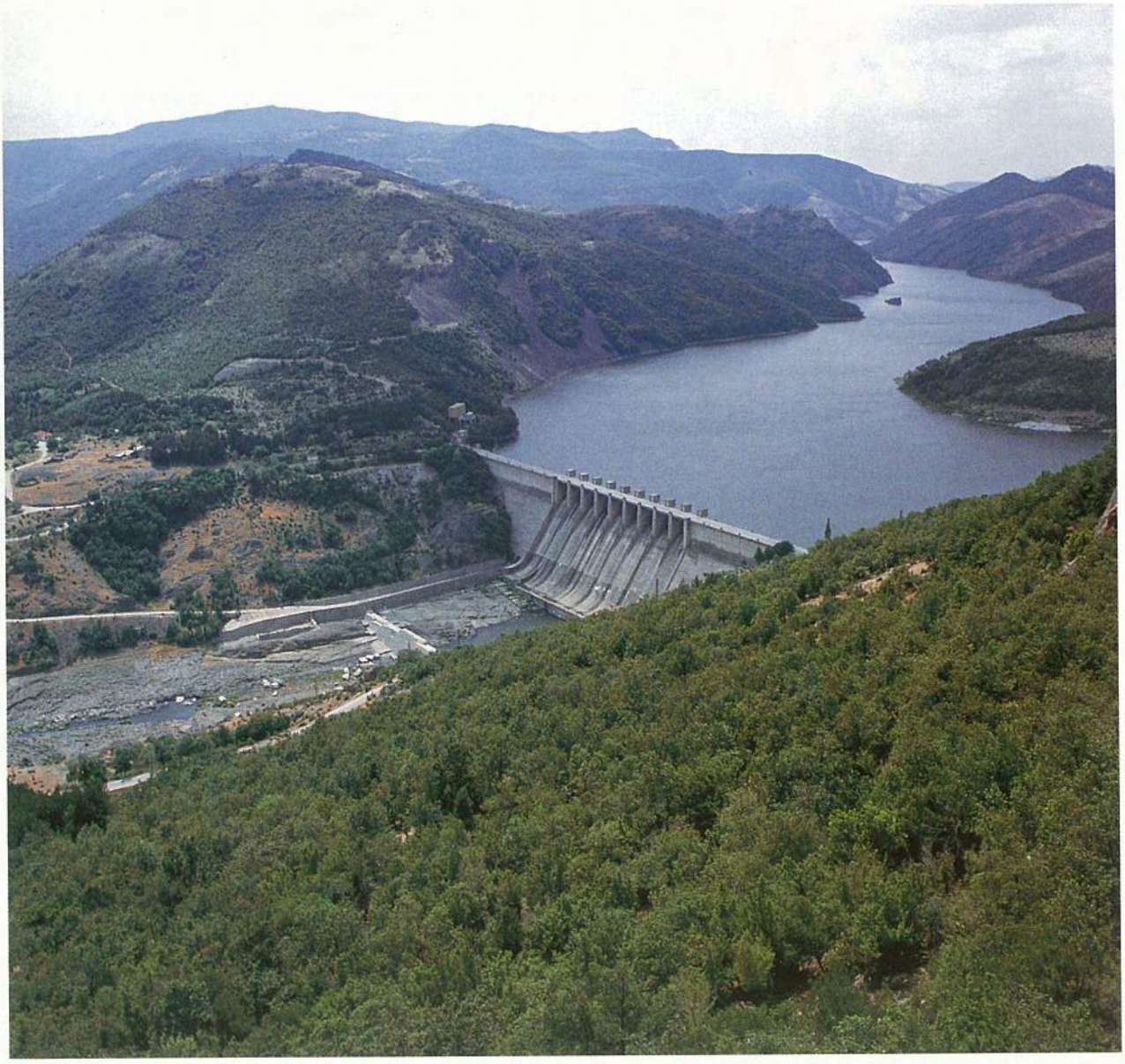
Some reservoirs perform important functions for wildlife and are effective replacements for lost natural lakes.
This is especially true in the arid Iberian peninsula, where strings of reservoirs on the River Guadiana and Tagus in western Spain have become important centres for ducks and coots.
The same is increasingly true in North Africa, where the Boughzoud Lake in Algeria, for instance, attracts many waterfowl.

Even in delta regions, artificial reservoirs can be important.
So many birds visit the small Valle Santa flood storage reservoir near Ravenna in the Po delta — which preserves some of the last remains of the Po's floodplain marshes, with reed beds, water lily (*Nymphaea alba*), pike (*Esox lucius*) and tench (*Tinca tinca*) — that it has gained a Ramsar listing.

But most reservoirs are constructed amid steep terrain.
This ensures that a maximum amount of water is stored for a minimum loss of land and evaporation surface, but leaves little chance for shallow marshes to develop at the edges.

Many reservoirs, particularly those used mainly for generating hydro-electric power, are also subject to strong and irregular drawdown — again making the chances for the growth of vegetation along the shoreline very small.

And, during droughts such as those which afflicted the Iberian peninsula during the early 1990s, artificial reservoirs may be emptied as communities become desperate for water.



M. Gunther / BIOS

The reservoirs that form behind dams, such as this one on the River Arda in Bulgaria's Rhodopes mountains, often make valuable wetlands

A. Beignet / BIOS

Wetland vegetation

Many threatened plant species are confined to wetlands. They flourish in these particularly dynamic and unstable environments where the conventional idea of biological succession has little meaning.

There are many annual plant species, for instance, that live for short periods when land is submerged each season, and others for which the depth or salinity of water is critical. Many also enjoy the calcareous conditions typical of many Mediterranean wetlands.

There are six main categories of wetland vegetation in the region, related broadly to the geomorphological categories described above. There are the halophytes of salt marshes and lagoons, the emergent reed swamps of freshwater marshes, wet meadows, riverine forests, dwarf rushes, and submerged and floating plants of freshwater lakes and lagoons.

The yellow flag iris flourishes in the pools of freshwater marshes and flooded forests

Halophytes

Salt lagoons tend to contain only a few plant species, with one species dominating. In lagoons where the salinity varies widely through the year, it is the salinity during the growing season that is of paramount importance.

M. Gunther / BIOS

Glasswort in the Oued Massa in Morocco, a large lagoon separated from the Atlantic by a narrow sand bar

At the outer edge of the lagoons, where they join the marine environment, are submerged sea grasses. In inter-tidal areas, which are most marked on the Atlantic coastline outside the Mediterranean proper, the dominant vegetation is usually eelgrass (*Zostera* spp.). In the calmer, more secluded and warmer waters of saline lagoons, eelgrass is usually replaced by ditch grass (*Ruppia* spp.). Both grasses are perennials and provide important spawning and nursery grounds for coastal fish and feeding areas for plant-eating waterfowl.

Up the shoreline, on seasonally flooded marsh, are annual halophyte species that germinate in the dry season when the water level is below the soil surface. These might include glasswort (*Salicornia* and *Arthrocnemum*), also known as marsh samphire, mixed with the salt marsh grass, *Aeluropus*, which can survive both winter flooding and heavy grazing. Further inland again, on salt flats flooded for a few weeks each year, typical vegetation includes tussocks of dwarf scrub.

Glasswort occupies large areas of salt marsh in the Mediterranean, especially within deltas, on the edges of lagoons, and around the salt lakes of North Africa. It helps maintain these structures by capturing sediment, creating a typically hummocky terrain.

There are other communities of highly marginal halophytes, such as the rushes (*Juncus* spp.) that may form a band only a few metres wide at the upper limit of winter flooding around lagoons, before tamarisk (*Tamarix* spp.) shrubs give way to wet meadows further onshore.

Freshwater reed swamp

In freshwater marshes and around lakes, the dominant species is determined by the depth of water and the extent of grazing and trampling by animals.

The boundary between reeds and meadows in particular depends on grazing. But, with a wide variety of grazing animals — anything from cattle and horses to wild copyu (*Myocastor coypus*), beaver (*Castor fiber*) and birds — the relationships between plants and grazing are complex. At its simplest, trampling and grazing opens up the dense vegetation, creating patches of bare soil where other plants, including emergent annuals, can gain a foothold.

P. Pernot / BIOS

***Typha* swamp in Spain's Doñana wetland**

The most common type of reed swamp is dominated by the tall reed *Phragmites australis*. Though sensitive to grazing and trampling by animals, it will grow anywhere that is wet for most of the year. It can be found on land permanently flooded to a depth of more than a metre, and even turns up as floating rafts in deeper water still. *Phragmites* is ubiquitous in European freshwater wetlands, but occurs only rarely in North Africa. In ideal conditions, with winter flooding and summers that are not too dry, *Phragmites* stands can last virtually unchanged for hundreds of years.

Where grazing is heavy, however, *Phragmites* may be replaced by short grasses such as *Aeluropus,* or by sea club-rush (*Scirpus maritimus*), which is more tolerant of salt than *Aeluropus* and thrives where grazing is light, often on the edges of deep lakes.

A final type of reed swamp is saw sedge (*Cladium* spp.), which prefers permanently wet, freshwater areas, but does not appear widely in the Mediterranean. The largest stands of saw sedge are in the Daimiel wetland of central Spain and the Marais de la Crau bordering the Camargue.

Grazing the wet meadows

Wet meadows thrive best where there is human activity such as the grazing of domesticated animals, which prevents invasions by either shrubs or beds of *Phragmites*, which will otherwise dominate most summer soils subject to winter flooding.
Typical plants in wet meadows include rushes and papyrus (*Cyperus papyrus*), spike-rush (*Scirpus* spp.) and black grass (*Alopecurus spp.*). On peaty acid soils in Spain and Greece, there are meadows of purple moor grass (*Molinia caerulea*).
Occasional burning, mowing and grazing of reed beds all help preserve meadows. The southern limit of wet meadows in the Mediterranean usually coincides with the ending of summer soil wetness.

Riverine forests

Most riverine forests have disappeared from the floodplains of Europe, though a few pockets survive on some deltas.

The Nestos delta in eastern Greece harbours a 60-hectare remnant of what was once 2000 square kilometres of almost continuous seasonally flooded hardwood forest. The Ebro delta contains stands of poplar (*Populus* spp.), alder (*Alnus* spp.) and white willow (*Salix alba*).

The last remnant of riverine forest on the Po delta is the Punta Alberete, a small WWF-protected reserve of poplar and willow, with herons and egrets feeding amid yellow growths of flag iris (*Iris pseudacorus*) and floating water lilies in pools of water. Likewise, France's Conservatoire du Littoral protects small areas of riverine forest at Mas Larrieu behind dunes at the mouth of the River Tech in Roussillon and at Tourtoulen in the Camargue along the Rhone river.

Away from the coast, the most likely refuge for flooded forest is on sand and gravel islands in the middle of braided, uncanalised sections of river. Poplar is typical on these islands — which dry out during low summer flows, but are flooded in winter. However, willow dominates on gravel islands in fast-flowing rivers.

Submerged and floating freshwater plants

These are the most dynamic and least predictable of all the wetland species of vegetation.

Among the most distinctive vegetation communities found in the Mediterranean are the dwarf rushes, which occur in isolated pockets on thin soils and rocks that are seasonally flooded with fresh water and where grazing and trampling leaves bare ground. They are important because many of the varied plants, particularly several species of quillworts (*Isoetes* spp.), are found only in the Mediterranean region.

They are annuals or short-lived perennials and may disappear one year to be replaced by different species the next, depending on precise environmental conditions such as salinity, water depth, temperature and flooding regime.

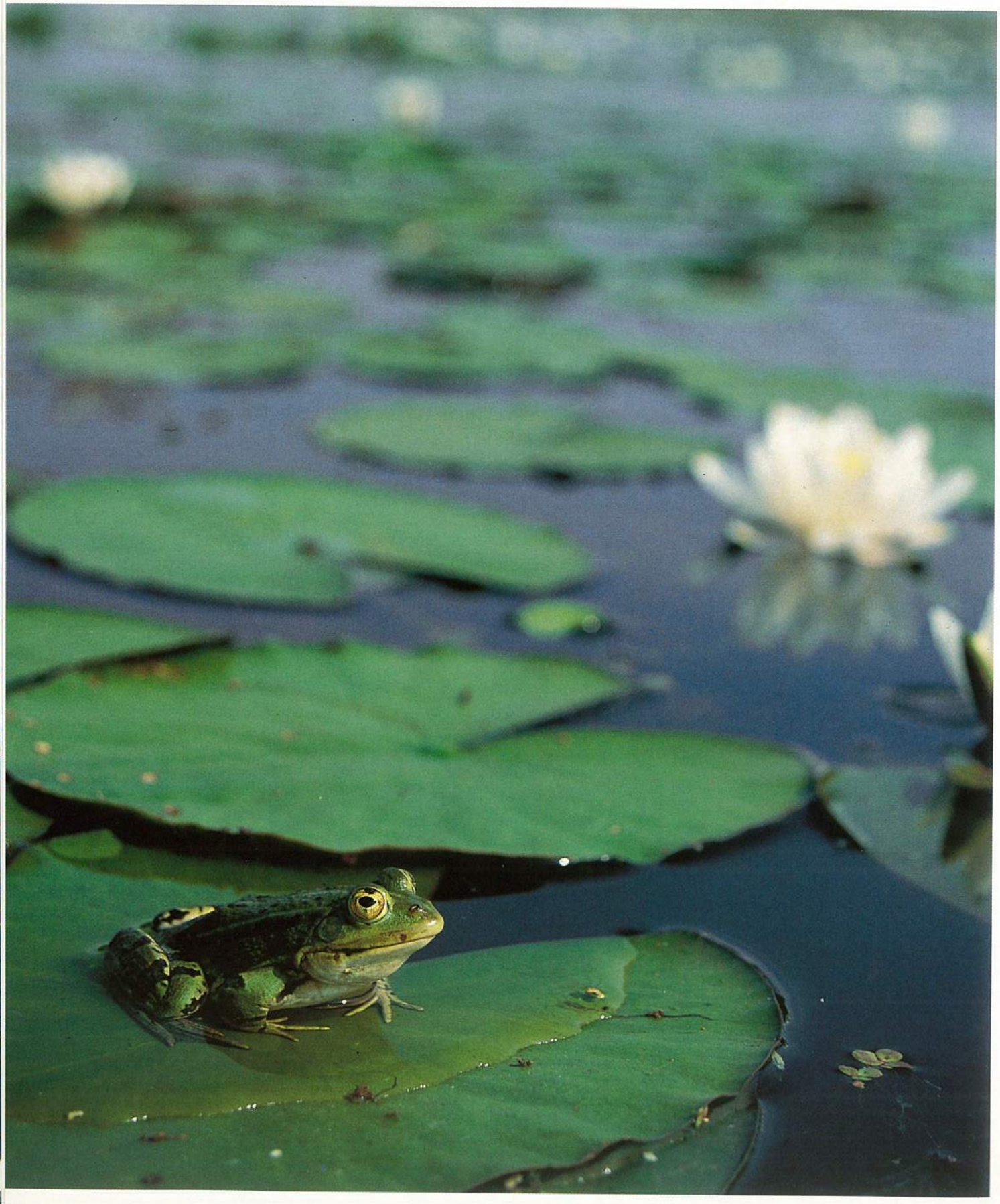
Many species of submerged plants are types of pondweed, such as fennel pondweed (*Potamogeton pectinatus)* and spiked water-milfoil (*Myriophyllum spicatum*). Fennel pondweed, for instance, covers about a third of the main lake at Ichkeul in Tunisia, and is the major source of food for the lake's vast populations of wintering ducks.

Man-made wetland habitats are of increasing importance for plants and animals in the Mediterranean basin. Besides reservoirs and salinas the most important of these are probably the rice fields of deltas such as the Rhone in France, the Ebro in Spain and the Axios in Greece. The rice paddies of the Ebro delta, for instance, nurture a rich harvest of water plants in the autumn. These include pond weeds, water lilies, bladderworts (*Utricularia* spp.) and stonewort, on which ducks descend for a night-time feed.

Where lake water is more saline, pondweeds are replaced by ditch grass. Where the water dries up for more than a month or so, they give way to shallow-water communities such as stoneworts (*Chara* spp.), which can tolerate summer drying.

E. Boyard / BIOS

Unpredictable, submerged and floating freshwater plants are the most dynamic of all wetland flora



F. Vidal / BIOS

Wetland animals

Birds are what really excite most nature-lovers about wetlands. And with reason. The salt and freshwater lakes and marshes of the Mediterranean are breeding and wintering grounds for millions of birds. They also act as "service stations", providing food and shelter for many more birds on their annual migrations between Africa and northern Europe and Asia.

The main flight paths over the Mediterranean hug the land, crossing the Straits of Gibraltar or rounding the eastern Mediterranean through Turkey and the rift valley on the Israeli/Jordan border. Others take short sea crossings — from Tunisia to southern Italy, or from Libya to Greece and the Balkans via Crete.

Thus the loss of Mediterranean wetlands could damage the survival of populations of birds thousands of miles away. Equally, the loss of far-distant habitats for birds could deprive the Mediterranean of some of its most spectacular wildlife displays.

As many of the region's wetlands are lost, the surviving wetlands become of increasing importance, and magnets for ever more birds. Lake Ichkeul, once one of many brackish and freshwater wetlands in coastal North Africa, is now almost unique and of global importance. Similarly the Camargue, by the simple act of surviving, has become of paramount importance for the western Mediterranean's flamingoes; and Lake Skadar on the Yugoslav-Albanian border grows in ornithological stature.

***Rana esculenta*, one of the most common wetland species**

Ichkeul

Perhaps one of the most important single sites for birds in the entire Mediterranean, especially for its winter population of waterfowl, is the lake and marsh of Ichkeul in northern Tunisia.

A. Endevelt / BIOS

The little egret (*Egretta garzetta*), a typical Mediterranean wetland breeder

Though covering only around 200 square kilometres, it contains anything from 100,000 to 200,000 waterfowl in winter, including tens of thousands of pochard (*Aythya ferina*), wigeon (*Anas penelope*), coot (*Fulica atra*) and greylag geese (*Anser anser*). The ducks feed on pondweed, while greylag geese consume sea club-rush.

The precise number of birds wintering at Ichkeul each year varies, depending both on the amount and salinity of its variable waters and on the competing attractions of other wetlands in the western Mediterranean. But, in different years, ornithologists have counted peak populations of more than 100,000 coot, wigeon and pochard.

At other times of the year, Ichkeul contains large numbers of breeding and migrating birds. Waders such as avocets (*Recurvirostra avosetta*) and black-winged stilts may stay all year. Resident herons and summer-visiting egrets and reed warblers (*Acrocephalus scirpaceus*) breed among the reeds, and white storks (*Ciconia ciconia*) feed on the edges of the lake.

Among the globally rare birds found here are the white-headed duck (*Oxyura leucocephala*) and the marbled teal (*Marmaronetta angustirostris*). Birds of prey surveying the reed beds for food include marsh harriers (*Circus aeruginosus*); peregrine falcons (*Falco peregrinus*) and kestrel (*Falco tinnunculus*) come down from the mountain overlooking the lake, where they breed.

North Africa

A second great wintering ground for birds in Tunisia is around the Kneiss Islands in the Gulf of Gabès, a unique area of inter-tidal mudflats in the Mediterranean. It is the most important place in the whole basin for winter waders, including dunlin (*Calidris alpina*), redshank (*Tringa totanus*), plovers and sandpipers — birds which come south after breeding during the summer in northern Europe and Asia.

With the Mediterranean region acting as winter home for up to half of some populations of species of Palearctic waterfowl, and with a half of these birds in Tunisia during some years, the country's wetlands are clearly of paramount ornithological importance. This importance has grown as other sites, especially in Europe, have disappeared.

The exposed mudflats of the gulf are full of the molluscs and invertebrates eaten by the birds, all 300,000 or more of them in a good year. Joining the waders come flamingoes, most on a winter jaunt from the Camargue. Some waders stay through the summer to breed in the salt marshes on the edge of the gulf.

A third wetland area of international importance in northwest Africa is the El Kala complex of three lakes just over the border from Tunisia in Algeria. Its two freshwater lakes, Tonga and Oubeira, along with the marine lagoon, Mellah, shelter around 40,000 birds each winter, mostly ducks, geese and coots, as well as flamingoes and cranes (*Grus grus*).

Rare birds nesting around Tonga include white-headed and ferruginous ducks (*Aythya nyroca*), but ducks and geese declined in Lake Oubeira after the introduction of grass carp (*Ctenopharyngodon idella*) to the lake led to the disappearance of most of its lakeside and submerged vegetation.

Away from the North African coast, the salt-encrusted chotts and sebkhets attract birds whenever they have standing water. During the winter, the shelduck (*Tadorna tadorna*) and flamingo will visit. In spring, any water that survives evaporation by the searing sun will attract the first migrating birds flying north, searching for water as they escape the Sahara. Peregrine falcons and marsh harriers hunt for frogs and birds in the larger sebkhets such as Halk el Menzel. When these natural wetlands are dry, birds collect instead on the country's growing number of man-made reservoirs.

Western Europe

On the European side of the Mediterranean, perhaps the most important surviving wetland for birds is the Doñana wetland on the delta of the River Guadalquivir.

Here, at various times, can be found more than 200 species, over half of all the bird species of Europe, including griffon vulture (*Gyps fulvus*), marbled teal, shoveler (*Anas clypeata*) and possibly still Andalusian hemipode (*Turnix sylvatica*), a quail-like bird that is almost extinct in Europe.

La Albufera, which is flanked by the major city of Valencia and a large holiday resort, demonstrates that — either by luck or good management — even the most hemmed in wetland can retain its value to wildlife.

Imperial eagles (*Aquila heliaca*), herons, egrets, spoonbills (*Platalea leucorodia*) and white storks breed in the evergreen oak (*Quercus* spp.) woods around Doñana's lagoons. Coot, wigeon and greylag geese flock to the marshes in their hundreds of thousands each winter.
With drainage and irrigation schemes upsetting the hydrology of the marshes — and pesticide spraying responsible for thousands of deaths among waterfowl — Doñana's status is under threat. Bird numbers have dwindled during the drought years of the early 1990s.

Other important Spanish wetlands for bird life include the Ebro delta in Catalonia; La Albufera, a coastal freshwater lake outside Valencia; and the inland Daimiel wetland, south of Madrid.

On the Ebro delta, up to 300 bird species live in or visit the lagoons and the Illa de Buda, a large island at the delta's tip. Each autumn, after harvesting, the rice paddies of the Ebro delta have become new attractions for coot and mallard (*Anas platyrhynchos*), shoveler and wigeon in particular. Many of the birds stay for the winter, when they are joined on the delta by tens of thousands of waders. Among the birds breeding here are eight species of heron, including locally rare pairs of purple heron (*Ardea purpurea*), and the red-crested pochard (*Netta rufina*).

T. Thomas / BIOS

There is a population of 70,000 flamingoes in the western Mediterranean

The red-crested pochard is mainly associated with La Albufera, a large coastal freshwater lake, just down the coast from the Ebro. La Albufera's 30 square kilometres of water is rarely more than a metre deep, and surrounded by reed beds and dotted with islands. At times, up to three-quarters of the European population of red-crested pochard winters on the lake. Here, too, rice paddies reclaimed over the decades from the lake now play host to large numbers of winter waterfowl.

A large number of the Camargue flamingoes move to the salinas at Sfax on Tunisia's Gulf of Gabes in winter. But long- term ringing studies have found them also in Morocco and Portugal, and individuals have turned up far to the east in Libya, Egypt and Turkey and to the southwest in Mauritania and Senegal.

In France, the Camargue is, of course, a major centre of bird life. Its famous colony of greater flamingoes is supplemented by shelducks, terns and gulls, warblers and tits, and eight species of breeding herons. Further round the coast, a surviving tract of riverine forest in Languedoc-Roussillon at Mas Larrieu is one of France's few breeding places for the penduline tit (*Remiz pendulinus*).

One of the most important Italian wetlands for birds is Lake Massaciuccoli in Tuscany, with more than 250 species spotted at various times round the lake, or in its reed beds. There are around 50 breeding species here. Highlights include kingfishers (*Alcedo atthis*), crakes (*Porzana* spp.) and water rails (*Rallus aquaticus*) amid the reeds, and a complete set of warblers — Cetti's (*Cettia cetti*), Savi's (*Locustella luscinioides*), reed, sedge (*Acrocephalus schoenobaenus*) and moustached (*Acrocephalus melanopogon*).

The greater flamingo

The most distinctive and specialised bird of the region is the greater flamingo, which requires large areas of open, shallow and brackish or saline water. The western Mediterranean population numbers some 70,000. However, they have only two regular breeding sites: the Fangassier lagoon in the Salin de Giraud in the Camargue and the inland salt lagoon of Fuente de Piedra in Malaga in southern Spain. The Camargue colony is much the largest and most stable. Two-thirds of the region's flamingo chicks are raised here.

This heavy reliance on two sites is a potentially precarious situation. The Malaga site was dry in 1992, following the prolonged Spanish drought. This same year hundreds of birds nested in the Ebro delta further north for the first time in 400 years. This breeding colony was destroyed and the chicks died after their parents were frightened away by aircraft.

However, in 1993 reproduction has been successful at that site.

Even the Camargue, with its average 10,000 breeding pairs of flamingoes, one of the world's top 20 flamingo nesting sites, is situated in an artificial habitat and not fully secure. The colony was almost wiped out in the 1960s.
Breeding stopped for five years, until conservationists at the Tour du Valat research station constructed a new breeding island with artificial nesting mounds amid the salt works.

M. Gunther / BIOS

Greek wetlands, until recently a major focus for wintering ducks and geese, have suffered a decline in numbers of birds of between 30 and 90 per cent since the beginning of the 1980s.

Sanctuaries in the Balkans

In the eastern Mediterranean wetlands, the range of species changes, reflecting arrivals from the eastern Mediterranean migration flight paths. Pelicans and cormorants, for instance, are prominent in Balkan and Greek lakes and wetlands. The region also contains a large proportion of the world's 3500 surviving breeding pairs of Dalmatian pelicans (*Pelecanus crispus*). Many nest at what remains of the Karavasta lagoon in Albania, which is scheduled to join a long list of Albanian wetlands already drained for agriculture.

The region lies close to the Bosphorus and millions of birds take this land-hugging flight path from Africa to Europe each year. The two most important areas are the Greek "lake district", a patchwork of surviving delta marshes and lagoons at the north of the Aegean Sea, and the inland lakes of the Balkans, stretching from Greek Macedonia up into Albania and former Yugoslavia.

The Evros delta, at the head of the Aegean, was once one of the most important breeding bird areas in Europe. Despite massive drainage, culminating in the emptying of the Drana lagoon, and the annexation of much of this border zone for military use, it remains important. White-tailed eagles (*Haliaeetus albicilla*), herons and terns nest here. Dalmatian pelicans spend the winter, and white pelicans

Dalmatian pelicans find a retreat in a salt lagoon. There are only 3.500 breeding pairs left

(*Pelecanus onocrotalus*) rest during their migration.
The nearby Nestos delta, though much reduced, still covers around 550 square kilometres. It is home to about 50 pairs of spur-winged plovers (*Hoplopterus spinosus*), three-quarters of Europe's total, and several pairs of lesser-spotted eagle (*Aquila pomarina*), as well as *Phasianus colchicus colchicus* (the original pheasant).

Several of the delta region's lakes are also important bird habitats. They include the reservoir of Kerkini, and Lakes Vistonis and Mitrikou, whose extensive reed and tamarisk beds, salt marshes and mats of floating plants attract waders in large numbers.

Birds of the Balkans

The wholesale disappearance of Balkan wetlands has left Lake Skadar, which straddles the Yugoslav - Albanian border, as one of the most important surviving bird areas in southeast Europe. Some 250 species of birds are seen here and half of them breed around the lake, which in the wet season covers up to 6000 square kilometres.

The summer skies over Skadar are full of herons, divers and gulls; in winter, flocks of little grebe (*Tachybaptus ruficollis*) and black-necked grebes (*Podiceps nigricollis*), greylag geese, ducks and coots rule the roosts. But of greatest conservation interest are the small surviving colony of Dalmatian pelicans, the white-tailed eagles and numerous breeding pairs of pygmy cormorants (*Phalacrocorax pygmeus*). The lake and its surroundings are second only in importance to the Danube delta for this last, rare bird.

At the Balkans' other key lake, Mikri Prespa, both white and Dalmatian pelicans breed, while pygmy cormorants nest in the reed beds beside the lake. And there are breeding colonies of goosanders (*Mergus merganser*), cormorants (*Phalocrocorax carbo*), spoonbills, egrets and herons.

Eastern Mediterranean

Further east again, the lakes and deltas of Turkey are also under threat from one of the fastest growing economies and populations in the region.

The Goksu delta, an area of marshy pools and dunes on a coastline savaged by tourist developments, hosts three species of wintering eagles — imperial, white-tailed and spotted (*Aquila clanga*) — as well as rare species such as marbled teal and purple gallinule (*Porphyrio porphyrio*) hidden in the reed beds, and around 100,000 wintering waterfowl.

The Menderes delta and the salt pans of Camalti Tuzlasi in western Anatolia also host numerous rare breeding birds such as greater flamingoes, Dalmatian pelicans, ruddy shelduck (*Tadorna ferruginea*) and pratincole (*Glareola pratincola*). The three inland lakes of central Anatolia — Karamuk, Eber and Aksehir — contain dozens of species of breeding birds including, until a decade ago, mute swan (*Cygnus olor*) and white-tailed eagle, which now only visit.

A fourth one, Lake Burdur, supports up to 75 per cent of the world's wintering population of white-headed duck.

A. Pons / BIOS

Otters survive in the Daimiel wetland in Spain

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Mammals and reptiles

Mammals are scarce throughout the Mediterranean. This is partly because their habitats are inevitably disturbed, and partly because of the region's hunting traditions. However, because mammals are not generally well adapted to the hot dry summers of the region, wetlands are favourite refuges and second in importance only to mountain regions.
In winter, wolves (*Canis lupus*) visit numerous wetlands of northern Greece, such as Lake Kerkini, Lake Prespa and the Evros delta, in great numbers.

The larger wetlands in particular provide important habitats for rare animals that require large undisturbed terrains. Doñana in southern Spain is the last stronghold of the rare Spanish pardel lynx (*Lynx pardina*), which feeds on rabbits and the large local herds of deer.
At Daimiel in central Spain there are otters (*Lutra lutra*), polecats (*Mustela putorius*), stoats (*Mustela erminea*) and water voles (*Arvicola terrestris*). At the Axios delta in Greece, the rare European souslik (*Citellus citellus*) form large colonies.

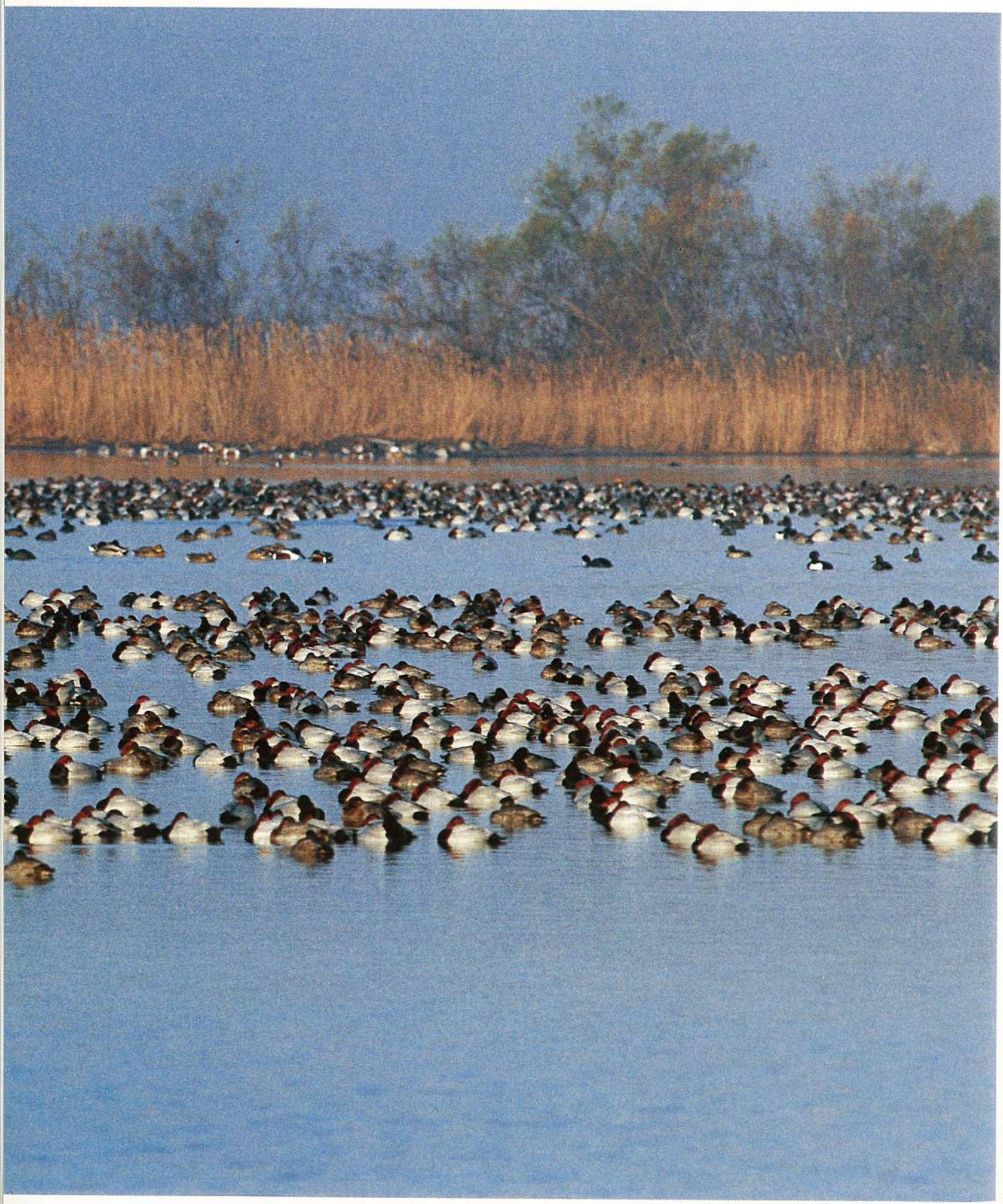
Wild boar (*Sus scrofa*) are frequent residents of larger wetlands. They roam the Doñana, Camargue and Daimiel, for instance, as well as North African wetlands such as Ichkeul, where there are also jackals (*Canis aureus*), mongooses (*Herpestes ichneumon winddringtonii*), otters and a feral herd of water buffalo (*Bubalus bubalis*).

In small wetlands, mammals are rarer. But reptiles and amphibians, which are under great threat in much of Europe, remain

B. Fischer / BIOS

The rare souslik, or ground squirrel

abundant. Here are grass snakes (*Natrix natrix*), and vipers (*Vipera berus*); marsh frogs (*Rana ridibunda*) and terrapins (*Emydidae* spp.), as well as local rarities. The Doñana, for instance, contains the spur-thighed tortoise (*Testudo graeca*), as well as skinks (*Chalcides* spp.), amid the sand dunes. Ichkeul has turtles.
The dice snake (*Natrix tessellata*) is found in and around Lake Skadar in Yugoslavia and the Azraq oasis in Jordan is the country's only refuge for the marsh frog and black water snake (*Tropidonotus tessellate*).
The rare sea turtles (e.g. *Caretta caretta* and *Chelonia mydas*) breed along the beaches of Greece and southern Turkey.



B. Pambour / BIOS

Traditional economic activities

The notion of wetlands as wastelands is a relatively recent one. It has evolved because wetlands proved initially unamenable to the processes of drainage, clearance and fencing that marked the spread of formal agriculture based on privately owned land. Thus wetlands have stayed outside this formal sector. Many have remained common lands, where hunting and fishing, grazing of animals and collecting of plants, has been widespread but uncontrolled.

Nonetheless, traditional activities based on the common-land wealth of the wetlands have been, and often continue to be, great sources of wealth. And, unlike much modern development, they were generally compatible with the preservation of the natural resources of the wetlands, both in terms of its biodiversity and its future wealth-creating potential. In modern parlance, most traditional wetland economic activities were "sustainable" uses of the resource.

Before the rise of tourism, fisheries were the dominant source of wealth on most wetlands, especially those with open water, such as coastal lagoons. The "valli" system of harvesting fish, particularly eels, that entered the lagoons of the Po delta and the northern Adriatic has proved itself over hundreds of years as both highly productive and sustainable.

Animal grazing, too, has been a long-standing and productive relationship between wetland ecosystems, domesticated animals and people. Like many traditional activities, grazing had a beneficial effect on many wetlands, maintaining a greater diversity of vegetation than would have been possible without the intervention of animals.

Ducks : the most ubiquitous of wetland birds are hunted throughout the mediterranean region.

Fisheries

Today, lagoon fisheries make up just 3 per cent of the overall fish catch of the Mediterranean basin, compared with 19 per cent for freshwater and 78 per cent for marine fisheries.

But lagoon fisheries, though small in regional terms, have a high productivity, typically ten times that of the open sea, and their fish command high prices. Thus they can be crucial parts of their local economies. The main fish caught are eels, mullet (*Mugil* spp.) and sea bream (*Dicentrarchus labrax*), all of which spawn in the sea, but feed and grow in lagoons.

The major surviving lagoon fisheries are in the Nile delta and the neighbouring lagoons of Sinai in Egypt, where some 3,000 fishermen still take catches from the Bardawil lagoon; the Ebro delta in Spain, which employs another thousand ; and a number of Greek lagoons. Though some 800 men still fish the lagoons of Languedoc-Roussillon in France, their product now represents only 10-30 per cent of the economic activity in the communes bordering the lagoons.

One of the most successful and durable systems of traditional fishing is the "valli" system used in the 10,000 hectares of lagoons of the Italian Adriatic, including the Po delta and the Venice lagoon. Though practised for many hundreds of years, the valli system comes close to many of the techniques of modern fish farming.

The hydrology of the lagoons is tightly managed, with dykes enclosing the areas of water and the sea, and landward water inlets controlled to maintain salinity levels. The fish are mostly migratory, entering the lagoon from the sea each spring, feeding and growing there, before leaving again in the autumn. At the outlets, the fishermen position traps that will allow the young fish to leave each autumn, but not the larger individuals, which are harvested.

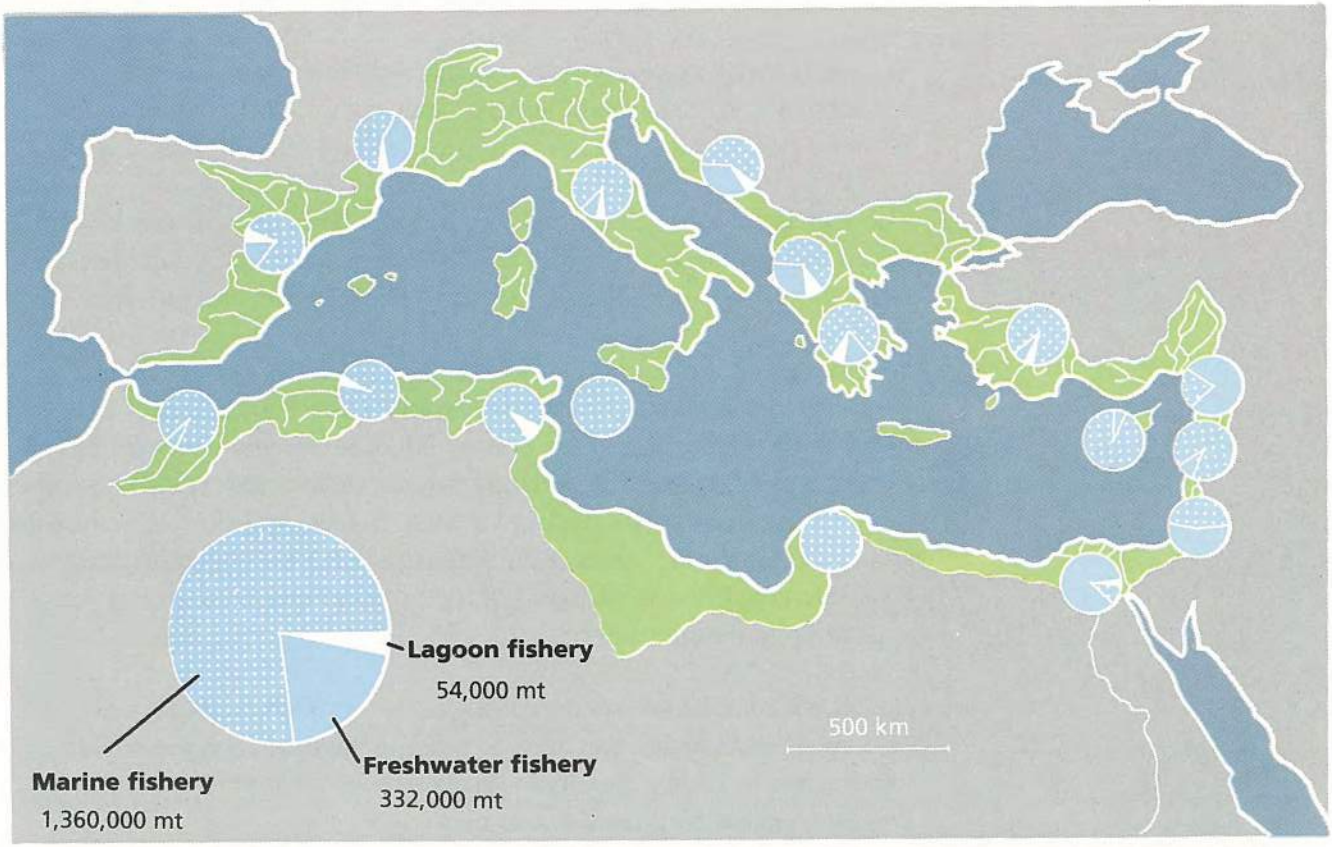
Traditionally, the traps were made of wood with reed filters, taken from around the lagoons. Nowadays, they are made of concrete with metal grills.

Today, Italian fishermen have intensified this form of fishery by artificially seeding the valli with fry, and setting aside special ponds for over-wintering fish.

The fish are mostly eels, the dominant fish in most Mediterranean lagoons, but sea bass, sole (*Solea* spp.) and mullet are also taken. Italy is the source of half the eels marketed in the Mediterranean and typical

In France and Italy, eels are the main catch; in Spain it is mullet and eels, as it is in the Ichkeul lake of Tunisia, where the annual eel catch alone is worth more than a million dollars, and elvers are sold in large quantities to stock European lagoons. In Egypt, sea bream dominate the nets in the great lagoon fishery of Bardawil.

annual yields in valli lagoons are 40 kilograms per hectare. Elsewhere in the Mediterranean, lagoon fisheries are less intensively managed. In France, typically, fishing takes place using fyke nets and other devices within the lagoon itself, rather than at the exit. There is no management of water regimes or seeding with fry, which colonise naturally. This has created problems in the past decade, when long-term drought has reduced freshwater inflow to the lagoons, reducing their attractiveness to fish seeking brackish water habitats in which to feed. Other recent problems include eutrophication, which repulses certain species such as sea bass.



Average contribution to catches (tonnes) between 1978 and 1987 of fisheries in freshwater, lagoons and the sea in the Mediterranean region. The circle represents 100% of the catch for each country.

Grazing

Traditional forms of grazing and plant harvesting are widespread in wetlands. Both can make an important contribution to the biodiversity of wet meadows. They prevent, more easily than cutting or burning, the takeover of wetlands by individual plant species, including reed. The trampling of animals creates bare patches in the vegetation where pioneer species can establish themselves. Many seeds germinate in hoof-marks.

Algae is taken from lagoons that suffer from eutrophication, for use as fertiliser. Sometimes, as in the Venetian lagoon in Italy, it is scooped up in large quantities for fear that when it rots, the lagoon will stink and fish will suffocate and die.

In the Camargue, for instance, grazing by cattle and horses controls reed beds, while encouraging growth of short club-rush and open-water plants such as pondweed. More open marshes in turn encourage birds such as egrets, waders and coots. Grazing regimes are successfully used in this way to increase the number of wildfowl for hunters as well as the value of wildlife reserves.

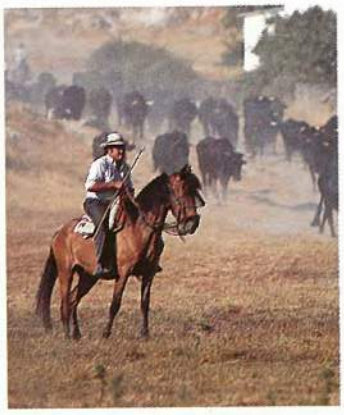
Typically, grazing animals are brought into the wetland in summer, when pastures on higher land are exhausted or dry due to summer heat. Thus at Ichkeul, herding families living within the National Park graze some 800 cattle, 2000 sheep and 300 goats as well as horses and donkeys on the marsh. Other herds are brought into the Park daily.

The Camargue marshes can hold up to three head of cattle per hectare. When the animals go to higher land in winter, they will require ten times more land — indicating the richness of the wetland pasture.

Local breeds of bull are raised for bullfighting in the Camargue and in wetlands in Spain and Portugal. In Tunisia, Greece and parts of Italy, water buffalo feed around the waters' edge. Sheep and goats are most common in North African wetlands, where, unlike cattle, they will eat salt-tolerant grasses. The distinctive white horses, which roam semi-wild across the Camargue, feeding on both freshwater and brackish marshes, have been exported to wetlands in the Po and Ebro deltas to manage vegetation in nature reserves.

Hay is still taken from wet meadows in places. Reed cutting continues on a small scale within wetlands to provide material for screens and windbreaks in France and Spain. Reeds are also exported to northern Europe to make traditional house roofs.

Traditional economic activities



B. Pambour / BIOS

Fighting bulls are raised on the wet meadows of Spain

The "cowboy" cattle grazers of the Camargue have developed a romantic reputation that, as the reality has faded, has helped to underpin the area's large tourist industry. The wild-roaming cattle were rounded up annually by pony-riding guardians, who lived in plaster huts thatched with reeds.

The importance of traditional "control activities" such as grazing and the cutting and burning of reeds inside wetlands can be glimpsed by what happens when they cease, damaging natural fisheries and the attractiveness of the wetlands to birds.

In Prespa National Park in Greece, for instance, traditional reed burning, aimed at protecting fisheries, was banned in 1974, when the Park was created. The result has been an expansion of the reed beds, which became so dense that fish could no longer reach their spawning grounds on the surrounding wet meadows. By 1989, the reeds had grown so much that when a fire started, it spread out of control, threatening a pelican colony amidst the reeds.

Wetlands include many diverse "traditional" economic activities. Small salt pans would qualify, though most have been replaced by the handful of large industrial operations such as that in the Camargue or Turkey's vast operations on Lake Tuz. Forestry has more or less died out, with most surviving wetland forests preserved as nature reserves and for tourists.

Local agricultural systems are still coming to light. One example is the saline agriculture practised on sand dunes amid the lagoons of northern Sinai close to the Nile delta, where farmers use saline waters to irrigate fields of salt-tolerant crops established in the dunes.

M. Gunther / BIOS

Changes and threats to wetlands

Drainage of wetlands has a long history in the Mediterranean. Along with the clearing of woodland, the laying of drains is one of the distinguishing features of the transformation of the European landscape over the past 2000 years.

In Italy, for instance, it began on coastal wetlands with the Etruscans in the 5th century BC, continued along inland river floodplains with the Romans, revived with the monasteries in the Middle Ages and with the engineering endeavour of the Renaissance period.

Dutch engineers, flush from their Herculean efforts in the Netherlands, instituted drainage projects in the Rhone delta and Italy, notably along the Tiber, in the 17th Century often in exchange for part of the land drained. Greater power aided the engineers in the 19th century, when steam pumps replaced windmills as the prime motive power. But the pace of drainage has never been as fast or as ill-considered as in the past 50 years.

Marshes and lagoons were drained to create this sunbathers' paradise on the beach of La Grande Motte in the Languedoc-Roussillon region of southern France

Recently, agriculture has been replaced as the main reason for drainage by industrial and urban developments, including tourist facilities. And drainage is now being replaced as the main threat to wetlands by hydrological projects such as groundwater pumping and water diversion for irrigation or large dams, often hundreds of kilometres from the wetland itself.

The widespread construction of dams on the rivers in southern Europe has been encouraged by demographic pressure, the semi-permanent drought that has hit much of the Mediterranean since the mid 1980s, and the availability of EC funds for large capital projects since Spain, Portugal and Greece joined the Community.

There are growing threats, too, from pollution, notably sewage and agricultural fertilisers that contribute to the eutrophication of lagoons and lakes, and the disturbance created by visitors. In many places it is these processes of degradation of wetlands, rather than their outright destruction, that are most worrying.

Maize fields, or other irrigated crops, have usurped marshes as the Po delta has been drained

M. Edwards / BIOS

Drainage

Drainage in the past was normally for agriculture, in particular to allow the growing of arable crops, such as wheat, on what had previously been seasonal pasture land.
By leading water away, drains lower and stabilise the water table. This provides greater depth for the root zone. Drains also removed salts, which can poison crops.

The only other traditional purpose of drainage was to eradicate the mosquitoes that carried malaria. In this century, until the past 15-20 years, agriculture remained the primary motive for drainage. But today, as agricultural surpluses in Europe have undermined the need for more arable farmland, it is housing, industry and tourist development that lie behind the installation of many drains. The scale of such developments can be immense. The Fos port and industrial complex near Marseille took 46 square kilometres of wetland, for instance.

The bare statistics of wetland loss over the past century are appalling, especially in the European Mediterranean. In Spain's Castille-La Mancha region two-thirds of all the wetlands, covering 200 square kilometres, have been lost in 25 years. In all, probably 60 per cent of the country's wetlands have gone, with many more drying out during the drought of the early 1990s. Egypt has "reclaimed" a quarter of its two largest Nile delta lakes, Burullus and Manzalah.

In Greece, 60 per cent of the wetlands have been drained since 1920. In the province of Macedonia, lakes covering 220 square kilometres and 95 per cent of its marshes, covering more than 900 square kilometres, have gone.

Hoxha's drains

In Albania, more than a third of the country's wetlands, including major lakes and lagoons such as Lake Maliq, have been drained, mostly since the 1940s. The motive was often as much to prevent malaria, which lingered on in this poor Communist state, as to provide farmland. The loss of 2500 square kilometres represents 10 per cent of the total land area of the country. During the late 1960s, a fifth of all capital investment by the Communist government was devoted to hydrological works, much of it drainage. Future damaging projects in the pipeline include draining of a further part of the Karavasta coastal lagoon.

Population pressure

Fast-rising populations of both residents and visitors are expected to be a feature of the Mediterranean basin during the coming decades, as they have in the past century.

More than 130 million people live in towns and cities on the Mediterranean coast. In the south and east of the basin, the population is expected to rise by more than 20 per cent during the 1990s. There are already 50 coastal cities with populations of more than 100,000. This rising tide of humanity is at the heart of most of the development pressures that threaten the region's wetlands.

The first step to the development of the Languedoc-Roussillon region for tourists at Narbonne-Plage and La Grande Motte in the 1960s was to drain marshes and lagoons near to proposed tourist areas in order to control the region's notorious mosquitoes. In the past, the draining of wetlands to remove habitats for mosquitoes was a public health exercise to prevent malaria. Today malaria has vanished and the issue has simply become amenity and tourist comfort.

The Mediterranean is today the destination for a staggering 30 per cent of all the world's international tourists. More than 100 million of them visit the region each year, and wetlands have become a major attraction. More than a million people visit the Camargue during the summer, many of them for riding or to see horses, bulls and flamingoes. Even in North Africa, major wetlands are a potent tourist attraction. Some days there are more than 1000 visitors in the Ichkeul National Park in northern Tunisia.

Access to core areas of some wetlands is strictly controlled, but this can increase pressures in the buffer zone around the core. Thus at Doñana, only 250 people a day are allowed into the park — causing one guide book to describe it as "harder for the average wildlife enthusiast to get into than Alcatraz was to escape from". But immediately outside the park fence is the large Matalascanas tourist complex, which is pumping freshwater from the wetland dunes and has probably dried up one lagoon. Plans for a further tourist complex to handle 32,000 people a year are currently on ice.

Eutrophication

Eutrophication is the main pollution threat in most wetlands around the Mediterranean. It occurs whenever either fresh or saline waters receive excessive sewage or farm fertiliser run-off.

The Nile delta's Lake Maryut, made famous in Lawrence Durrell's Alexandria Quartet as a haven for wildlife, receives both agricultural drainage and raw sewage from the metropolis of Alexandria. The most westerly of the delta's four lakes, it is now undergoing rapid eutrophication. Fish catches in the lake dropped by 85 per cent during the 1970s.

The rotting of sewage directly consumes large amounts of oxygen dissolved in water. Fertiliser, meanwhile, can trigger explosive growths of algae. These "blooms" of algae clog waterways and prevent sunlight from penetrating into the water. They can also release toxins and, when the algae dies and begins to rot, they consume vast amounts of oxygen dissolved in the water.

Conditions in Mediterranean lakes and lagoons, where warm waters speed growth of algae and the calm stratified waters prevent the oxygen being replenished by clean water, could scarcely be better for eutrophication. When lagoon water becomes "anoxic", plants, fish and mussel beds die and sediments begin to release hydrogen sulphide and other noxious gases that can take weeks to clear. Such a crisis in Etang de Thau near Montpellier in Languedoc (France) in 1987, killed millions of francs' worth of shellfish.

M. Gunther / BIOS

Tourists don't just require beaches or wildlife ; they want hotels and roads and water

M. Edwards / BIOS

The River Po receives the effluent from 6 million pigs and cattle

Problems on the Po

Probably the region's most extensive eutrophication arises from the pollution of the river Po, which drains much of northern Italy. Since the damming of the Nile, the Po has been the second largest source of "fresh" water to the Mediterranean after the Rhone river. Along its course, the Po receives untreated sewage from 16 million people, as well as waste from thousands of factories and farms containing six million pigs and cattle. As a result, the quantity of phosphorus and nitrogen nutrients flowing into the Po delta and the Adriatic Sea has more than doubled in the past two decades to more than 100,000 tonnes per year.

In the brackish lagoons of the Po delta, eutrophication has become the norm during most summers. The southernmost lagoon of the Po delta, Sacca di Goro, is worst, with permanent beds of green algae forming each summer since the mid-1980s. Decomposition of these beds causes periodic crises in which oxygen disappears from the entire lagoon, hence killing all life. Eutrophication now frequently extends from the delta and lagoons into the open sea of the northern Adriatic.

Fetid Lac du Tunis

Probably the most polluted lagoon in the Mediterranean is the Lac de Tunis, just outside the Tunisian capital, which suffers badly from sewage and industrial effluent. A report from the UN Environment Programme's Mediterranean office says that the lagoon "exhibits extreme eutrophication in summer; massive growth of [algae] that covers a third of the surface, and the water column to 1 metre depth becomes anaerobic, with blooms of red bacteria".

Hydrogen sulphide and ammonia are released into the water and fish kills may amount to 10 per cent of lagoon yield. Even so, most of the pollution is in the northern half of the lake. And miraculously, birds, especially flamingoes and waders, are still a major attraction in the south of the lagoon in winter. The city is aware of these problems and has recently successfully implemented a project to improve water flows.

Turkey, a country industrialising fast but so far with little environmental legislation or awareness, pumps all manner of toxic wastes, including large amounts of heavy metal wastes, into the great salt lake of Tuz. Since most of Turkey's salt for human consumption is taken from salt pans in the lake, there is concern that its table salt, polluted in particular with mercury and lead, may be a national health hazard.

If anything, problems are even worse in North Africa and Turkey, where waste treatment has not begun to catch up with rapid demographic and economic growth. The city of Tunis created an ecological nightmare in the Lac du Tunis, although recently much improved through better water circulation. Things are no better in Lake Maryut near Alexandria.

Sewage collected by the new sewer network in Cairo, a city of 10 million people, is now pumped into the Manzalah lagoon in the Nile delta. It has destroyed vegetation and fish, causing the number of plant-eating coots counted there to fall from 50,000 to a few hundred during the 1980s, since the sewers were installed. Fish deaths are becoming an annual event in the increasingly eutrophicated lagoons of Languedoc-Roussillon.

Industrial pollution with organic material that rots can have a similar effect. In Lakes Karamuk and Eber in central Turkey, paper and cellulose factories on the lakeside (using as raw materials reeds, reedmace *Typha* and straw from the surrounding marshes) pour cellulose wastes into the lakes, turning them eutrophic.

Overfishing

Overfishing is a perennial problem in Mediterranean lakes and lagoons, a product of catch technologies racing ahead of methods of managing fish stocks sustainably.

The introduction of cheap, light nylon nets has meant that many more nets are laid than in the past. Also, small meshes catch younger fish and outboard motors mean every part of a lagoon or a lake can now be reached.

Yields from Greece's largest freshwater lakes have fallen by more than half since the 1930s, to less than 2000 tonnes per year, causing economic hardship in remote rural areas. A prime reason for the decline has been improved technology for netting fish, which has caused a collapse in recruitment. In Lake Koronia, in the Greek province of Macedonia, yields in the lake peaked at 1400 tonnes in 1960, when nylon nets were introduced. But since 1980, yields have been below 200 tonnes. Common carp (*Cyprinus carpio*), the most valued fish, has declined the most.

Elsewhere in Greece, at Mikri Prespa, overfishing has been widely blamed for the slump in fisheries yields to a quarter of former levels in recent years.

Too many nets pose a threat to diving birds as well as fish. The birds become caught in the nets while under water, and drown. This is a problem in central Turkish lakes such as Lake Karamuk, where villagers leave their nets permanently in the lake.

The Grado workshop on the Mediterranean wetlands, held in 1991, concluded: "In practically all cases the degradation of Mediterranean Ramsar sites is due to unsound development practices that do not consider the sustainable and wise use of resources... This condition is exacerbated by international or EC financial assistance, which is often misguided and constitutes at times the main resource to be exploited".

A. J. Crivelli / Tour du Valat

Commercial fish traps at Tsoukalio in Greece

Threat from aquaculture

The ill-advised introduction of new fish species, as much as the over-exploitation of the old, can damage wetlands. In 1983, Lake Oubeira, part of the El Kala complex in Algeria, was stocked with exotic grass carp. In the decade since, the carp have destroyed most of the lake's reed beds as well as much other vegetation, in turn eliminating nesting birds such as herons and coot and reducing the number of wintering mallard and wigeon.

Neighbouring Lake Mellah, a briney lagoon, which for a long time has suffered from overfishing, is now threatened by a scheme to exploit clams (*Ruditapes* spp.) and mussels. Such a project will also involve an alteration of the hydrology of the lagoon. The recent decline of bird life here due to the disturbance of fishing could, ornithologists fear, be set to continue.

The past decade has seen a major expansion in World Bank and EC-funded intensive aquaculture projects in lagoons and coastal waters — especially for sea bass (*Dicentrarchus labrax*), mussels (*Mytilus galloprovincialis*), oysters (*Ostrea edulis* and *Crassostra gigas*) and shrimps (*Penaeus japonicus*). But the results have sometimes been unfortunate, with chemicals, excreta and bacteriological contamination threatening the quality of the surrounding waters. Excreta from fish farms add to the nutrient load of wetlands, causing algal growths and eutrophication.

There is a growing view that intensive aquaculture, which is frequently in conflict with traditional lagoon fisheries, should not be practised in natural wetlands.

Since many lagoon fish migrate to the open sea each year, destruction of habitats outside the wetland itself may damage life within it. Eutrophication in the open sea of the Adriatic and in bays throughout the Mediterranean may damage wetland fisheries. And trawler fishing in coastal waters often damages coastal vegetation, such as beds of sea grass (*Posidonia*) that are important for fish as spawning and feeding grounds. This is a common problem all around the Mediterranean region.

Hunting

It can be persuasively argued that the single greatest cause of the degradation of wetlands and their wildlife has been hunting. And yet, the case can also be made that hunting could be one of the most benign and wisest uses of wetlands.

Spent lead shot is a significant source of poisoning in wetlands where hunting is popular. One estimate is that more than a thousand tonnes of lead shot is discharged into the Mediterranean wetlands each year.
The shot falls to the bottom of marshes and is eaten by waterfowl as grit. In the US, where the amount of lead found in birds is no higher than in the Mediterranean, lead shot has been banned for all hunting of waterfowl, and replaced by steel shot. But no Mediterranean nation has yet taken this step.

There are some 9 million registered hunters in Europe, at least half of them in the Mediterranean, a greater concentration than probably anywhere else on Earth. They kill millions of waterfowl each year. Along the French Mediterranean coast alone, between 1 and 2 million ducks are shot each year.

Yet, without hunters, habitats for many birds would have been lost. Many of the largest Mediterranean wetlands would not exist if they had not generated wealth from hunting. The Doñana, now a famous National Park, was once a royal hunting reserve. Much of the surviving freshwater marshes of the Rhône and Po deltas are set aside for hunting. The annual carcase value of ducks taken from the Camargue is probably more than $ 20 million.

But to be sustainable in the long term, hunting practices must usually be controlled and, in the Mediterranean region, hunting regulations are less thorough and less well policed than in northern Europe. Although scientists have recommended that no hunting be permitted during the breeding season or before the autumn migration, hunters are still active during this sensitive period. In addition, the European Directives on hunting, which supposedly control the closed and open seasons throughout the European Community, are rarely fully applied.

Some local hunting associations have made a considerable effort to buy up remaining wetlands and this is an important first step towards preserving these areas and collaborating with other wetland users. Considering the large numbers of hunters in the Mediterranean more such initiatives would be very welcome. Management of these areas for hunting shoud also take into consideration the needs of all those who use these wetlands (fishermen, hunters, farmers, birdwatchers) so as to optimise the use of available resources and to reconcile different, and sometimes conflicting, interests.

Disturbance

Increasingly in Europe, the threat to wetlands is not so much of outright destruction as of degradation, through management problems and a failure to control access to what is usually public property.

An analysis of threats to Ramsar wetlands, drawn up by the Ramsar Bureau in 1990, put disturbance (including hunting, recreation and boating) at the top, threatening 112 out of 318 European and Mediterranean Ramsar sites. Pollution came next with 105 sites and agricultural schemes third at 64 sites.

While tourists bring in much revenue and underpin economic activities, such as grazing, as well as the protection of birds, they also disturb the peace that birds, in particular, require.

In some wetlands, the peace of bird life has been shattered by the conversion of lagoons into boating and water-skiing lakes. Tourists also demand the widening of roads, causing disturbance and killing animals. The corpses of the rare Spanish pardel lynx are frequently found on the roads of Doñana.

M. Gunther / BIOS

An aerial view of hides in the Camargue from where duck hunters await their targets

Hydrological management

Large-scale hydrological alterations of wetlands are now, with the decline of piecemeal drainage, the main cause of their destruction. Modern, cheap and mobile pumps make it possible for farmers to abstract from beneath wetlands and surrounding areas large amounts of water for irrigating crops, such as rice and cotton. As water tables fall, the wetlands dry out as surely as if they had been drained at the surface.

But wetlands can also be deprived of water from afar, through the construction of dams upstream on major river systems. The result is both some loss in overall water supply to the wetland and, equally important, an interruption of the seasonal natural cycle of high and low flows that is essential to the pattern of plant life, birds and fisheries downstream. Even more worrying for the longer term is the loss of sediment, trapped behind dams. Without the sediment, the processes that create and maintain features such as sand spits, marshes and deltas, cease.

Increasingly, governments are talking of using dams and pipelines to divert water from one river catchment to another, with the result that large proportions of a river's flow are lost entirely from that river. The Acheloos diversion in Greece is currently under discussion, and threatens massive destruction of wetlands.

Climate change, of which the Spanish drought of the early 1990s could be a precursor, may in the coming decades cause major changes in flows in rivers and bring vastly increased pressure for water transfer schemes. Global warming will also increase evaporation rates and raise sea levels. Deltas and lagoons behind sand spits, which are already often starved of sediment to maintain their defences against the sea, could succumb to the rising tides.

An irrigation canal in Greece's Nestos delta. Water taken for crops is lost to the natural wetland

Waterworks on the wetlands

Artificial water storage is not widespread in wetlands, but there is substantial water abstraction, particularly from the groundwaters that underlie and sustain many wetlands, for example for the irrigation of rice paddies.

The damage from irrigation was vividly seen during the 1980s at the Daimiel wetland park in central Spain, where in 1979 local farmers began large-scale abstractions of water from the aquifer that stretches beneath the wetland. Abstractions are now 100 million cubic metres per year greater than inflow; the water table is falling, and the entire area is becoming desiccated.

One river passing through the wetland virtually dried up as the spring that fed it failed. The second river was losing most of its flow through infiltration into the parched aquifer. Daimiel became so dry in places that fires have broken out in its peaty soils.

An emergency programme, begun in 1988, to bring water from a neighbouring catchment has drastically changed the chemical composition and flow of underground water in the wetland. It has required the partial canalisation of the river. As a result, wet riverine habitats have been lost. The rescue plan also required the draining of lagoons upstream in the river to supply the extra water. These lagoons were themselves important habitats for birds.

M. Gunther / BIOS

Strawberries replace fish in the Doñana wetland

A similar irrigation scheme is under way outside the fence of the Doñana wetland reserve, Spain's largest. Irrigators abstract more than 50 million cubic metres a year. The water table is falling by about 50 centimetres a year, bringing warnings from hydrologists that river flows will fall, marshes will permanently dry up and the water beneath the park will become saline as sea water invades. Ultimately the scheme will prove unsustainable because the saline water will be drawn into the irrigation pumps themselves.

The same threat looms at the other end of the Mediterranean, where groundwaters beneath the Azraq oasis have been plundered since 1980 to supply desperately needed water for the Jordanian capital, Amman. The natural discharge at the oasis has sunk to a fifth of its former level. There are growing fears that the salt lake that forms in the area after rains could begin to turn the aquifer saline, thus destroying one of the region's most precious sources of fresh water.

Salinity balance upset

On coastal wetlands, one principal effect of many hydrological schemes is to alter the delicate balance that determines the salinity of marshes and lagoons.

The Etang de Leucate in Languedoc suffered a doubling of its salinity after the construction of a marina on a sand spit and the digging of a channel from the sea into the lagoon. The number of species of fish in the lagoon increased, but annual catches fell to a fifth of their former 200 tonnes.

Water management to cater for the rapid growth of irrigation of rice crops in the Camargue, for instance, has increased the throughput of "fresh" drainage water into the Etang du Vaccarès. The lagoon has become less saline and more permanent than before the rice growing era. The nearby Etang de Berre, linked to the sea by a wide channel, has suffered reduced salinity for a different reason. In 1966, a hydro-electric power plant began discharging freshwater into the lagoon at an annual rate three times the volume of the lagoon. Local fishermen complained bitterly when their sardine (*Sardinus pilchardus*) and eel catch disappeared.

Wetland to desert

Pumping of water for irrigation from the groundwaters beneath wetlands is a frequent and damaging form of water exploitation. Often it is seen as an additional way of draining "excess" water from a wetland.

But the long-term results can be disastrous for farmers as well as the wetland.

Thus it was at Tunisia's Garaet El Haouaria, 36 square kilometres of lake and freshwater marsh using for hunting, grazing and fishing as well as by bird life. In the 1960s, drainage for agriculture removed open water. Then wells were dug deep into the aquifer to provide water for both towns and tomato processing works.

Finally, farmers begin to use the shallow aquifer for seasonal irrigation of crops.

Soon, the shallow wells grew saline because the fresh underground water was being replaced by saline water from the coast. Irrigation was abandoned. Some farmers persisted by growing rain-fed wheat in the parched soils. But most of the children of the farmers who moved into the area a generation ago have departed for the cities.

M. Edwards / BIOS

Upstream dams

One of the most heavily engineered rivers in Europe is the Rhone, which has 48 hydro-electric dams and numerous water diversion schemes. These have substantially reduced river flows in spring and summer, when they are at a peak because of snowmelt in the Alps.

Meanwhile, the normally low winter flows have risen, as water is released from reservoirs to power winter demand for electricity. As a result, annual discharge of the river as it enters the Camargue is down by 10 per cent, and the difference between high and low flows has fallen by 30 per cent.

Sediment flow into the delta has fallen from an estimated 50 million tonnes a year last century to 5-8 million tonnes presently. In the past decade, the delta's seaward edge has retreated by between 30 and 100 metres.

Water for maize - not ducks

Since the completion of the Mequinenza dam on the Ebro in 1972, 90 per cent of the river's sediment has been held upstream of the delta. Several parts of the delta, which was enlarging until the 1970s, are now retreating by as much as 50 metres a year. Salt invasion from the sea threatens rice fields and the mussel beds in the brackish bays, as well as freshwater wild life. In the longer term, the flooding of the southern part of the delta seems likely, opening its lagoons to the sea.

The worsening drought in Spain during the early 1990s threatens to do further damage to the Ebro delta. Parched southern regions of Spain are looking increasingly enviously at the Ebro's flows and, in drawing up a National Water Plan to tackle the escalating water crisis, the Spanish government considered proposals to divert part of the Ebro's flow south into other river catchments.

Future dams

Such is the demand for water in the Mediterranean that the clear evidence of the harm they cause downstream has done little to stop new proposals coming forward. In mid 1992, the Greek government announced proposals to proceed with a $1.3 billion plan to divert a third of the flow of the Acheloos River, the country's longest river, through a tunnel in the Pindos Mountains to the River Pinios, from where it would irrigate tobacco, rice and vegetable fields in the east of mainland Greece.

At the mouth of the Acheloos sits the 600 square kilometres of the Mesolongi wetland. Besides its fisheries, it is a Ramsar site and a wintering ground for Dalmatian pelicans and the endangered slender-billed curlew (*Numenius tenuirostris*), which would be severely threatened.

An equally great disaster looms at Ichkeul, where Tunisia's national water plan has already built three out of six dams planned for all rivers feeding the wetland. The dams would deprive the wetland of roughly two-thirds of its present water supply.

The likely effect of completing the dams during the 1990s would be to make the main source of water for the wetlands saline through its outlet to the sea. Plans to install a sluice would only mitigate this. It would turn one of the last freshwater lakes in North Africa, and arguably the most important bird centre in the whole of the region, into an increasingly small and saline sebkhet, with the loss, apart from bird habitat, of a nationally important and sustainable fishery.

Sea levels, river flows and sediment

Few features of the planet, even the largest, are ever stable. Land areas rise and fall, while global sea levels have been rising at around a millimetre a year for the past century at least. But human activities are beginning to influence some of these processes on a large scale.

Most predictions are that global warming — the result of human activity increasing the amount of greenhouse gases, such as carbon dioxide, in the atmosphere — will melt ice and raise sea levels by between a half and one centimetre a year in coming decades.

The greenhouse effect is likely to impose sharp changes in regional climates. Climate models suggest that some parts of the Mediterranean are likely to suffer reductions in rainfall. This will be accentuated by the increasing rates of evaporation and erosion that will follow higher temperatures. All this could cause major changes to the hydrology, chemistry and sediment loads of river basins and wetlands.

The changes will in turn influence ecosystems, particularly in the transitional environments of wetlands. In addition, higher water temperatures are likely to favour the formation of algal blooms in lagoons and coastal waters — already a serious problem in the Adriatic, for instance, because of pollution.

The effects of rising sea levels may be particularly noticeable in the Mediterranean, since there is virtually no tidal range. Also, several major wetlands are on river deltas that are already retreating because they have lost much of their supply of sediment, trapped behind upstream dams.

Under such circumstances, an increase in global sea levels could cause catastrophic loss of lowlands and marine inundation of lagoons. Deltas at risk, according to the UN Environment Programme, include the Ebro, Rhone and Po delta/northern Adriatic coastline and the Nile. Such changes are made more likely because a warmer world, with a more energetic atmosphere, is also likely to produce more extreme climatic events, particularly more intense storms.

The effect of these events, which are already crucial in creating and destroying wetland geomorphological features such as sand spits, will be hard to predict.

Retreat of the Nile delta

The Nile delta ceased to grow more than a century ago, when the first barrages were built, diverting much of the river's flow onto fields. But since the completion of the Aswan dam upstream in 1964, and the collection of more than 95 per cent of the river's load of silt behind the dam, the delta has been in full retreat. The former village of Borg-el-Borellos, at the mouth of one of the main channels out of the delta, is now 2 kilometres out to sea.

The Nile sediments, on reaching the sea, were once washed eastwards along the coast by currents, maintaining the sand bars that lie in front of its large lagoons. Now the bars protecting Lakes Manzalah and Borullus are eroding and face collapse.

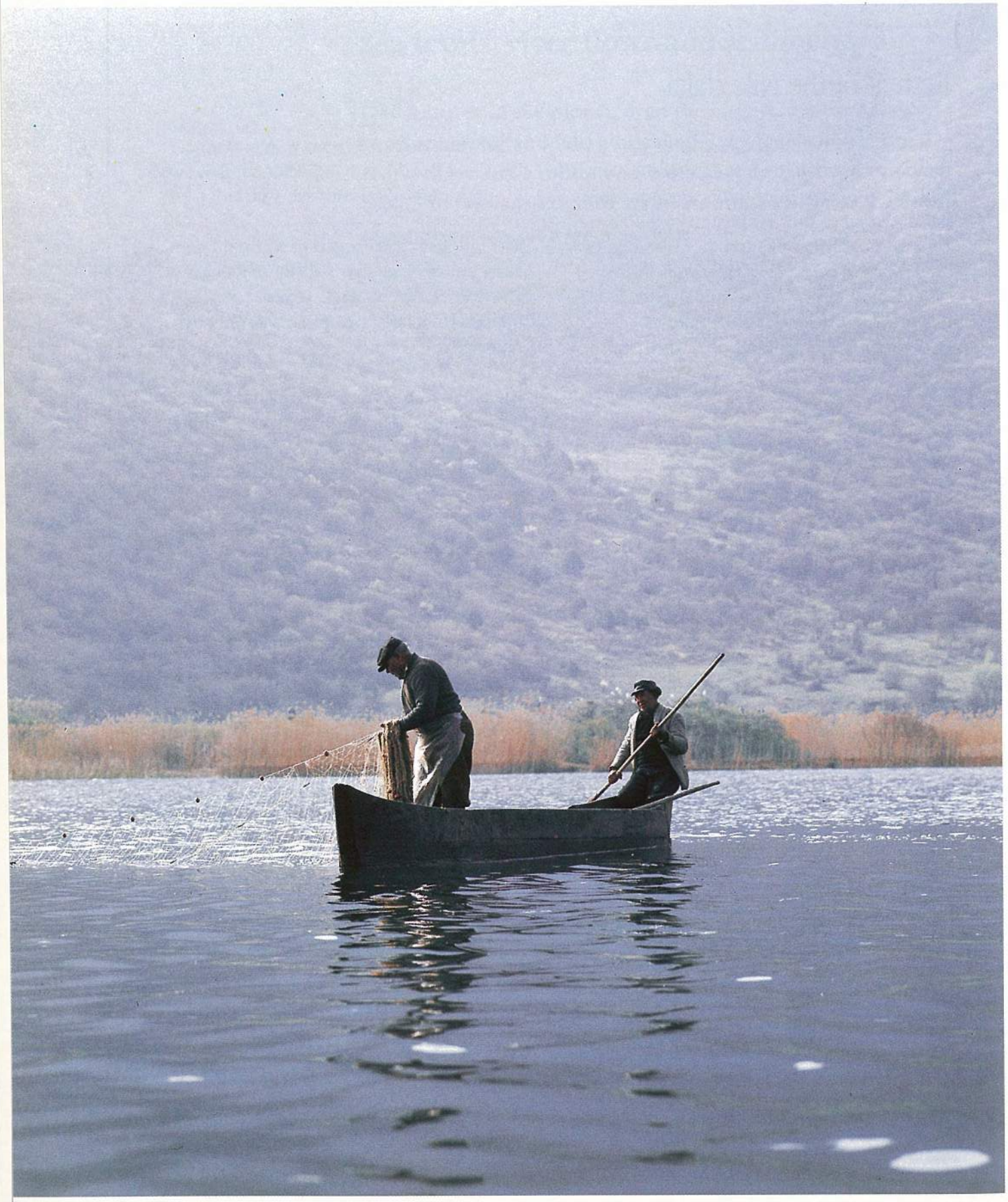
This would turn the lagoons into marine bays and flood low-lying delta farmland and groundwaters alike with salt water.

The integrity of these lagoons could be an early and spectacular casualty of rising sea levels in our greenhouse world. Likewise, the Bardawil lagoon is protected only by narrow, low-lying dunes.

Ultimately, large areas of farmland in the most productive area of Egypt and a third of the country's population, including major cities such as Alexandria, could be at risk from the retreat of the delta.

Extract from the "Book of the Dead" (about 1420 BC). Well before Christ the Egyptians had understood the importance and wealth the Nile valley.

Lafranchis / BIOS



Towards integrated management

Integrated management is a new phrase for an idea as old as human exploitation of the landscape: that productive natural systems should be sustained rather than plundered, their output maximised in the long and not the short term ; and that achieving this requires taking an intelligent overview of how aspects of that productive landscape fit together.

Wetlands are highly integrated systems. It is foolish to drain a marsh for agriculture without thinking through the consequences for fisheries or hunting, or to build a dam upstream without wondering how the coastline will cope without its silt. Equally, it is wrong-headed to encourage birds to nest on a wetland without wondering whether their eating patterns will harm local agriculture.

In the heavily populated Mediterranean region, with strong development pressures and a still-expanding population, sophisticated management will be required in the coming decades to protect and manage what remains of the region's water resources, including wetlands.

Nations, and groups of nations, will need to prioritise their use of water and find new ways of sharing it, balancing the needs to "exploit" water resources with the need to keep water in rivers and wetlands to protect natural, productive ecosystems.

Are traditional fishing practices disappearing? Fishermen on Lake Prespa

Water resources

Managing water resources in the Mediterranean is set to become a key feature in the region's development in the 21st century. And that will mean taking a harder look at the importance of wetlands hydrologically, both as an end use and a store for water, and in sustaining other natural resources such as fisheries.

Studies by the Mediterranean Action Plan of the UN Environment Programme show that a number of nations are already reaching crisis point in their use of water. Libya and Israel already use up all their annually renewable water resources, as conventionally defined, and are switching to unconventional sources, such as tapping "fossil" waters beneath deserts - an essentially non-renewable resource - the use of sewage to replenish groundwaters, and, most expensively, desalination of sea water.
Egypt is approaching this point, with a water "exploitation index" reaching 100 per cent, a fact complicated by its extreme reliance on the River Nile, which rises in other countries and may be vulnerable to climate change.
Malta and Tunisia are already above 50 per cent which, in practical terms, requires very careful management of resources, especially because of growing uncertainty about whether climate change could reduce rainfall, and therefore water availability.
Algeria, Morocco and Spain, all with fast-growing populations, are certain to enter this category within the next decade or so. Drought, arguably, has already propelled Spain there.
The only Mediterranean countries classified by UNEP as likely to have low pressure on water resources are Italy, France, the Balkan states, Greece, Turkey and Syria. But each of these countries has seasonal and local pressures on water supplies that leave wetlands open to destructive exploitation, such as the Acheloos river diversion project in Greece.

The Daimiel wetland. Can it survive as Spanish water supplies dry up?

M. Gunther / BIOS

Towards integrated management

Protected areas

The classic method of conservation of wetlands in modern times has been through the creation of national parks and reserves, where human activity is strictly curtailed. Many such parks are protected under international agreements. The most important of these for wetlands is the Ramsar Convention on Wetlands of International Importance especially as waterfowl habitat, which has been signed by all nations in the region except Albania and Turkey, since its inception two decades ago.

While the Convention has been of immense benefit to wetlands, its over-riding purpose at the outset was to protect birds. There is insufficient pressure to protect other aspects of wetlands such as fish or mammals or plant life, invertebrates or aspects of their geomorphology. But emphasis is now shifting fast, away from birds, towards the wise use of wetland resources.

Besides public national parks, outright purchase of land is another option for conservation. The French Conservatoire du Littoral, for instance, owns and manages large areas of wetlands, including several on the Mediterranean coastline. International conservation bodies such as the World Wide Fund for Nature (WWF) do similar work, buying up small areas of relict riverine woodland, for instance. But ownership of the land is of no value if the threat comes from a dam 500 kilometres upstream, from pollution or from uncontrolled offshore fisheries.

Occasionally, park restrictions can be too severe and ill-applied, such as the banning of reed cutting and burning in the Prespa Park in Greece, which created a damaging reed "takeover" of both meadows and open water. Such centralised management can also be used to usurp control of the common wetland resource by individuals or a powerful group, such as hunters, or even ornithologists. It is claimed that a massive hydrological scheme to replenish the water in the Daimiel wetland in Spain is under the control of farmers who want more water for irrigation.

But the danger can also be that unthinking conservation management can drive a wedge between, on the one hand, the interests of the wetland and its conservation and, on the other, of the local communities — who are often descendants of people who successfully managed the wetland for many centuries. A new balance needs to be found.

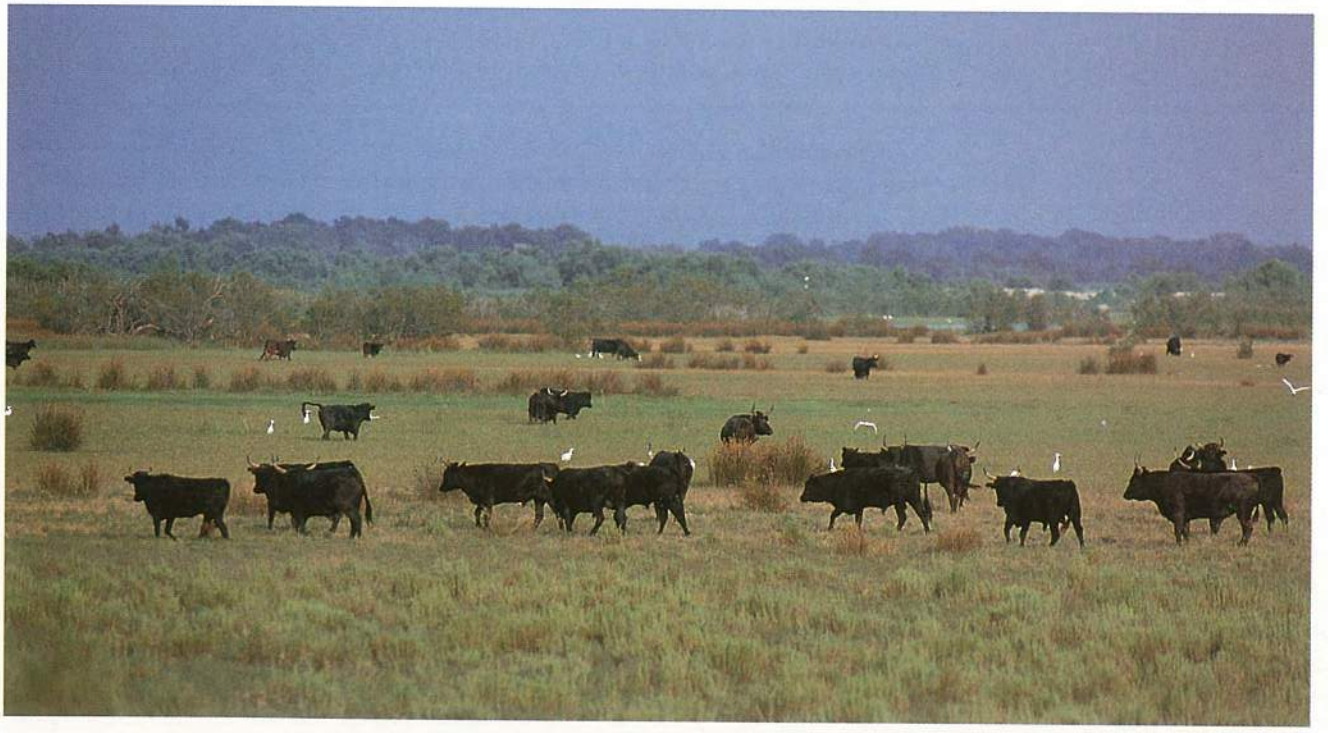
New deal

If conservation is always seen as the enemy of economic development, then it will always be on the retreat conceding marshes here and river flow there. The challenge is to rediscover and sustain ways to make long-term profitable use of the natural, bountiful wetland systems

That requires new partnerships between private, communal and publicly owned property. And above all it requires local people to recognise and embrace the long-term benefits of such an approach, and to have sufficient confidence in the systems of control that they can believe that promised long-term benefit will be realised.

One starting point in fisheries, for instance, would be to sustain traditional management systems in lagoons, such as the ancient Italian "valli", against rivals such as prawn farms and mussel beds. For many, the cultural tie to traditional methods of sustainable utilisation of wetlands is the key to re-instilling the ethic that conservation and economic interests go hand in hand.

Sometimes the value of a wetland can be revived almost by accident. Lac Fetzara in Algeria, close to the El Kala lakes complex, was drained in the 1930s by French colonial engineers. But more recently, local engineers revived its use as an emergency store for floodwaters, only to discover that their "new" lake created valuable grazing pasture.



M. Gunther / BIOS

Restoration and rehabilitation

Despite the widespread damage to wetlands in the Mediterranean, there remain alluring prospects for restoration and rehabilitation in many places.
Most obviously, these arise where the intended or actual agricultural or industrial use of a wetland is no longer required. Opportunities arise here as nations of the EC shed up to 15 per cent of their farmland through "set-aside", in an effort to cut farm surpluses.

There is wide scope for applying set-aside grants to wetland restoration. Former farmland can be seasonally or permanently flooded, abandoned lakes and marshes reconnected to the fluvial system and alluvial forests replanted.
Even small, well targetted, rehabilitation projects can recreate habitats for migrating species and so revive wildlife widely within an individual wetland and throughout a river system.

Reductions in pumping for irrigation schemes can raise water tables and revive wetlands over wide areas.
The reduction of some heavy industries in the European parts of the region also offers potential for rehabilitation.
Dykes around marshes drained for industrial development in the Venice lagoon are now being lowered to allow water to return. Besides its ecological benefit, this policy reduces the risk of flooding in the lagoon and may increase the take of the lagoon's extensive fisheries.

But to gain the best from these projects, it may not be enough simply to "return the land to nature". Long-term management is likely to be necessary, particularly of water levels, to maintain what may now be a very artificial hydrological regime.

Wetlands can provide valuable grazing

European Community

The lessons of sustainability need learning also by national governments, and by international funding agencies such as the World Bank and supra-national organisations with legislative as well as funding roles, such as the European Community.

The latter has only recently shown its willingness to integrate the policies of its different directorates, an essential pre-requisite for the integrated management of wetlands. Both the Birds Directorate of the EEC from ten years ago and the new Habitats Directive adopted in 1992 promote protection of natural wetlands. But their impact is obviously limited while other sectors of the EEC, with larger budgets and greater influence, continue to fund "development projects" affecting Mediterranean wetlands through initiatives such as the Integrated Mediterranean Programme and the Structural Funds.

In the past these funds, destined for the poorer regions or weaker sectors in order to share the benefits of the single market, have supported projects without always paying sufficient attention to their negative impact on the environment and on wetlands in particular.

G. Martin / BIOS

The pygmy cormorant is among the region's rarest birds

M. Edwards / BIOS

The European Community has decided to set aside up to 10% of its arable land in an attempt to cut down farm surpluses

M. Gunther / BIOS

Conclusion

This tragedy unfortunately has its counterparts in other southern European countries such as Spain and Portugal. And the World Bank and other agencies are set to repeat them in Turkey, Tunisia, Morocco and elsewhere. Much of the damage to important wetlands could be alleviated with a little care and better planning. On other occasions not. But in all cases, scientists and environmental planners have struggled to demonstrate conclusively the likely impacts on the ground of development schemes involving wetlands — and also struggled to construct and argue the case for alleviation measures. In the case of the EEC, the new planning system requires that impacts on the environment should be taken more fully into consideration.

Much remains to be learned about how wetlands and their wildlife function. Only then will scientists be able to speak with sufficient authority when arguing their conservation case. Only then will integrated management of wetlands be successful.

Virtually all the surviving wetlands in the Mediterranean face serious threats to their survival from man. Yet, more than most natural environments, they cannot be given "back to nature". Many owe their current state, including much of their biological diversity, to centuries of human intervention. Where would the wet meadows be without domesticated grazing animals ? Where would the flamingoes go if the highly managed lagoons of the salinas were abandoned ?

Techniques for wetland management, and especially for restoration, have to be developed. On the edge of the Venice lagoon, for instance, land drained for industrial developments that never happened can be allowed to become wet again. But how best can the lagoon vegetation be encouraged to grow ?

How should former salinas be managed ? Many cannot simply be left to revert to nature since their stable salinity regimes — vital to birds with few alternative sites for breeding — will need to be maintained artificially. How can rice paddies be returned to freshwater marsh ? Indeed, given the kind of wildlife they can attract after harvesting, should they, like former salinas, be managed towards a different, more stable end ? There are big political questions, too. Should conservationists back the transfer of water from other catchments into rivers containing wetlands, in order to help their preservation — as has happened to the Daimiel wetland in Spain ? Or should such large-scale hydrological engineering be opposed on principle ? These and other questions, such as the fraught issue of how to place a value on a wetland — to set beside the value of arable farmland or water for cities — will be addressed in future books in this series.

Perhaps the most vital need is to find economic and political means to

Springtime flooded meadows in Turkey

prevent wetlands suffering the classic "tragedy of the commons", in which the users of common resources (forests and pastures, as well as wetlands) degrade those resources by overuse, because if they do not use the resource first, somebody else will. In past cultures, the means of preventing the tragedy were often embedded in social taboos and feudal laws. Their modern replacements, law and economics, mostly relate to private property not to the management of communally owned resources. But, where governments and local people can see the common need to preserve natural productive environments and devise methods of doing it, then the protection of wetlands makes abundant economic as well as ecological sense.

The Venice lagoon: hydrology disrupted

Probably the most visited wetland lagoon in the world is the Venice lagoon, which covers 550 square kilometres around the tiny speck that is Venice, one of the most spectacular tourist attractions in the world.
For most visitors, the lagoon is a threat, through flooding, to the city. Few realise that without the lagoon there would be no Venice.

In November 1966, the tide was almost two metres above normal, and St Mark's Square, the city's premier tourist attraction, was more than a metre deep in water, floating garbage, sewage and rats. The reason was that, after centuries of living close to harmony with its surroundings, the city's engineers are increasingly at odds with the lagoon.

Major re-engineering of the lagoon began in the 18th century, when rivers that once brought fresh water into the lagoon were diverted away in an effort to prevent the lagoon from silting up. During the present century, engineers have reclaimed land from the lagoon — for farming, for the extension of traditional aquaculture inside embanked ponds, for the city's airport and for an industrial complex. Meanwhile, they have dredged channels into and through the lagoon to allow large ships to reach the industrial port of Marghera.

But the dredging caused many natural channels to silt up. Today, tides can reach only two-thirds of the lagoon, making high tides higher.
The dredging has also triggered erosion of other channels, so that flood tides can today enter the lagoon much faster than before. The lagoon is assuming the character of the sea.

That will eventually spell doom for Venice and its lagoon, unless the process can be reversed. Which it is. Land reclaimed for industry, but never used, is being given back to the lagoon. Farmland is being flooded; mud flats conserved.

But ecologists go further. They reject city plans to build three huge barriers at the entrances to the lagoon as the ultimate flood defence. Instead, they want an end to deep dredging of the shipping channels. And, ultimately, they want the diverted rivers directed back into the lagoon to resume their job of holding back the sea and to recreate the natural dynamic balance that created and can sustain the lagoon.

Glossary

Algae : seaweeds, diatoms and other small plants that lack flowers, stems. roots and leaves and live in water

Anaerobic : an organism or process that operates in the absence of oxygen

Anoxic : without oxygen

Aquaculture : cultivation of aquatic organisms (plant, shrimp, shellfish and fish)

Aquifer : porous rock containing water

Braided river : one flowing in a series of separate channels

Brackish : slightly salty

Calcareous : containing calcium carbonate from chalk or limestone

Emergent plants : aquatic plant with stems and leaves above the water

Endemic species : a species with a restricted geographical distribution

Eutrophication : water rich in nutrients that may result in "blooms" of algae

Greenhouse effect : accumulation in the atmosphere of gases, such as carbon dioxide, that trap heat

Groundwater : the water stored within an aquifer

Halophytes : plants that grow in salty soils and marshes

Inter-tidal : between high and low tide

Karstic : typical of a limestone region

Meander : a bend in a river

Ox-bow lake : a meander in a river eventually cut off when the river takes a straighter or new course

Perennials : plants that grows for at least three years

Salina : salt pan

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The **Station Biologique de la Tour du Valat** was established in the Camargue (France) in 1954 by Dr. Luc Hoffmann as a private research institute, primarily for field ornithological studies.

In 1993 the estate consists of 2500 ha of land belonging to the Fondation Sansouire, created under French law in 1976. The estate is one of the few in the eastern Camargue on which extensive areas of near-natural landscapes have survived the post-war expansion of arable agriculture. Funding for the research and conservation programme of the Station comes from a variety of national and international organisations, but the major part of the core funding is provided by the Fondation Tour du Valat, a foundation under Swiss law.

The scientific programme of the station has evolved over the years, and has included programmes on the management of vegetation using domestic herbivores, fish ecology, optimal foraging strategies, behavioural studies, and migration and breeding success of colonial waterbirds. Most of these studies have been undertaken in the Camargue, but the Station has increasingly worked in collaboration with other scientists in the Mediterranean region.

This programme has provided the Station with a fundamental understanding of Mediterranean wetland ecology which can be applied to wetland management problems in the region.

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