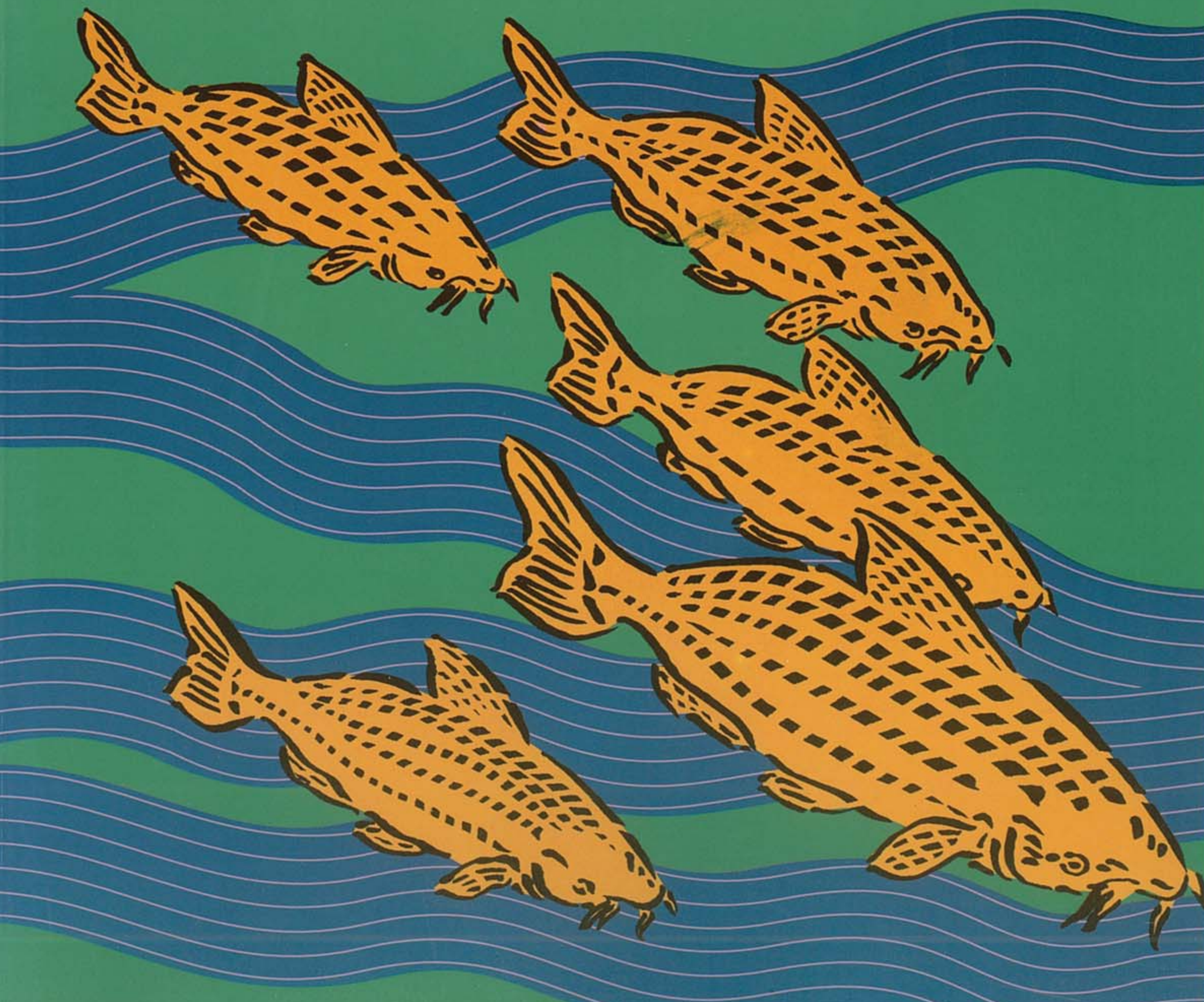
TOUR DU VALAT

MedWet

Conservation of Mediterranean Wetlands

Conservation of freshwater fish

P. S. Maitland & A. J. Crivelli



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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, Wetlands International 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.

Peter S. Maitland & Alain J. Crivelli, 1996
Conservation of Freshwater Fish
Conservation of Mediterranean Wetlands - number 7
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Titles of the collection :

1. Characteristics of Mediterranean Wetlands
2. Functions and Values of Mediterranean Wetlands
3. Aquaculture in Lagoon and Marine Environments
4. Management of nest sites for Colonial Waterbirds
5. Wetlands and Water resources
6. Aquatic emergent Vegetation, Ecology and Management
7. Conservation of Freshwater Fish

Conservation of Mediterranean Wetlands
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Conservation of freshwater fish

Peter S. Maitland & Alain J. Crivelli

Number 7

Series editors : J. Skinner and A. J. Crivelli

A. J. Crivelli

Preface

The great diversity of the well-loved Mediterranean region continues to fascinate to this day. Cradle of diverse civilisations, the region has seen substantial human population growth with its inevitable consequences on the coastal zones and hinterland.

In addition, the Mediterranean basin is polluted or degraded in many places – deforestation and rapid, intense, uncontrolled urban, industrial and tourism development have taken their toll on fragile habitats and their capacity to regenerate.

Yet the basin supports an extraordinary biological diversity in all aspects of fauna and flora. The fish communities illustrate this point particularly well – while Great Britain holds 34 species and Denmark 44, Spain has 68 species and Greece 106 ! In consequence it is unsurprising to discover that the Mediterranean region also has the greatest proportion of endangered species.

It is therefore a pleasure to see this interesting new publication from the MedWet programme dedicated to the freshwater fish of the region.

It is to be hoped that this well-documentated and lavishly-illustrated publication will be widely distributed and will find a wide readership among decision-makers (politicians, planners or funders), managers and users of this resource. It should also improve recognition of the economic and ecological roles of fish populations and the part they play as bio-indicators.

Lagoons, lakes and coastal water courses lie at the heart of the issue. Would that Man of the nineties, so keen on immediate profit, find the time to think of future generations and, above all, leave them a natural heritage in which to lead a healthy life.

Jean-Pierre Ribaut
Head of the Environment, Conservation and Management Division
Council of Europe

Mountain streams are important habitats for fish and require protection.

Contents

A. J. Crivelli

Introduction

It is a surprising fact that fish are the most abundant and yet the least known of the vertebrate classes living on the planet.

Over 20,000 species have been described so far and it is likely that the final total will indicate that three in every five vertebrate species are fish. Every year, about one hundred new species are described so the total of species may well be near 30,000. They live in virtually all kinds of aquatic habitat and have developed a wide variety of fascinating form and function.

Fish occur in both marine and freshwater environments, but although fresh waters occupy only a minute fraction of the earth's surface, it has been estimated that one-third of all fish belong to primary freshwater species*, mainly carps, characins and catfishes. Because of the fragile nature of freshwater habitats and the pressure which they are under in all parts of the world from human activities, it is this sector of the fish fauna which is under greatest threat. Fish populations are limited by land boundaries to their immediate water body and thus the whole population is vulnerable to a single incident of toxic spillage or acidification*.

The shallow, flooded margins of Lake Skadar (Montenegro) provide key spawning grounds for fish.

In much of the Mediterranean area, where the climate is hot and dry, fresh water is in short supply and fish and humans are in competition for this scarce resource. Improved standards of living in most countries and a rise in human population have combined to make increasing demands on freshwater resources, and have resulted in conflicting interests in available water. Because of such demands, fish in southern Europe, where water is short, are more threatened than those in the north, where water is plentiful. It is an ironic and sad fact that, for reasons discussed below, most of the endemic* species of European fish (some of which have never been studied properly) occur in the south, particularly around the Mediterranean. In the struggle for fresh water there, fish habitats and fish species themselves are losing out and increased conservation action is essential[1].

J. M. Prévot / Bios

Water pollution is often fatal to fish.

1 - Crivelli & Maitland, 1995

The River Ter, Catalonia.

M. Raurich / Stock Photos / Bios

The River Ter: a Mediterranean river system in Spain

The Mediterranean region is one of the most densely populated and industrially developed parts of Spain and the River Ter, which is under extreme pressure, is typical of the rivers there.

Human influence on the Ter started in the Middle Ages with iron industries which caused the deforestation of large areas of the catchment. During the Industrial Revolution, cotton and paper mills proliferated along its banks, attracted there by the quality of its water. An inheritance from this period is the large number of small dams and artificial channels created for water mills.

Regulation of the Ter was completed during the 1950s by the construction of two large reservoirs in the middle reaches of the river. Since then, the extensive development of industrial facilities and the unplanned growth of urban areas has meant that there are now extensive sewage discharges to the river. At the same time the water of the river is needed for intensive farming, domestic consumption and industry. Thus, at present, the Ter remains undisturbed only in its head waters. In addition to this anthropogenic impact, fluctuations in water discharge, typical of the Mediterranean climate, create variable conditions in the river – summer is very dry whilst high discharges are common in autumn[1].

Most of these factors have impinged on the invertebrate and fish faunas of the River Ter and many other Spanish rivers which are now less diverse than formerly (several species have disappeared – e.g. the Atlantic Sturgeon *Acipenser sturio*), contain a number of foreign species (e.g. Largemouth Bass *Micropterus salmoides*), are of less value economically (to both sport and commercial fishermen) and are generally degraded.

1 - Sabater et al., 1992


J. Gregori

Freshwater fishes

There are various historical reasons for the present nature and composition of the Mediterranean fish fauna. Based on the distribution of primary freshwater fishes, 12 peri-Mediterranean ichthyological districts are recognised.

The uniqueness and restricted range of several endemic taxa occurring in the southern European peninsulas and northern Africa suggest a preliminary Mediterranean dispersal rather than a dispersal by river captures between southern and northern Europe. The analysis of the fossil record, palaeogeography and palaeoecological data suggests a major penetration of primary freshwater fishes into peri-Mediterranean districts during the Messinian lacustrine 'Lago Mare' phase, some 5 million years ago. The present distribution of these fishes is mostly the result of Late Pleistocene events (the last Wurm glaciation), 18,000 years ago when, during the more extended marine regressions, river confluences occurred in epicontinental seas[1].

The Adriatic Roach, *Rutilus rubilio*, is an Italian endemic.

1 - Bianco, 1990

Fish taxonomy

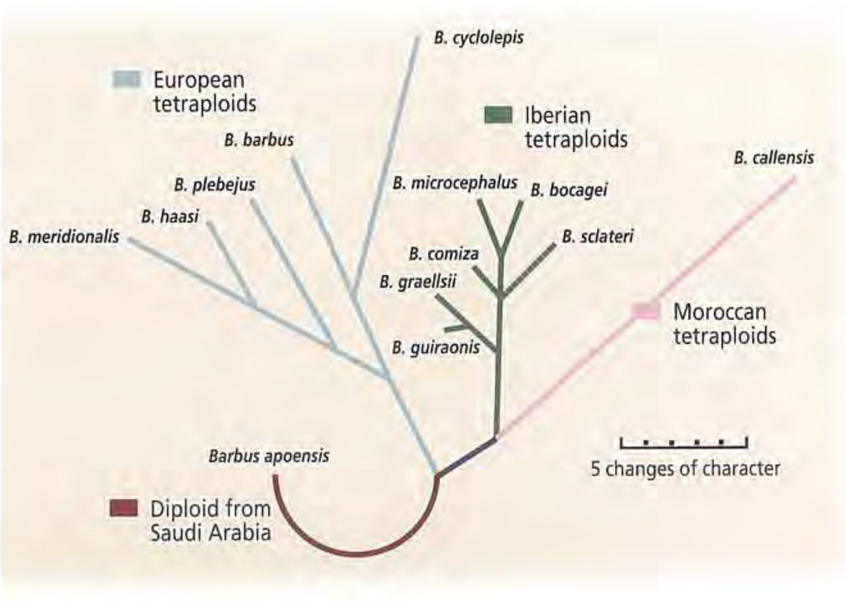
It is widely thought that the status and taxonomy of the fauna of Europe is now well known, and this is certainly a prerequisite for any conservation action plan which may be needed for a habitat or species.

Before conservation plans can be agreed upon, it is essential to be able to define a species, its distribution and the extent of its populations.

Whilst our knowledge may be adequate for birds and some other well known groups, this is not the case with fish and substantial further taxonomic research on this group is required within Europe – particularly in the Mediterranean area, where the greatest diversity occurs. With few exceptions, fish have long been considered mainly as a harvestable resource and not as individual species with an important ecological role in most aquatic habitats.

Within Europe, the numbers and diversity of fish species decreases from south to north. In contrast, and partly as a result of this, northern fish species are much better known than those in the Mediterranean area where such knowledge is essential for proper conservation management.

Although the study of fish systematics in Europe has a history of more than 200 years, there are still considerable areas of uncertainty, emphasised by the discovery of significant numbers of species new to science in just the last 20 years. These new species, together with the taxonomic ambiguities which still occur among other better studied groups (including some which are of substantial economic importance), present considerable taxonomic problems which must be solved before their populations can be managed on a scientific basis. For example,



The paleogeography of the genus *Barbus*: phylogenetic tree.

Source: Berrebi, 1995

there are several groups of fish in Europe (e.g. the genus *Barbus*) where our ignorance of the inter-relationships among closely related species means that the threat of indiscriminate inter-basin introductions may well lead to extensive competition or hybridisation resulting in the extinction of stocks of ancestral species.

J. Gregori

Barbus méridionalis caninus.

European *Barbus* – a problem for taxonomists

The members of the genus *Barbus*, commonly known as barbels, belong to a complex group of Old World Cyprinidae that provides a good model for studying evolutionary phenomena in freshwater fish. With nearly 800 species, *Barbus* has been described as a 'monstrous aggregation'. These features include major and contrasting evolutionary lineages spread over three continents (Africa, Asia and Europe), with associated genetic differences related to these lineages. Also, many members of the genus hybridise – a very useful phenomenon for understanding speciation and the past history of the group.

Sophisticated modern biochemical techniques of analysing enzymes or DNA show that in the north of the Mediterranean basin species of this group, with distinct genetic differences, occur along an intercontinental gradient.

Two main groups are represented here – the subgenus *Barbus* and the subgenus *Labeobarbus*. It is believed that the various evolutionary branches of this genus may reflect the main past migrations of the freshwater fish fauna over large parts of Europe[1].

1 - Berrebi, 1995

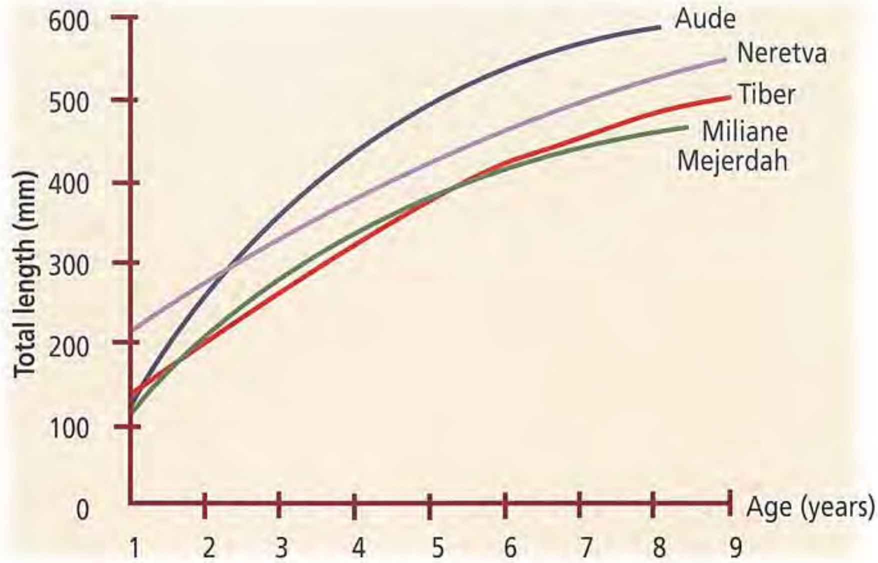
Growth of fish

Fish growth is closely related to the quantity and quality of food eaten, though other factors (space, temperature, health, etc.) are involved too.

One of the outstanding features of fish is their phenomenal plasticity as far as growth is concerned. When food and other conditions are suitable many species are able to grow very fast, but in adverse circumstances, perhaps with no food or very cold conditions for long periods, they are able to survive but with no growth at all. This is in contrast to most warm blooded birds and mammals which are less tolerant and usually die after a short period without food – unless they are able to hibernate or go into some other kind of torpor. Unlike birds and mammals, fish also continue to grow throughout their lives and do not stop on reaching sexual maturity.

Many species of small fish (e.g. Mosquito Fish *Gambusia affinis*) – especially in warm countries – live for only a few weeks to a maximum of one year but some large species (e.g. Danube Catfish *Silurus glanis*) may live for 30 years or longer. Age at maturation (i.e. when fish are able to reproduce) varies very much among different species and even among different populations of the same species. In general, sexual maturity is related to size which in turn is dependent on growth, thus fish in fast-growing populations tend to become mature earlier than those in slow-growing ones.

Zooplankton is an important food for fry and juveniles.



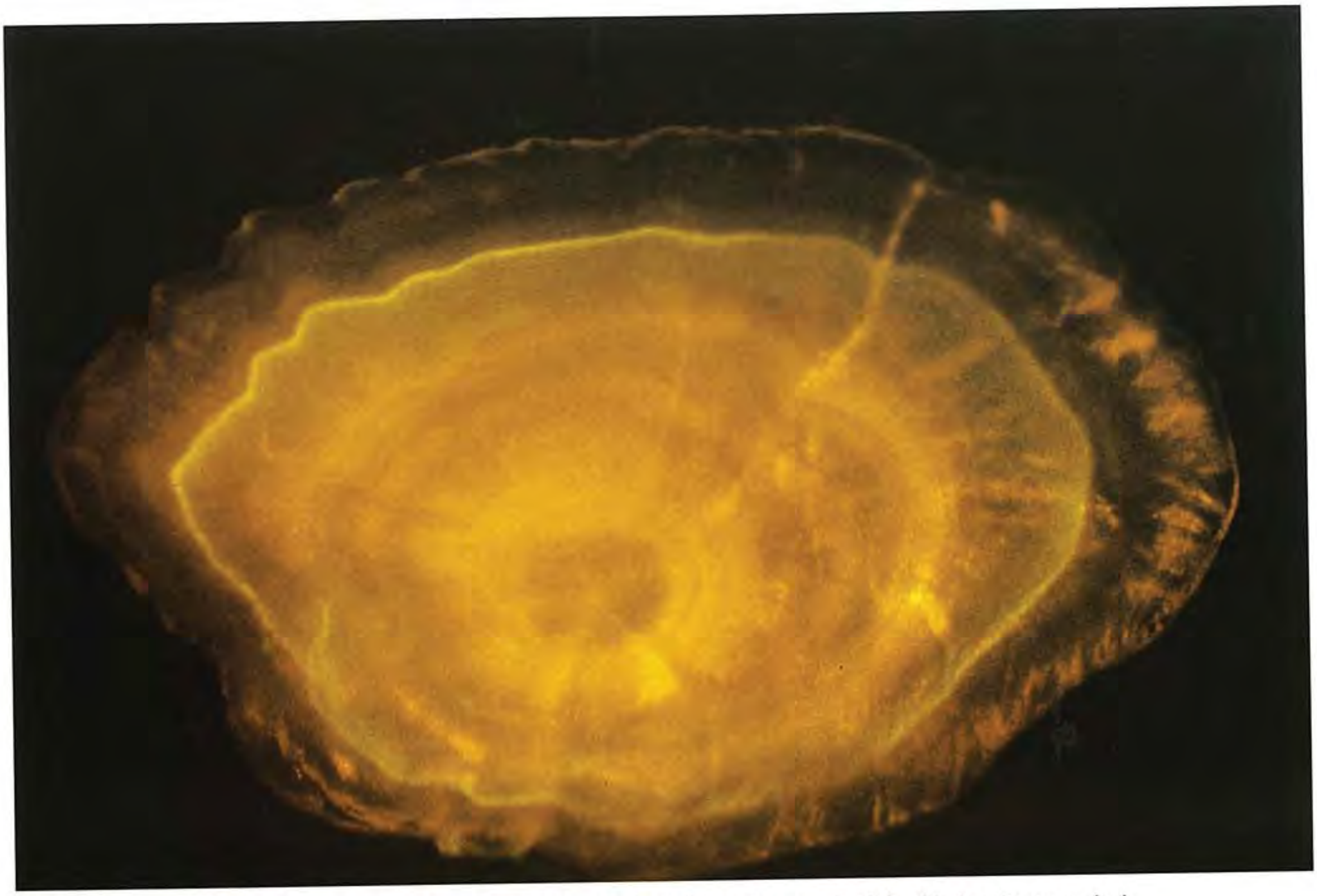
The growth of *Alosa fallax* in different Mediterranean rivers: Aude, France, Neretva, Bosnia-Herzegovina Tiber, Italy Miliane and Mejerdah, Tunisia.

Source: Douchement, 1981

Both food and temperature affect growth; fish at higher latitudes mature later than those at lower ones. In Finland, Roach *Rutilus rutilus* do not mature until they are 5-6 years old, whereas in southern Europe the same species may be mature at 2-3 years.

Some fish spawn only once: the Atlantic Salmon *Salmo salar* usually spends 2-6 years in fresh water and a further 1-2 years in the sea before it is mature and comes back to fresh water to spawn; very few fish live beyond this to spawn a second time. In the case of the Allis Shad *Alosa alosa* and Eel *Anguilla anguilla* there appears to be complete mortality after the first spawning. Other species such as Brown Trout *Salmo trutta*, may spawn several times during their lives.

The nature of the life cycles of large slow-growing species and smaller short-lived species means that they are both vulnerable to fishing pressures and can be fished to extinction. Because they are confined to discrete systems, all the life cycle requirements for a species must be found within that system. Where this is not the case, species are either migratory or do not establish permanent populations.



J. Panfili

An Eel otolith dyed yellow with tetracycline. The outer, translucent ring indicates the growth of the fish since it was marked.

Estimating the age of fish

Fish biologists see scales as something more than a simple part of fish anatomy. The structure of scales and the way each is laid down in the fish's skin means that each records in its circuli the growth of its bearer in the same way as the rings in the trunks of trees. Given a single scale from a mature fish a competent biologist can often identify the species, establish its age, calculate its rate of growth throughout its life and say how often it has spawned. In migratory fish it is often possible to establish the time spent in fresh water and in the sea, or in its nursery stream and in its parent lake.

Opercular bones, fin rays and otoliths, a bony bony structure in the inner ear, may also be used for ageing fish which have no scales (e.g. Danube Catfish).

Fish biodiversity

Europe has a relatively restricted climate and its fresh waters and their communities are correspondingly less varied than those of most other continents.

There are numerous small and medium-sized lakes, but only a few very large ones. However, some of these occur in the Mediterranean area and good examples are Garda, Lugano, Maggiore, in Italy, and Ohrid and Skadar in the Balkans. Europe has many important rivers and though none of them approach the enormous running waters of Asia and America (e.g. the River Amazon) there are several very large rivers in the Mediterranean area – for example, the Rivers Ebro, Nile, Po and Rhone.

At local level, a major waterfall on a river will prevent migratory fish gaining access to the river above and this may halve the number of fish species occurring there compared to a neighbouring river with no waterfall.

The diversity of the fish in a river or lake is closely related to the diversity of the physical (and to some extent, the chemical) habitat available. As the physicochemical habitat is simplified and degraded by human activities so the diversity of the fish fauna (and other biota*) declines. However, within the Mediterranean area there are local and regional variations in diversity within completely natural systems.

The freshwater fish fauna of the northern Mediterranean area is more diverse than that of the rest of Europe, which is still suffering impoverishment created by the last ice age (and which shares a substantial part of the widely-distributed northern Asiatic fauna). It includes 230 endemic taxa (see below) within 13 families. Thus there is a notable increase in diversity among fish communities as one moves from north to south. The greater biodiversity* in southern Europe is due to the large number of locally endemic Mediterranean species.

Countries	Indigenous* species	Introduced species
Iceland	5	0
Ireland	21	14
United Kingdom	42	15
France	49	24
Spain	32	19
Portugal	29	10
Greece	106	11

Only Iceland has escaped the negative consequences of fish introduction.

Fish on Mediterranean islands – natural and introduced

The freshwater fish faunas of the Mediterranean islands are naturally impoverished, largely because of extended periods of drought and the consequent lack of water bodies. For example, in Malta, there are no lakes or perennial streams and thus no indigenous fish. Similarly in Cyprus there are no permanent natural fresh waters – and consequently no native fish. However, there are now a number of reservoirs on Cyprus and 19 species of fish can be found in these. Most of the fish have been introduced for angling but a few have originated from aquaculture systems. Another large island, Crete, is also without any native fish, for the same reasons.

However, some islands do have native freshwater species, and altogether the Mediterranean islands of Corfu, Levkas and Rhodes (Greece), Corsica (France), Sardinia and Sicily (Italy) and the Balearic Islands (Spain) have 16 native and some 14 introduced fish species. The native species include seven migratory species, four of which are rare (Sea Lamprey, *Petromyzon marinus*, River Lamprey *Lampetra fluviatilis*, Atlantic Sturgeon, Allis Shad), two are relatively frequent (Twaite Shad *Alosa fallax*, Sand Smelt *Atherina boyeri)* and one is common (Eel). The native freshwater species and those which have been introduced are listed in the table below.

Indigenous species	Introduced species
Salmo trutta macrostigma	*Cyprinus carpio*
Ladigesocypris ghigii	*Tinca tinca*
Pseudophoxinus stymphalicus	*Salvelinus fontinalis*
Valencia hispanica	*Stizostedion lucioperca*
Valencia letourneuxi	*Perca fluviatilis*
Aphanius fasciatus	*Lepomis gibbosus*
Gasterosteus aculeatus	*Ictalurus melas*
Economidichthys pygmeus	*Esox lucius*
Blennius fluviatilis	*Oncorhynchus mykiss*
Knipowitschia goerneri	*Salmo trutta*
	Carassius auratus
	Scardinius erythrophtalmus
	Micropterus salmoides
	Gambusia affinis

The number of introduced species on Mediterranean islands now exceed the number of native species.

Endemic fish

The freshwater fish fauna of the north Mediterranean region is unique, with 230 endemic taxa (132 species and 98 subspecies) distributed among 13 families.

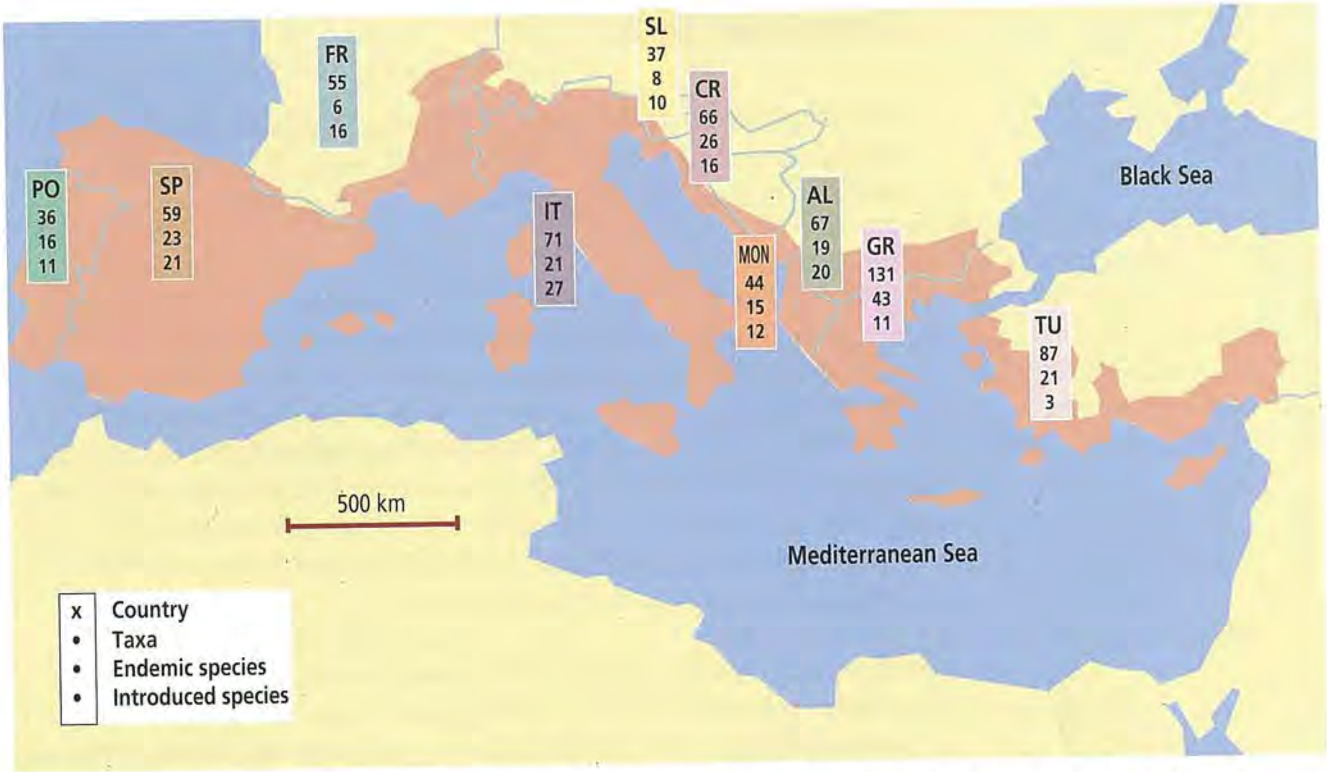
Cyprinidae are the largest group with 83 species (62.9 % of the total) and 67 subspecies, followed by Cobitidae with 14 species (10.6 %) and 26 subspecies, Gobiidae with 11 species (8.3 %) and no subspecies, Cyprinodontidae with 8 species (6.1 %) and no subspecies and Salmonidae with 7 species (5.3 %) and 13 subspecies. The remaining nine species and six subspecies are found in the Petromyzonidae (two species), Acipenseridae (one species), Siluridae (one species), Percidae (one species and one subspecies), Blennidae (one), Cottidae (one species) and Gasterosteidae (one species).

The majority of these endemic fish occur in lowland rivers and natural lakes but mountain torrents and springs are also of importance. In contrast, marshes, coastal lagoons and artificial canals and reservoirs are only infrequently inhabited by these endemic taxa. Four endemic species (which all occurred at single locations) have already become extinct and over 70 % of all the endemic taxa are regarded as being threatened in some way[1].

J. Gregori

Beauty is not a prerequisite for protection !

1 - Crivelli & Maitland, 1995



The north Mediterranean area with fish taxa by country. The Iberian peninsula is taken as a whole. Source: Crivelli, unpublished.

Loss of biodiversity in Lake Egirdir

Nine species of fish used to occur in Lake Egirdir in Turkey – six were endemic to this part of the Mediterranean area: *Capoeta pestai, Aphanius chantrei, Noemacheilus lendli, Phoxinellus zeregii, Phoxinellus handlirschi* and *Phoxinellus egrediri.* Three other species were also established there: Common Carp *Cyprinus carpio,* Spined Loach *Cobitis taenia* and *Vimba vimba*.

In 1955, 10,000 Pikeperch *Stizostedion lucioperca* were released and this species quickly became established.

The consequences of this introduction were rapid and irreversible. The three species of *Phoxinellus* disappeared and the two local endemics *Phoxinellus handlirschi* and *Phoxinellus egrediri* can be considered as extinct. In addition, *Noemacheilus lendli* and *Cobitis taenia* have also probably disappeared. *Aphanius chanteri* has found refuge from Pikeperch in the lake's inflows. *Capoeta pestai,* Common Carp and *Vimba vimba* have survived but their numbers have greatly declined[1].

Thus the introduction of a single piscivorous fish species can cause major changes to an ecosystem.

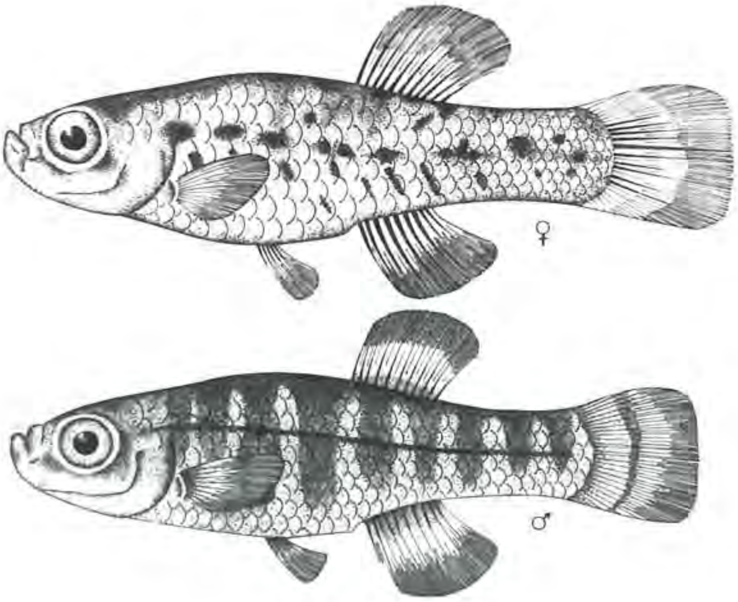
1 - *Crivelli, 1995*

Cyprinodontidae – characteristic Mediterranean fishes

The Family known as Toothcarps (Cyprinodontidae) are found all round the Mediterranean but are absent from central and northern Europe. They can thus be considered as characteristic of the Mediterranean area. They are all small fishes and are found here in only two genera – *Valencia* and *Aphanius*. Although these fish are vulnerable in some ways, part of their success in this area is believed to be due to their ability to disperse (in the absence of predators or competitors) by using the transitional habitats of brackish or hypersaline waters in which true marine or freshwater fishes are usually absent.

There are two species of *Valencia* in the north Mediterranean area – *Valencia hispanica* in Spain and Valencia in Greece.

Aphanius species are more common and nine species have been recorded altogether – *Aphanius iberus* in Spain and Algeria, *A. dispar* in Egypt and Israel, *A. mento* in Israel and Syria, *A. apodus* in Algeria (though it may now be extinct here); *A. anatoliae, A. burduricus, A. chantrei* and *A. cypris* occur only in Turkey. *A. fasciatus* is much more widespread and is found in Albania, Algeria, Egypt, France, Greece, Italy, Lebanon, Libya, Montenegro, Morocco, Tunisia and Turkey.



Aphanius burduricus **is endemic to Burdur lake in Central Anatolia, Turkey.**

S. Balik

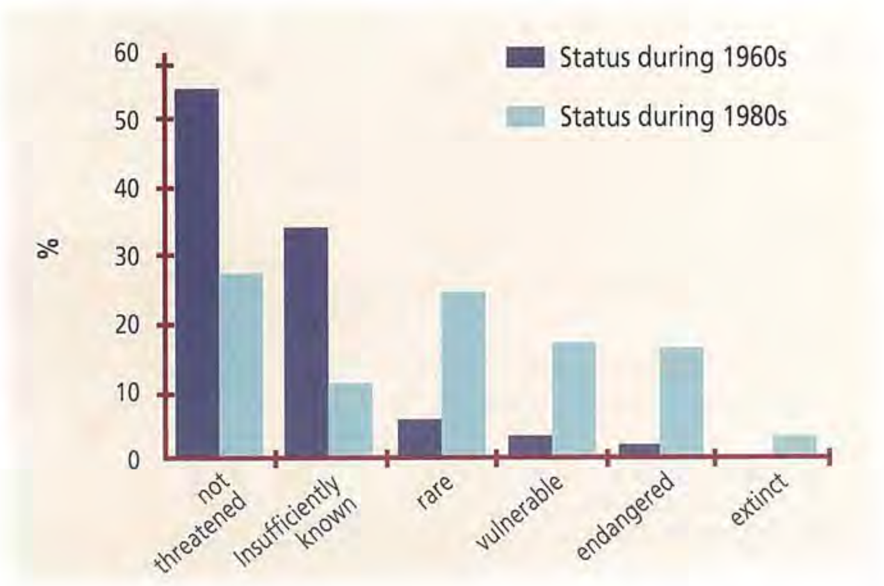
Threatened fish

It is clear that in many countries public support for the conservation movement has strengthened and broadened substantially over the last decade.

Natural habitats like meadows and mountains, forests and seashores, rivers and lakes as well as wildlife like butterflies and bees, birds and mammals are all topics of popular interest and concern, but fish – until recently – appear not to be.

There are certain characteristics of freshwater fish (and some other aquatic organisms) which are especially relevant to the structure of their communities and to their conservation. Their habitats are discrete and thus fish are contained within particular bounds. This leads to the differentiation of many independent populations with individual stock characteristics developed since their isolation. It should be noted that this is true even of migratory species where, despite substantial mixing of stocks in the sea, the acute homing instinct* has meant that there is a strong tendency for genetic isolation (e.g. Salmonidae).

Because each population is confined to a single (often small) water body, within which there is usually a significant circulation of water, the entire population is vulnerable to the effects of pollution, disease, etc. Thus, for the conservation of a species, the number of separate populations is usually of far greater importance than the number of individuals. Migrations are a feature of the life cycles of many fish and at these times they may be particularly vulnerable. In particular, in



The changing status of endemic freshwater fish in the north Mediterranean region.

Source: Crivelli, unpublished

diadromous* riverine species, the whole population has to pass through the lower section of its river to and from the sea. If this section is polluted, obstructed or subject to heavy predation, entire populations of several species may disappear, leaving the upstream community permanently impoverished. This is the situation with several rivers in Europe at the moment and such communities may only have about 50 per cent of their normal species complement. Several of the Spanish rivers which have dams near the mouth are good examples.

Apart from the general loss of fish populations around the Mediterranean area and the threats to some formerly widespread species, of particular concern is the fate of the many endemic fish taxa found here. A recent survey found that only 27 % of these taxa are not now regarded as threatened. Only 35 (15.2 %) of the 230 endemic taxa are officially protected in at least one country. Twenty four of these protected taxa were first given legal protection between 1981 and 1990, and the remaining 11 between 1991 and 1992. It is clear, therefore, that fish protection in the north Mediterranean region is a relatively recent and still rather rare phenomenon. If nothing is done to enhance the conservation of endemic fish and their habitats in this area, then dozens of taxa will disappear within the next decade, constituting an irreparable loss of biodiversity within the aquatic ecosystems of the Mediterranean region.

The Karst Sculpin – one of Europe's rarest fish

Surprisingly enough, it was as recently as 1964 that the Karst Sculpin *Cottus petiti* was discovered in a small part of the drainage system of a small stream in southern France. Moreover, this species, one of the newest vertebrate species to be found in Europe, was discovered by chance as its distribution is restricted to only a few kilometres of water downstream of a single small spring originating underground in karstic limestone.

This tiny (30 mm) new species of fish is entirely dependent on the quality and quantity of water which emerges from the limestone. Any accidental damage to the stream (by engineering or other human activities) or pollution or depletion of the underground water in the limestone could rapidly eliminate this unique population. Other major risks are the introduction of disease or other fish species (which could be either predators or competitors).

A species conservation plan is, therefore, an urgent necessity to ensure the future of the Karst Sculpin and one is in preparation. This will involve not only the safeguarding of the spring and its water quality but also a captive breeding programme so that, even if the population in the wild is eliminated, it may be possible to restore the stock from those held in captivity[1].

1 - Persat et al., 1996

Fish genetics

The isolation of different fish populations gives rise to subpopulations which show different genetic traits.

For some fish, these traits have been shown to include fecundity*, egg size, survival rates, growth, precocious sexual maturity, seaward migration, behaviour at sea, return migration, spawning frequency, resistance to disease and resistance to low pH. Some fish species have a wide variety of characteristics under genetic control, some of them apparently quite obscure.

It has been shown for Brown Trout that the success of each generation of young is very density dependent. In essence, the habitat has a relatively finite capacity as a nursery stream for the young of each species, probably based on the quantity of food and the territory available for each fish, and the number of adults spawning there is unimportant above the minimum needed to provide the young which the water can sustain. The variation in the number of adults spawning each year is not reflected in the relatively constant number of resulting young. This suggests that, in many waters, there is already intense competition in the wild among young fish, and the addition of large numbers of farm-bred fish simply introduces further competitors for food and space.

***Salmo trutta marmoratus*, is a species sought-after by fishermen, helping the local economy along the Soca River in Slovenia.**

The Marbled Trout – threatened by introductions

The Marbled Trout *Salmo marmoratus* is an endangered endemic species in the north Adriatic basin. It formerly occurred in several rivers in the area, including the River Soca in Slovenia. Originally the Marbled Trout was the only salmonid in the River Soca, but in 1906 Brown Trout were introduced near the source of the river and many other introductions have taken place since then. Unfortunately, the Brown Trout interacts and hybridises with the Marbled Trout and the latter has disappeared from many of its former habitats or is present only as a hybrid.

In consequence, the Marbled Trout is now one of the most threatened fish species in Slovenia and occurs in its pure form only in the River Zadlascica, a tributary of the River Tolminka. It is the inaccessibility of this small river which has saved its fish from genetic pollution*.

A programme is now under way to save the Marbled Trout from extinction. Extensive survey work detects pure stocks (identified accurately only by biochemical analysis of tissues) and maps where the hybrids occur. Four new pure Marbled Trout populations have recently been discovered in collaboration with the Slovenia Fisheries Research Institute. In addition, a pure breeding stock has been established and the plan is to use this to restore the Marbled Trout to some of its former waters, perhaps only after the Brown Trout or hybrids have been eliminated above impassable barriers, such as waterfalls. Stocking in the hybrid zones will also be carried out to flood the population with Marbled Trout genes and a genetic monitoring programme is planned every two years here and in the sanctuary areas to assess the efficiency of the conservation programme. There is also a campaign to try to prevent stocking of Brown Trout and this has already stopped in most of the Soca basin. As Marbled Trout are sought-after by foreign anglers, the programme has a firm economic foundation[1,2].

1 - Povz, 1995
2 - Povz et al., 1996

R. Montes / Stock photos / Bios

Fish habitats

Fish occur in a wide variety of aquatic habitats, but some types of water are more important than others, especially for endemic species.

The largest proportion of the 230 taxa of freshwater fish endemic to the northern Mediterranean region occur in lowland rivers (67 %) and natural lakes (54 %). Mountain torrents (34 %) and springs (17 %) are also important, but, in contrast, marshes (11 %), coastal lagoons (6 %) and reservoirs (7 %) harbour only a few endemic species[1].

The River Guadalquivir in Spain.

1 - Crivelli & Maitland, 1995

Rivers

Rivers in the Mediterranean area, and indeed all over the world, are a huge natural resource which is of major importance to people.

So great is the need and so many are the uses that most rivers are under enormous pressure and many conflicts have arisen among the various users. In the end, the common scenario is that many of these groups suffer and the quality of the river deteriorates so that it becomes less and less useful.

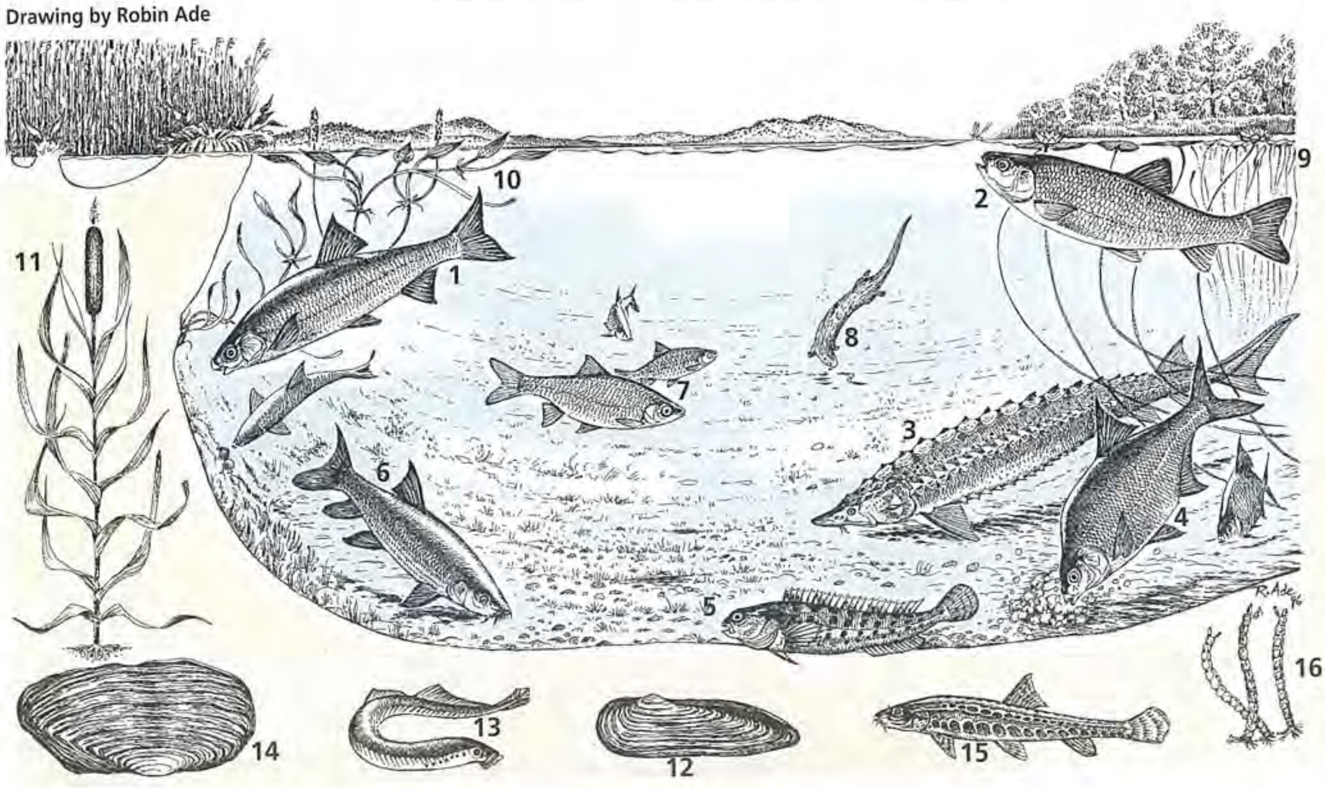
There are many kinds of running water, sometimes several of them occurring, inter-connected, within a single catchment. Small trickles and seepages (often temporary in nature), ditches, larger fast-flowing streams and rivers, large slow-flowing rivers and canals may all be important as fish habitats.

An examination of the types of fresh waters which are given conservation protection shows that rivers have been sadly neglected – strong preference having been given to standing waters in the establishment of nature reserves or other protected areas. This bias is probably because of the much greater difficulty in protecting rivers. They are not less worthy of conservation than lakes.

Lowland river

1. *Chondrostoma nasus*
2. *Leuciscus cephalus*
3. *Acipenser sturio*
4. *Abramis brama*
5. *Blennius fluviatilis*
6. *Barbus barbus*
7. *Rutilus rutilus*
8. *Lutra lutra*
9. *Nymphea alba*
10. *Potamogeton natans*
11. *Typha latifolia*
12. *Anodonta cygnes*
13. *Lampetra fluviatilis*
14. *Unis pictorum*
15. *Cobitis taenia*
16. *Chironomus spp.*

Drawing by Robin Ade




R. Vertacnik

The River Krka near Knin, Croatia.

The main criteria used to identify rivers of conservation interest are diversity of habitats and species, naturalness of catchment and river corridor and representativeness of rivers of a particular type. Other factors which should be taken into account are rarity (of river type, species or communities), size or extent, fragility of habitats and communities, and geographic position. Truly wild rivers come high among systems evaluated on these categories. Evaluation of the conservation value of a river thus requires a good knowledge of not only its plant and animal communities, but also its place in national and international classifications of river types.

A broad range of features characterise a natural river (including the fact that its catchment would also be relatively natural). For example, its channel would not be canalised or ditched in any way and the channel substrate would consist of entirely natural materials like sand, gravels stones and boulders and not concrete, brickwork or gabions. The water

The River Krka – in need of protection

The River Krka in Croatia is an unusual river in many respects and in need of urgent protection. It has a length of some 60 km and has two major tributaries – the Rivers Butisnica and Cikola. Much of its course runs in deep canyons through a hard limestone plateau and, with eight magnificent waterfalls, a few rapids and numerous underwater springs, the River Krka is of great natural beauty and value. The river basin has a surface area of 2083 km^2 but the underground catchment is much larger and extends into Bosnia. The water quality is variable – good in the upper reaches but poor in the lower reaches.

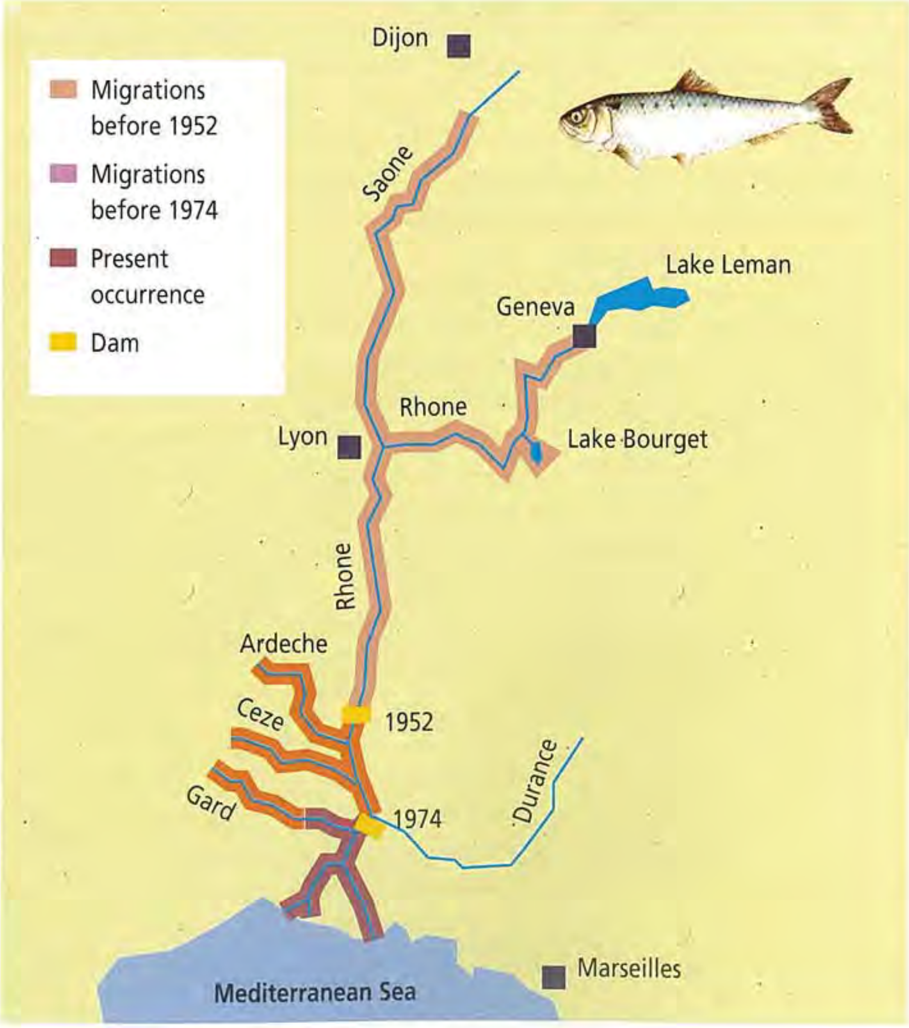
A recent survey of the river recorded 18 species of fish but another seven species which had been recorded previously were not found. The dominant fish throughout much of the river is *Leuciscus illyricus*; other species occurring there are Brown Trout, Rainbow Trout *Oncorhynchus mykiss*, Adriatic Salmon *Salmo obtusirostris krkensis*, Marbled Trout, *Leuciscus svallize*, Rudd *Scardinius erythrophthalmus hesperidicus, Leuciscus polylepis, Barbus plebejus, Aulopyge hugeli, Paraphoxinus pstrossi*, Common Carp, Tench *Tinca tinca*, Eel, Three-spined Stickleback *Gasterosteus aureatus*, Mosquito Fish *Gambusia affinis*, Freshwater Blenny *Blennius fluviatilis* and Mrakovcic's Goby *Knipowitschia mrakovcici*.

The richness of the River Krka with several endemic taxa is a reflection of its geological past. Many aspects of the fish fauna have still to be examined and it is likely that several endemic species remain to be discovered, especially in some of the small tributaries and springs in the inland karstic region. 'It is one of the most beautiful of Croatian rivers, a product of the work of nature which has lasted millions of years and should be

1 - Mrakovcic et al., 1995

quality would be high and reflect the geology and soils of the natural catchment rather than any influence from human activities. The biota too would be characteristic of the geographical area concerned – there would be no introduced alien species nor any loss of native ones. Such systems have two major features – they are sustainable and they have a characteristic, usually high, biodiversity. The native fish fauna would fully reflect such naturalness and clearly, since it would have been fully established there for hundreds if not thousands of years, is likely to be stable and unstressed.

It is clear that rivers are limited resources which are subject to often conflicting demands from a wide range of users – yet basically all of these users want the same thing: reliable supplies of clean water. Rivers – and their entire catchments – therefore need to be actively managed in such a way as to balance the needs of the various users and to ensure that both the quantity and quality of the resource are maintained[1].



Reduction in migration route of *Alosa fallax rhodanensis* due to river management activities.

1 - Boon et al., 1992

The River Rhone – an abused Mediterranean river

The River Rhone is the largest river (in terms of discharge) flowing into the north Mediterranean. The catchment area of all French rivers flowing into the Mediterranean occupies 134,360 km^2 (24.4 % of the area of France) and most of this is occupied by the catchment of the Rhone (15 % of the area of France) whose upper catchment lies partly in Switzerland. This area has considerable diversity in both geographic and climatic terms and includes four of the main types of world ecoregions. This explains the presence of seven fish species which all have a very restricted range in Europe. Unfortunately, many man-made changes have taken place in the Rhone valley in recent decades, severely threatening the fish populations.

A recent study[1] has shown that there have been considerable changes in the fish fauna of the River Rhone and most of these are attributed to human interference. Physical barriers in the form of dams and weirs have reduced migration routes by forming obstacles to fish migration. This is believed to be one of the major reasons for the local decline in stocks of Twaite Shad. Habitat destruction has been widespread following river management and sand and gravel extraction from within river courses, and has led to the decline of many fish species including the Asper *Zingel asper*. Water abstraction has led to low flows (and even the drying out of small rivers and their tributaries) and the extinction of several species locally. Domestic and industrial pollution has affected many water courses and the presence of large cities such as Lyon and Grenoble and industrial areas associated with them has led to enormous discharges not only of organic pollutants, which are biodegradable*, but also of heavy metals and other toxins. Seven nuclear and fossil-fuel power plants heat the water of the Rhone by 1-4°C, depending on the time of year. The combined effect of these activities has been to degrade water quality and reduce or eliminate populations of sensitive fish species.

Angling and commercial fishing have also affected the populations of some fish (e.g. Twaite Shad) and several alien species have been introduced to the river, where they are believed to be a significant threat to native fish as they become established. Several of these fish come from other parts of Europe (e.g. Pikeperch, Danube Catfish) but many come from other continents (e.g. Pumpkinseed *Lepomis gibbosus* and Black Bullhead *Ictalurus melas* from the United States).

Several of the native species occurring in the River Rhone are now regarded as distinctly threatened (notably Atlantic Sturgeon, Twaite Shad, Freshwater Blenny, Asper, Mediterranean Barbel *Barbus meridionalis,* French Nase *Chondrostoma toxostoma* and the Blageon *Leuciscus souffia*).


J. Roché / Bios

1 - Changeux & Pont, 1995

Lakes

Fresh waters have traditionally been divided into standing waters and running waters – and this is a definite and acceptable start to their classification. Though occasional problems may arise (e.g. with canals and the backwaters of slow-flowing rivers) there is usually little difficulty in deciding whether a water belongs to the standing or the running water series.

While fish can potentially move throughout a river system they are unable to move between catchments, nor between isolated lakes.

Rarely are the two unconnected, however, for many running waters pass directly into standing ones or have standing waters in their catchments, and most standing waters receive several running waters, and exit via a single running outflow.

Standing waters exhibit great variety, ranging from small shallow temporary pools, through ponds and lakes, to extensive waters which may be over 20000 km² in area and 500 m in depth. Superimposed on the size and shape of a water basin are important regional differences, especially those related to geochemistry and climate. Depth is one of the most important characteristics of a lake as this controls the

Lake Skadar lies on the frontier between Montenegro and Albania and is the largest lake in the Balkans.

A. J. Crivelli

proportion of the lake's volume which receives solar radiation and hence the thermal stratification* and stability of the lake. Solar energy is also used in photosynthesis, which forms the basis for the productivity in standing waters. Because most energy is absorbed within the uppermost 3 m of water, shallow waters are usually highly productive.

In catchments where precipitation is greater than evaporation, most standing waters have an outlet from which water eventually finds its way to the sea. Water in such basins is constantly renewed; consequently nutrient salts do not accumulate, and the water stays fresh. In catchments where evaporation is greater than precipitation, higher lakes are flushed periodically, but lower ones are not; the latter accumulate dissolved chemicals and are commonly called salt lakes. Several of the waters around the Mediterranean come into this category, at least on a seasonal basis. Spain has a number of small saline lakes in the basins of the Ebro, Guadalquivir and Tagus Rivers whilst in Tunisia the Sebkhet Sidi El Hani is a large shallow depression important for Flamingoes. In Turkey, Lake Tuz is a large (90 by 32 km) closed saline basin. There are very obvious differences between the fish communities which are found in freshwater and in saline lakes. If the salt content of the latter is very high there may be no fish at all.

Fishing for Carp using hooks baited with maize. Lake Mikri Prespa, Greece.

A. J. Crivelli

Lake Mikri Prespa

Many Greek lakes (and Balkan lakes in general) are unique in Europe due to their great age. They were formed in the Tertiary period, over 4,000 million years ago, long before the majority of lakes to the north which are of Quaternary origin. The majority of the Greek lakes are shallow, alkaline, eutrophic and warm and all of them support commercial fisheries – though in recent years the catches have declined largely, it is believed, due to overfishing.

Lake Mikri Prespa is situated mainly in Greece with a small portion stretching into Albania. It lies at an altitude of 853 m above sea level, and has a surface area of 5341 ha with a mean depth of 6.7 m and a maximum depth of 7.9 m. It is a typical cyprinid lake with most of its 11 native fish species being Cyprinidae – 7 of these are endemic. There are 6 introduced species. Fishery statistics have indicated significant changes in the populations of several economically important species (e.g. Common Carp and the Prespa Nase *Chondrostoma prespensis*) which at times have neared the critical level of collapse. For example, a spectacular re-establishment of the Common Carp population, following the crash of the stock of this species in the 1970s and 1980s, was recorded in the spring of 1991. Although the evidence indicates that much of the decline in some of these fish species is due to overfishing, other factors such as reduced water level have exacerbated the fishery decline.

However, the total biomass of the fish population in Lake Mikri Prespa has increased substantially in the last decade, probably due to the following reasons:

- a marked decline in fishing effort in the late 1980s, for socio-economic reasons and because of a collapse in the numbers of Carp – the favourite target species;
- the introduction of new regulations prohibiting the use of nets with meshes less than 45 mm;
- a longer closed season;
- a very successful breeding season for Carp in the spring of 1991 – related to exceptionally high water levels at the time;
- a decrease in catches in the winter 'pelaizia' fishery with a consequent decrease in the by-catch* of immature fish;
- a decrease in predation pressure from piscivorous birds, probably resulting from increased turbidity in the lake[1].

A. J. Crivelli

1 - *Crivelli et al., in press*

Reservoirs

To make economic use of water resources – especially in those parts of the Mediterranean area with low or variable precipitation – it is common practice to construct reservoirs.

These form a component in most water supply systems and in many areas there are now more reservoirs than natural lakes. The recent construction of large systems like the Aswan Dam makes these among the largest freshwater bodies in the world.

Hydro-electric schemes have deleterious effects on local waters, because of abstraction, dams and turbines, water transfer and other activities. However, some fish are less affected than others by such schemes, and there is evidence that plankton-feeding fish may be favoured by the fluctuating water levels which has little effect on the floating plankton, but which negatively affect the main feeding grounds of benthic feeders in the littoral zone.

Apart from a few hydroelectric dams, most Mediterranean reservoirs are shallow and many irrigation reservoirs dry out completely at the end of the summer. Many are very eutrophic*. After a reservoir is created on a river system, most lotic* species of fish disappear and exotic species have been introduced to replace them. In Italy, the Twaite Shad used to migrate from the Adriatic Sea through the River Po and the River Ticino to Lago Maggiore. This migration has been prevented by dams. This creates a new type of fish population which is not necessarily stable.

On the positive side, some new types of habitat have been created by humans, notably numerous reservoirs of a variety of sizes and, in lowland areas, canals. Most of these have provided extremely suitable habitats for fish communities, but although many have been developed for sport fisheries or occasionally for commercial fisheries, very rarely have they been exploited for fish conservation purposes.

L. Cianciotto / Panda Photo / Bios

Low water levels in a dam near Cagliari, Sardinia – hardly ideal for fish.

Tunisian reservoirs

Permanent waters are rare in Tunisia and only sea fish are consumed regularly, mainly by people with good incomes living in towns. There is no tradition here for fishing in fresh waters and only 1 kg/year of freshwater fish is consumed by those living in the country.

A project was initiated to utilise the recently constructed reservoirs to produce freshwater fish and thus make more protein available to local people. At present, there are 18 large reservoirs (with a total surface area of 12,400 ha) and 21 small farm ponds (with a total surface area of 300 ha).

Of the native fish species, only eels and barbels *(Barbus callensis)* grow sufficiently large to be valuable commercially and so fry of mullets (*Mugil* spp) and various non-native species (Common Carp, Danube Catfish, Pikeperch, Largemouth Bass, Grass Carp *Ctenopharyngodon idella*, etc.) have been introduced to the reservoirs because many of the fish species which thrive there (e.g. Goldfish *Carassius auratus*) are not good to eat.

The first results indicate that commercial fisheries are really only feasible in a few (30 %) of these reservoirs. However, production of fish for local consumption is a valid objective and may help to increase the amount of protein available to local inland populations living in small villages around the reservoirs. It is important that local fishing regulations are developed and implemented to avoid overfishing and subsequent collapse of stocks[1].

1 - *Losse et al., 1992*

Lagoons

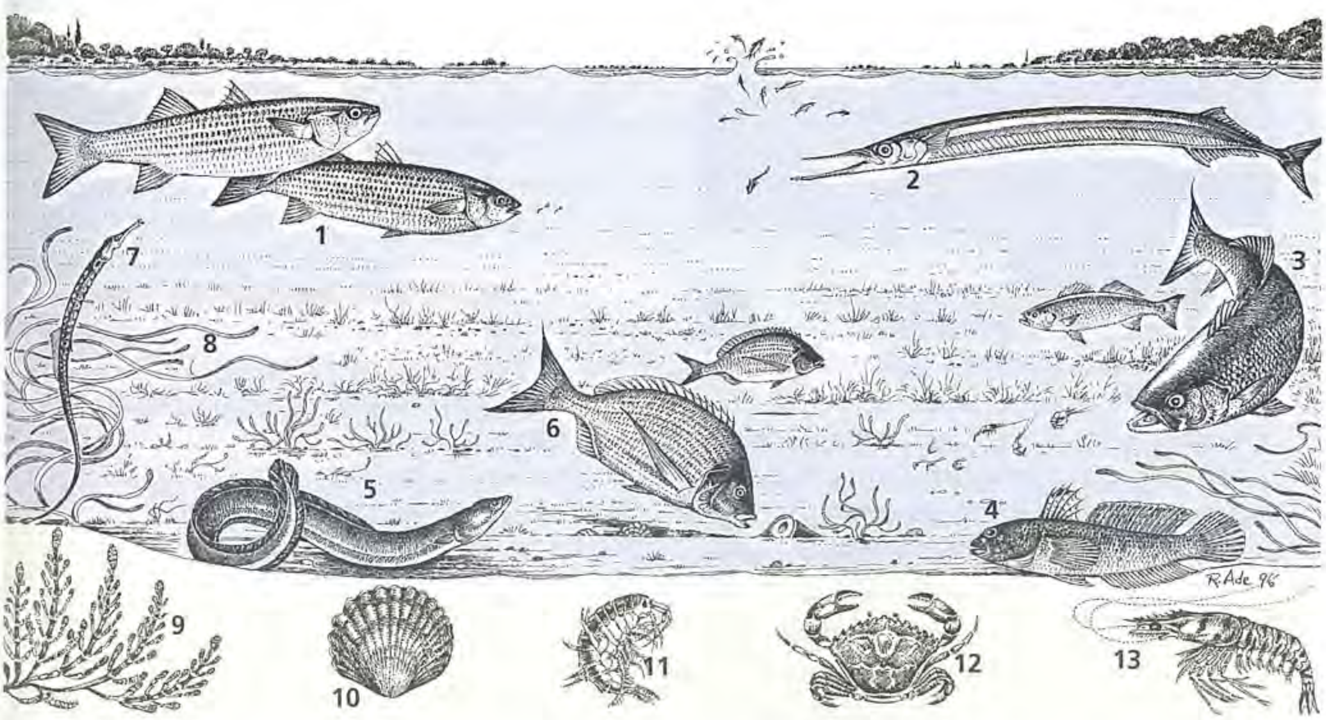
There are many coastal lagoons scattered in an irregular fashion around the Mediterranean. Most lagoons are shallow (less than 4 m) and are connected to the sea by narrow channels which may be artificial or natural, permanent or temporary and through which water exchange with the sea takes place.

Mediterranean lagoons are not only brackish but may be sufficiently fresh to support freshwater fish communities, if only at certain times.

Lagoon salinity varies between 5 and 80 ‰ and the hydrological factors controlling the rate of exchange of water in the different zones of the lagoon with the sea is largely responsible for the nature of local biological communities, rather than geomorphological or other factors.

The yield of lagoon fisheries depends on the primary production and thus fish yield increases as a lagoon becomes more eutrophic. Lagoons are very rich in fish species and are especially important for euryhaline* and eurythermal* marine species. The lagoons in Mediterranean France alone are known to hold at least 136 fish species; 179 have been recorded from the coastal waters in the same region. The fish inhabiting lagoons can be divided broadly into two main groups:

- small sedentary species with a short life span which occur at high densities and spend their entire life cycle within the lagoon (e.g. Gobiidae, Syngnathidae)



Saline lagoon

1. *Mugil cephalus*
2. *Belone belone*
3. *Dicentrarchus labrax*
4. *Gobius niger*
5. *Anguilla anguilla*
6. *Sparus auratus*
7. *Siphonostoma typhle*
8. *Zostera marina*
9. *Salicornia spp.*
10. *Cerastoderma edule*
11. *Gammarus spp.*
12. *Carcinus aestuarii*
13. *Penaeus kerathurus*

Drawing by Robin Ade

- larger migratory fish which only use the lagoon for part of their life cycle (e.g. Sparidae, Mugilidae) and at various developmental stages in different species.

The location, physical structure and permanence of the channels connections to the sea are of major importance in ensuring the abundant and diverse recruitment of fish species to the lagoons. In addition, coastal currents and the direction of prevailing winds also seem to play a major role in the colonisation of lagoons by marine fish[1].

A. J. Crivelli

Patok Lagoon in Albania still supports a traditional fishery.

Bardawil lagoon

Bardawil Lagoon is an important lagoon system in Egypt with a major local fishery. It is a large lagoon of 65,000 ha, 90 km in length, whose salinity ranges from 37-65 ‰. It is connected to the sea by three channels, two of which are 300 m in length and 4-7 m deep and are managed by regular dredging, the third being natural. In 1988, 917 fishing boats operated within the lagoon, employing about 3,000 fishermen. The lagoon provides about 15 % of the income of the region.

Fish populations within the lagoon are conserved by local regulations, the most important of which is a complete ban on fishing for four months each year. Annual fish production is around 2,500 tonnes, comprising Sea Bream *Sparus auratus* (65 %), mullets (20 %), soles (5 %) and various other fish (4 %). The cash value of production in the period 1985-87 varied from 2.6-4.7 million pounds Egyptian. Exports of fish in 1987 were valued at 12 million dollars US[2].

1 - Quignard et Zaouali, 1981
2 - Al-Bawab, 1988

Ecosystem role of fish

Early ecologists emphasised the dynamic nature of communities, but showed at the same time that they all adhered to certain broad principles.

The basic ideas concerning inter-relationships within ecosystems have evolved from elementary ideas about food chains, through food webs and energy flow pathways, to sophisticated computer simulation models of such systems. The contribution of work from fresh waters to this field has been considerable, for the communities involved are often less complex and more self-contained than those of marine or terrestrial ecosystems. Many aquatic communities are dominated by fish.

All ecosystems have certain general features and levels of organisation in common. The ability to support quantities of life of various kinds depends initially on the amount of energy available, linked closely with the trophic nature of the system. Organisms within the community transfer through what are known as trophic levels. There are three groups of organism concerned with this transfer of energy:

A simple food chain in Israel reservoirs

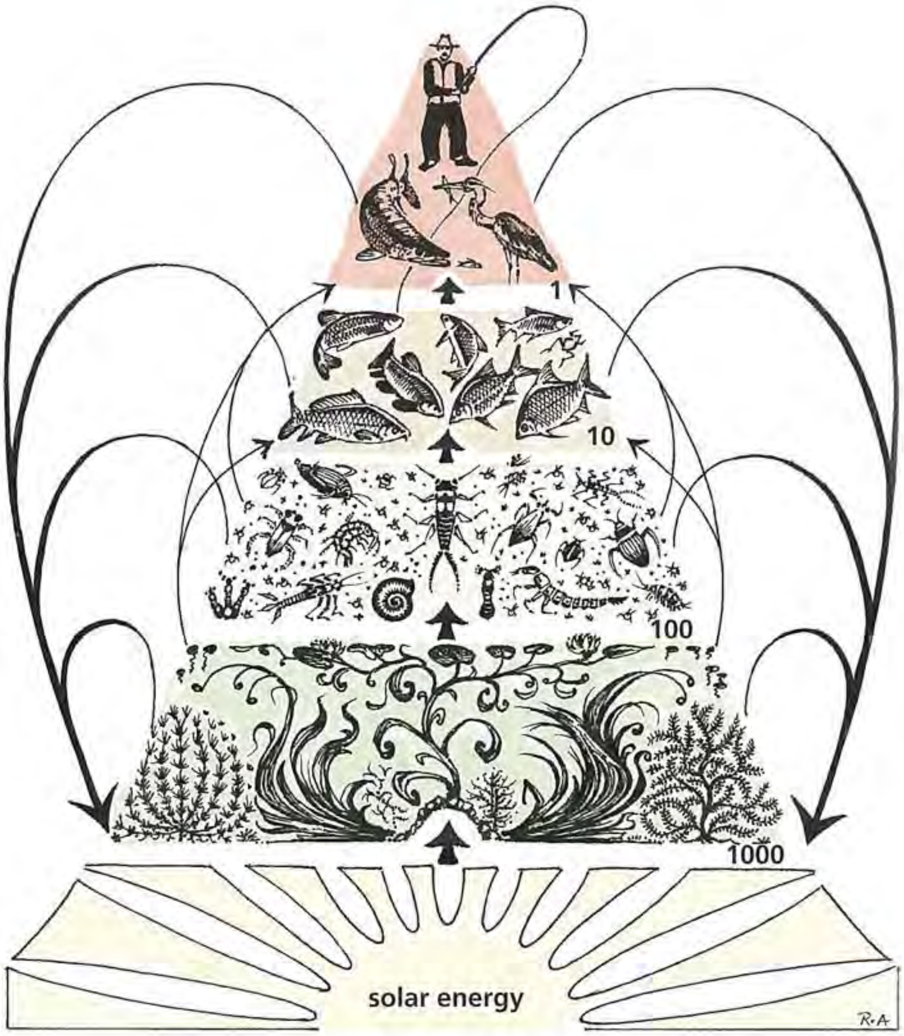
More than 200 reservoirs with a total capacity of more than 130 million m^3 have been constructed in Israel in the last three decades. Most of these reservoirs have a very short annual hydrological cycle, filling during the winter and drawing down for irrigation during the summer. This regime produces a very unstable ecosystem which is not able to support a natural fish population and is characterised by massive blooms of algae and subsequent unstable populations of zooplankton.
To solve this problem, filter-feeding fish (Silver Carp *Hypophthalmichthys molitrix* and Bighead Carp *Hypophthalmichthys nobilis*) have been stocked in more than 30 reservoirs.


A. J. Crivelli

A reservoir in Israel with fish ponds in the backround.

The fish have been very successful in this situation and have prevented extensive summer algal blooms, as well as reducing the density of zooplankton. The presence of fish in the reservoirs has improved the quality of the irrigation water and reduced the tendency for the irrigation systems to clog up[1].

1 - Sagi, 1992



An aquatic food web.

Drawing by Robin Ade

- Primary producers (mainly plants), which utilise the energy from solar radiation and available inorganic nutrients to produce plant material.
- Consumers (e.g. both herbivores and carnivores), which cannot synthesise material from inorganic sources only, but have to rely on organic substances already elaborated by primary producers.
- Decomposers (mainly bacteria and fungi), which attack other organisms (usually after they are dead), breaking them down into simpler compounds and releasing many of the inorganic salts again, making them available to primary producers.

In Lake Kinneret, Israel, for example are found good examples of long term relationships between, firstly, a carnivorous fish, a barbel *Tor canis*, and its prey, the Kinneret Sardine *Mirogrex terraesanctae*, and secondly, a cichlid *Sarotherodon galilaeus* and an alga *Peridinium cinctum*. The coexistence and relationships among these species probably represent a very long term evolutionary process due to the great age of Lake Kinneret (20,000 years) and is obviously very successful – both fish species *(Tor* and *Sarotherodon)* successfully exploiting two very abundant and easily available endemic food sources *(Mirogrex* and *Peridinium).* For example, the population of *Mirogrex* in Lake Kinneret between 1987 and 1990 was always between 61 and 218 million fish and was the basis of a very successful fishery there[1].

Food chains and food webs

Simple systems, formerly known as food chains, are rarely found in isolation in nature. In a common Mediterranean ecosystem such as a lowland river or lake, for example, a basic part of the energy flow pattern might be through an alga, such as *Pediastrum* (utilising available solar radiation and nutrients) which is eaten by an invertebrate, such as the mayfly *Ephemera*, which in turn are eaten by a fish, such as a dace *Leuciscus*.

This simple chain, however, is complicated by a variety of cross-links; it is likely that invertebrates other than the mayfly eat the alga, and that fish other than Dace eat the mayfly. Since many animals are also opportunists as far as feeding is concerned, and rarely restricted to one type of food, it is likely that the mayfly will browse on algae other than the species under consideration, and that the fish concerned will eat various invertebrates additional to the mayfly. Many invertebrates are omnivorous or carnivorous, and it is likely that the mayfly may eat other invertebrates (e.g. midge larvae, such as *Chironomus*) which feed on the alga, or themselves be eaten by predacious flatworms, these in turn being eaten by Dace. The Dace themselves may well be eaten by a piscivorous fish such as a perch *Perca* which in turn could be the food of a heron *Ardea*. All the organisms concerned may well be attacked by parasites of one kind or another.

Even in the most complex situation, however, it is still possible to consider principles common to the structure of the communities and the flow of energy within them. In general, animals at the base of a food chain are relatively abundant, while those at the top are relatively few in number, and there is a progressive decrease between the two extremes.

This simple concept may be modified in different ways, however, and it is best to consider all systems as dynamic ones, with energy flowing through them, each trophic level having less available energy than the one below it.

The bottom-up: top-down theory predicts that in eutrophic lakes changes in piscivore biomasses will have strong impacts on planktivore numbers, weaker but observable impacts on zooplankton biomass and little or no long-term effects on phytoplankton biomass. A partial winterkill at Lake St George in Canada allowed a test of this theory. After winterkill, the recovery of piscivores was slower than that of planktivores, but eventually both segments of the community returned to prewinterkill abundance levels. Thus the data over a 7-year period were consistent with the model – the implication being that the trophic cascade at Lake St George uncouples at the zooplankton-phytoplankton link[2].

1 - Walline et al., 1992
2 - McQueen et al., 1989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Fisheries

Commercial inland fisheries in freshwater and in coastal lagoons are traditional activities practised since antiquity in this region but they are at risk of being replaced by agriculture and tourism in the management plans for Mediterranean wetlands.

Freshwater and lagoon fisheries have always been considered as marginal activities in wetlands and have been totally ignored by government departments. This can be explained by the fact that on an overall national scale these fisheries are of little economic importance and employ only a small number of people. The situation today is serious : freshwater and lagoon fisheries are threatened with disappearance for ecological, socio-economic and historical reasons.

Traditional freshwater fisheries are on the decline throughout the region.

Commercial fisheries

Virtually all large lakes and rivers in the Mediterranean area have commercial fisheries, the total annual production from such waters being some 332,000 tonnes during the period 1978-87.

This compares with 1,369,000 tonnes from the Mediterranean itself and with 54,000 tonnes from the lagoon systems. Some of the fish forming the basis of commercial fisheries are introduced, but most freshwater fisheries rely on native species caught by methods which vary according to the species, water and tradition of local fisherpeople. In large lakes, fish are caught by gill nets and traps, though in some waters, seine nets or trawls may be used. Most river fisheries rely on traps or lift nets to capture both catadromous* and anadromous* species, though in some broad rivers, seine nets may be used. Apart from local subsistence fishing, only a few large rivers actually support many commercial fishermen, for example there are only six full-time and seven part-time fishermen along the whole length of the River Rhone. Commercial fisheries in Mediterranean reservoirs are also rare – though there are some exceptions, for example, the Kerkini irrigation reservoir in Greece supports about 300 part – and full-time fishermen.

There are many traditional fisheries in natural lakes in the Mediterranean area. These are important locally and a wide range of fish are caught in the different types of lake. One of the highest production rates (109 kg/ha) is found in the highly managed Lake Kinneret, where 62 % of the catch is one species (the Kinneret Sardine).

A. J. Crivelli

Fish traps in the channel between lagoons and the sea are an ancient form of fishery. Akyatan, Turkey.

The most valuable species in the lake fisheries are salmonids and coregonids in the deep oligotrophic lakes (e.g. Leman, Maggiore, Veggoritis, Ohrid) and cyprinids in the shallower richer lakes (e.g. Trasimeno, Skadar, Ionnina, Koronia).

Lagoons support the largest number of fishermen. For example, there are 3,000 fishermen on Bardawil Lagoon in Egypt, 1,000 in four lagoons on the Ebro Delta in Spain and 810 fishing the lagoons along the Languedoc-Rousillon coast of southern France. Fishing in most lagoons is highly seasonal and occurs in autumn and spring. The main target species are Eel, *Mugil cephalus*, Sea Bream *Sparus auratus* and Sea Bass *Dicentrarchus labrax*; all of these are euryhaline and all spawn in the sea – using the lagoons as nursery areas for feeding and growth[1].

The Lake Kerkini irrigation reservoir in northern Greece has the most important freshwater fishery in Greece. The lake is also famous for its wildlife, particularly the fish-eating birds.

A. J. Crivelli

1 - *Crivelli, 1992*

Lake Ohrid and its salmonid fishery

Several large lakes in countries to the east of the Adriatic Sea are unique, because their origins go back much further than the Glacial Period. Three of these – Lakes Megali and Mikri Prespa and Lake Ohrid form the Dassaretes basin on the Albanian/Macedonian/Greek border and all three are of tectonic origin. Because of their long geographical isolation, the fish faunas of these lakes have a high degree of endemism. Lake Ohrid is the best known of these lakes and lies at 685 m above sea level with a surface area of 369 km^2 and a catchment of 680 km^2. The maximum depth is 286 m.

Although 68 species of fish are known to occur in Albania, 43 of which are endemic to the north Mediterranean region, little is known about the distribution and status of most of them. The exception are the salmonids and two endemic taxa living exclusively in Lake Ohrid – the Belushka *Salmothymus ohridanus* and the Korani S*almo letnica* – form the basis of important fisheries there. The Belushka has an annual yield of 5-10 tonnes per year in the Albanian waters of Lake Ohrid. It is caught mainly in winter, is highly valued and usually consumed fresh. The Korani gives an annual catch of 15-30 tonnes in the same waters and is also much in demand as a food fish.

Though this valuable salmonid fishery has been sustained over a long period there is evidence that it is now in decline. The main threats are from activities in the catchment which in turn affect the lake. However, the introduction of Rainbow Trout and the management practice of stocking the lake with hybrids between the Belushka and the Korani are both regarded as harmful to the stocks of endemic salmonids[1].

A. J. Crivelli

With the exeption of the salmonid fishery of Lake Ohrid, Carp is the principal freshwater target species in the Balkans.

1 - Rakaj & Flloko, 1995

Lake Trasimeno in Italy has an intensively managed fishery.

F. Ardito / Panda Photo / Bios

Lake Trasimeno

Lake Trasimeno in Italy has a surface area of 12,800 ha, a maximum depth of 6 m and a mean depth of 2 m. It has an intensively managed fishery which yields some 65 kg/ha per year. The most sought-after species are Pike, Eel, Perch, Sandsmelt, Tench and Carp. The lake is managed by the Consorzio pesca Acquacoltura Trasimeno which owns and operates a large modern fish farming facility, with laboratories, hatcheries, tanks and outdoor ponds. Present production includes Pike, Carp and Grass Carp fry in bulk and research is aimed at various other species including exotic species such as sturgeon for both aquaculture and stocking. The production of fish ranges from 440 to 1100 tonnes and any surplus is sold for stocking other waters.

The yield from the lake itself varies from year to year but in 1984, 1986 and 1987 the fishermen landed fish worth one million, two million and three million dollars US, respectively. The actual number of fishermen (organised in several cooperatives) has decreased from 480 in 1956 to 190 in 1987. Most of the fish from the hatchery are stocked as fry and fingerlings and though these play an important part in maintaining the level of the catch their impact on native species is unknown and of some concern. In the lake today there are 18 fish species, but only five of these are native. One native species (Adriatic Roach *Rutilus rubilio*), at least, has become extinct in recent years[1].

1 - Mearelli et al., *1990*

Angling

Angling has only recently started to become popular in the Mediterranean area and, so far, has only developed to a significant extent in a few of the more developed countries, notably France, Spain and Italy.

However, it seems likely to increase in popularity as leisure time and tourism increase and thus the conflicts between anglers and commercial fishermen, which are already evident in some areas, may increase. A common phenomenon, evident elsewhere in Europe, is that, where angling becomes a popular pastime and brings in money to the local economy through tourists, it takes precedence over commercial fishing which then declines.

There has been increasing controversy in recent years concerning the impact of angling on aquatic wildlife. A central problem concerns litter, which, in addition to being unsightly has a serious impact on birds and mammals because of hooks and monofilament line in which they become entangled. The presence of anglers often disturbs wildlife. Anglers can alter habitat, either unintentionally (e.g. by trampling down vegetation), or intentionally (e.g. weed cutting and bank clearance). Anglers may also impinge directly on aquatic communities by poisoning unwanted fish, shooting predatory birds or introducing new fish species. Stocking with desired fish species to enhance the population may in practice have the opposite effect.

An angler on the Guadalquivir in Seville, Spain.

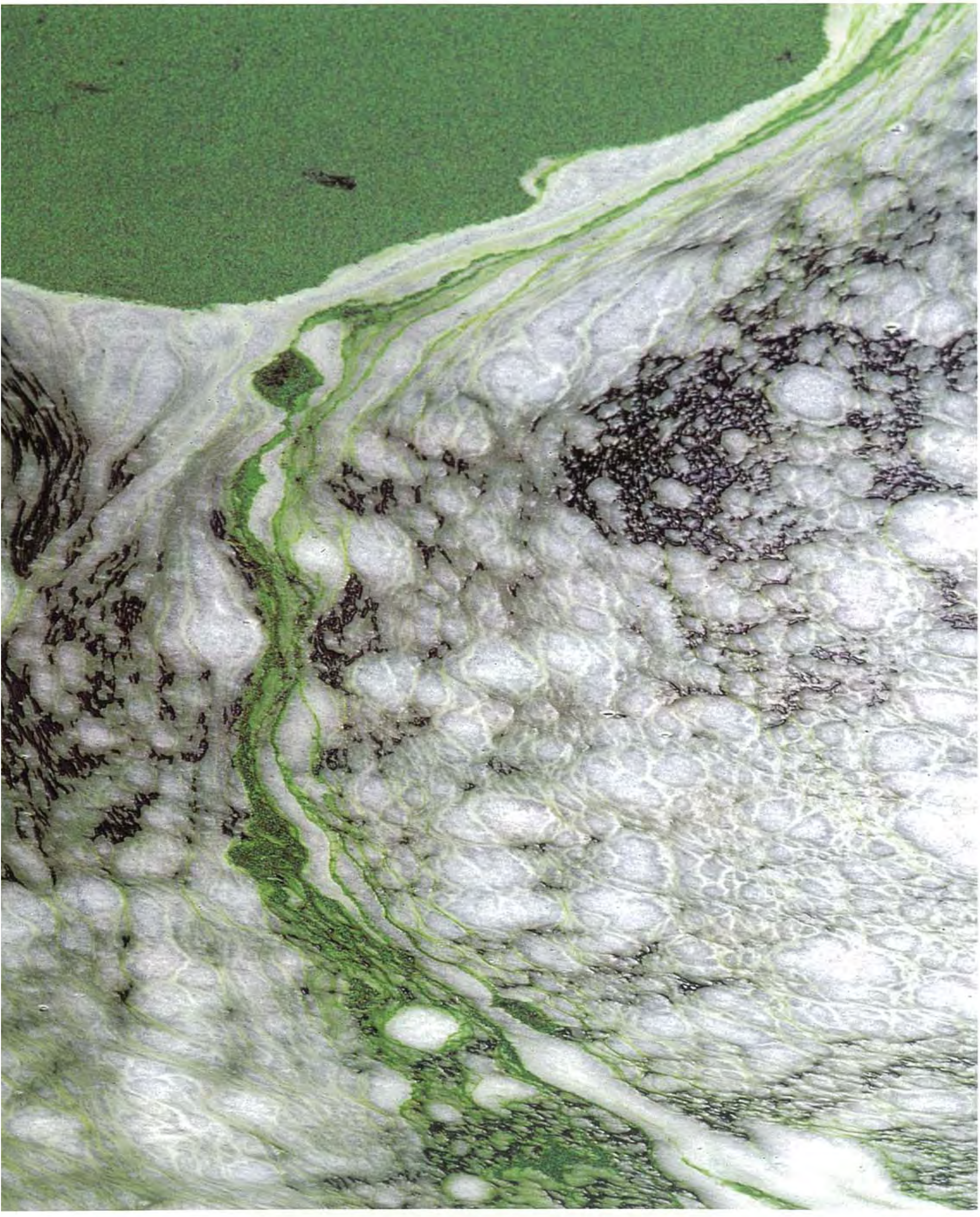
J. Roché / Bios

Anglers press for constant restocking of lakes – an increasingly controversial practice.

The reasons for this are varied but include the introduction of disease, overstocking and the elimination of important genetic components evolved by the native stock.

Recent estimates suggest that there are currently about 30 million anglers in Europe. However, participation and regulations vary greatly among different countries – for example, in Sweden 25 % of the population fishes, whereas in the United Kingdom, the Netherlands and France some 6-10 % of the population are anglers. In contrast, at the lower end of the participation scale, in Spain and Italy, only 1-2 % of the population fishes. In part, these differences can be explained by the availability of fishing waters, but tradition, the ownership and organisation of fisheries, water pollution, etc. are also related factors[1].

1 - Bongers, 1992



J.J. Alcalay / Bios

Threats to fish

Fresh water has been used by humans from earliest times, at first only for drinking and washing, but later for fishing and navigation. The majority of settlements in many countries are related to spring lines and other sources of pure water.

With improving sanitation, water was used for cleaning and removing domestic wastes, as well as for irrigation in agriculture. Within the last two centuries, improving standards of living, increased sophistication of agricultural methods, industrial development and production of hydropower have meant that, world-wide, water has become more and more important to humans. Further, extended leisure time in modern societies has increased pressure on recreational facilities for aquatic activities like angling, wildfowling, sailing, swimming, water skiing and power-boating. All of these activities can threaten fish and localised endemic species are often particularly vulnerable.

Eutrophication is a major threat to fish populations.

Pollution

The pollution of fresh waters is probably the most significant factor in causing major declines in the populations of many fish species in Europe, North America and elsewhere.

Most pollution comes from domestic, agricultural or industrial wastes and can be totally toxic thereby killing off all the fish species present or selective, killing off a few sensitive species or so altering the environment that some species are favoured and others not. Many pollutants are present at sub-lethal levels and could raise the susceptibility thresholds of fish to other factors (e.g. disease). More research is needed on this important topic. Eutrophication is sometimes thought of as a mild form of pollution whilst the recent acidification from atmospheric pollution of many waters in Scandinavia and elsewhere has shown that even waters far away from urbanisation are not necessarily safe.

In the Donana National Park in southern Spain, one of the most important nature reserves in Europe, a recent study examined the levels of organochlorine and heavy metals in a variety of vertebrates. These included Common Carp, Common Barbel *Barbus barbus*, *Mugil capito* and Eel from the main water body in the Park. Significant levels of organochlorine pesticides, PCBs and heavy metals were found in some of the fish and these are assumed to have come from an agricultural area near the park and from a working mine about 40 km from its northern boundary[1].

M. Scataglini / Panda photo / Bios

Chemical pollution on the Martino River near the Circeo National Park, Italy.

1 - Rico et al., 1987

Threats to fish

Pollution is a serious problem in many parts of the Mediterranean. The influence of polluting substances on natural waters is variable according to local conditions and organisms within the water concerned. Pollutants can act in two main ways: directly, by settling out on the substrate and smothering life there, or by being acutely toxic and killing organisms; or indirectly by reducing the oxygen supply so much as to kill fish, or by altering the habitat in other ways which are detrimental to fish.

Effluents with high suspended solids are typical of mining industries, poorly treated domestic sewage, and various washing processes. Most of the solids settle out soon after discharge, at a rate dependent on their size, density and local current conditions. The effect of inorganic particles is mainly a physical one, and plants and invertebrates may be completely covered and destroyed. Fish often die through their gills becoming clogged. If the particles involved are organic, their decay may add the problem of deoxygenation to that of alteration of the substrate.

The impact of toxic substances on organisms in natural waters is complicated by the fact that different species have varying resistance thresholds to poisons (which may act variably at different temperatures) and that some poisons are cumulative in their effect and others are not. Most toxic substances originate from industrial processes, though some arise from mining and agriculture.

Pollution of the Rhone

Like many other rivers in the Mediterranean region, the River Rhone is affected by organic, chemical and thermal pollution. The presence of major cities and their industrial centres (Lyon, Grenoble) has lead to heavy organic loads due mainly to domestic sewage and discharges of nitrogen, phosphorus, organochlorides and heavy metals, to which must be added the the radioelements discharged by various nuclear research centres.

Studies of fish in the Rhone have shown that this pollution has lead to many changes, for example:

- it favours the most tolerant species in the community (e.g. Chub *Leuciscus cephalus*, Roach and Bleak *Alburnus alburnus*);
- it leads to the bioaccumulation of pollutants that render the fish unfit for human consumption (commercial fishing has been banned upstream of Lyon);
- it renders fish more susceptible to disease;
- it increases mortality among fry;
- it leads to siltation of important gravel spawning beds.

In addition to these problems of general pollution there are also regular fish kills due to accidents. There have been nine fish kills during the last 20 years from accidental chemical spills into the river[1].

1 - Changeux & Pont, 1995

Organic materials in sewage effluents are a source of major pollution of fresh waters. Though these effluents often contain plant nutrients, these cannot be utilised for some time because of the high oxygen demand of the decomposing organic material. In extreme cases, especially in lakes and slow-flowing rivers, so much oxygen is used up that anaerobic conditions result and no organisms other than bacteria and some fungi can exist. In less severe cases, species with low oxygen requirements (e.g. worms and midge larvae) can exist, and indeed, in the absence of predators and competitors and with abundant supplies of organic material for food, may build up dense populations.

With the high production of electricity from thermal power stations, the temperature regime of many natural waters has been significantly influenced by heated effluents. Relatively little is known about their influence on natural communities; it is likely that high temperatures will kill some cold-adapted species and favour the development and reproduction of others. Also, the effect of organic effluents and some toxins is likely to be increased. In some temperate areas, species restricted naturally to tropical waters have become established in the vicinity of heated effluents. The main effects of heated effluents as far as pollution is concerned are that warmer water holds less oxygen than cooler, and decomposition processes are speeded up.

In the Mediterranean area, the fresh waters in most countries have suffered from industrial pollution. The absence of regulations controlling discharges together with the lack of enforcement of existing regulations in these countries has created serious and recurring pollution of their fresh waters, with progressive loss of important native fish populations. The enormous tourist influx into the Mediterranean region each year leads to increased sewage loads during the summer when rivers are at their lowest.

In the context of catchment management in the Mediterranean area, although the pollution control authorities in some countries have been successful in controlling point discharges of pollution they have been less successful with non-point sources, such as agricultural fertilisers, runoff from roads and open soil, etc. Fortunately this topic is giving rise to much discussion at the moment and it is likely that some progress in this difficult area may be made in the next few decades.

Land use

As much of the rain water falling on a catchment eventually finds its way into the nearest water course it is obvious that land use can have a major impact on the nature of local water bodies and consequently on native fish populations.

In rural areas in the Mediterranean, the deforestation process took place centuries before extensive urbanisation and thus the main change at present is the increase in these impermeable surfaces. These greatly reduce infiltration to the ground and increase total runoff and peak flows. The final results are highly detrimental to river ecosystems and native fish communities.

The clearing of forests for agriculture and industry, the ploughing and fertilisation of land and the various herbicides and pesticides used on crops may all have significant effects. Land drainage schemes can totally alter the hydrology of adjacent river systems leading to lower flows in dry weather and higher flows in wet weather, thus considerably altering fish habitat. In addition, there may be problems of siltation from earth washed in from ploughed fields or cleared forestsand fish spawning gravels may be affected as a result. A serious problem in many lowland areas is the drainage or filling in of many ponds which were formerly important sites for various species of fish. This factor alone is threatening the safety of a few species in some countries e.g. *Valencia hispanica* in Spain.

Many waters in the Mediterranean area have been affected by changes in land use. In the rivers draining the Catalan area of Spain, for example, there have been marked changes in yearly discharge (shown in total runoff, peak discharges and lag times between rainfall and runoff) after an increase in urbanisation within their watersheds. The main changes in the catchments of the rivers have been the removal of vegetation followed by the regulation of rivers and the laying down of extensive impermeable surfaces (e.g. roads and buildings).

P. Bertrand / Bios

Bad catchment management can lead to catastrophic flooding. Coulon River near Cavaillon, France.

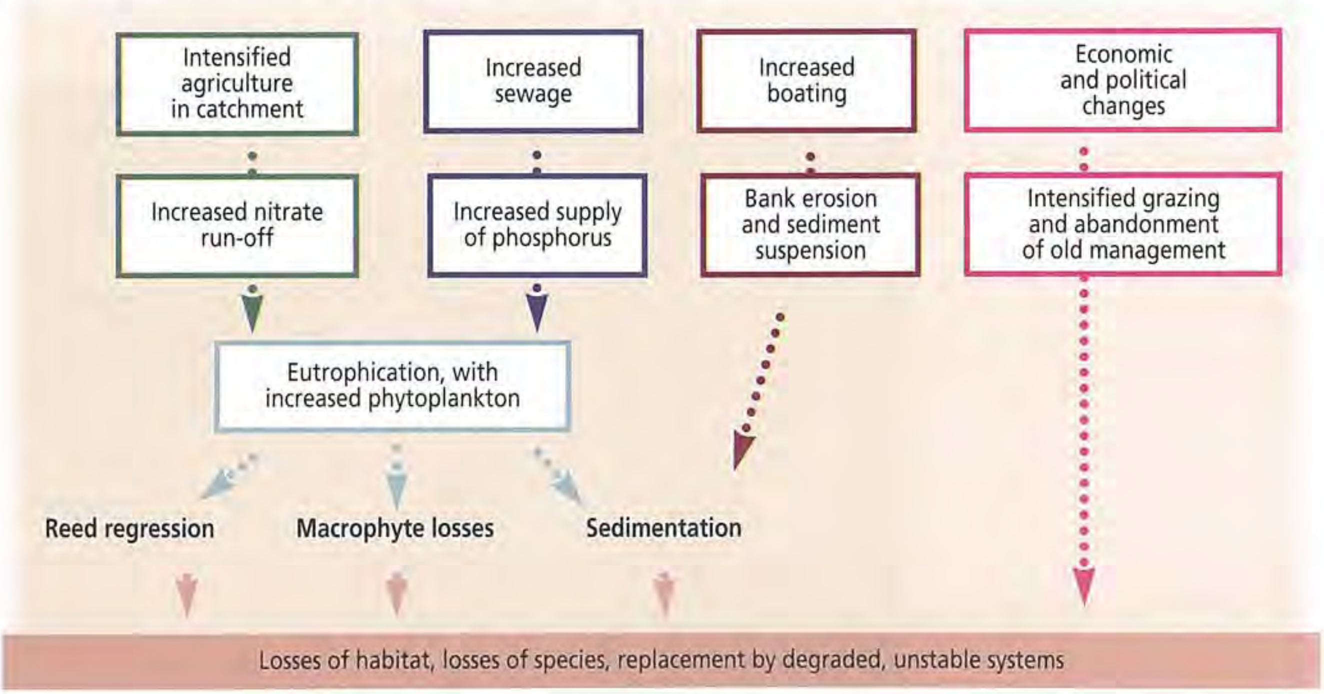
Eutrophication

The effects of nutrients originating from organic sewage and agricultural fertilisers can be potentially serious, especially in the long-term. Principal among these nutrients are compounds of nitrogen and phosphorus – much of this phosphorus is not immediately available, but is bound up in various ways and becomes part of the benthic biomass and the lake ecosystem in general. This is one of the principal features of the eutrophication process. Instead of a simple system with a constant addition of nutrients, and a constant dilution through the inflow-outflow system of the lake, there is actually considerable accumulation of nutrients within the ecosystem both in its living components (plants, invertebrates and fish) and especially within the bottom deposits.

The effects of such eutrophication are various and include increased algal growths, deoxygenation of the lower cooler layer of water during stratification in summer and under ice in winter, and a tendency for the fish community to change from one dominated by salmonids and other fish which are sensitive to conditions of low oxygen to one where coarse fish (which are much more tolerant of low oxygen conditions) predominate. For example, in Italian lakes, cyprinid species such as Bleak, Rudd, Adriatic Roach and Chub increase in numbers for they are better able to use the increasing availablity of organic matter.

Eutrophication is likely to be the main cause of the extinction of many fish in lakes. Eutrophication is also a major problem in lagoon systems and each year more and more hypertrophic* events are observed in Mediterranean lagoons which kill many living organisms there. With the repetition of such crises (sometimes every summer) the stock of fish within the lagoons (especially non-migratory species) declines seriously.

Main cause and effect relationships for eutrophication. Modified from Moss, 1983

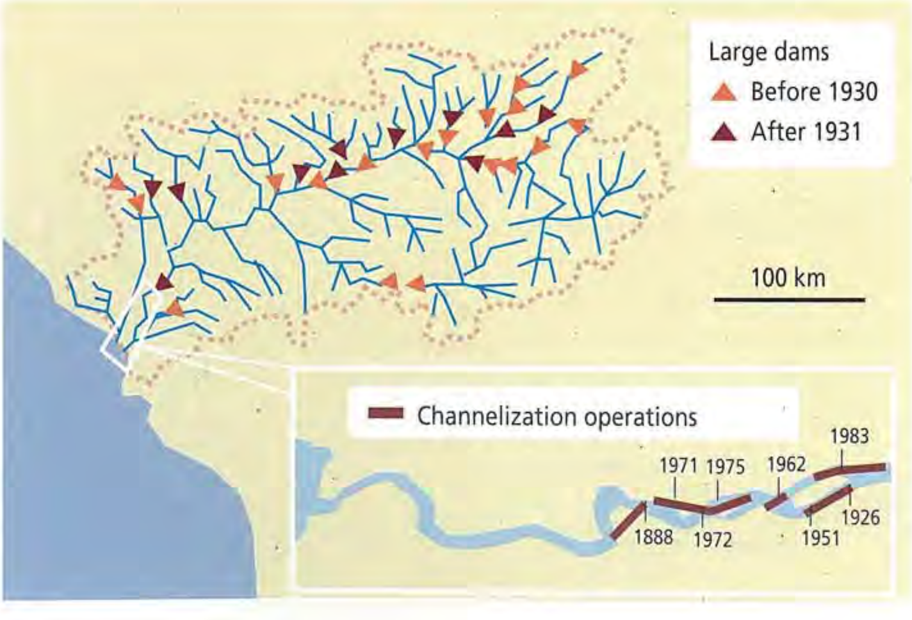


Engineering for water supplies

River and lake engineering have been responsible for the immediate elimination of various fish species in many freshwater systems all over the world.

The Guadalquivir River in Spain is 680 km in length and has a catchment area of 63,822 km². Since the 18th century numerous engineering schemes have increasingly regulated the rivers, especially channelisation to straighten meanders and the construction of dams. Since 1905, 60 reservoirs have been constructed within the river basin – 11 of them on the main river. In 1931, the Alcala del Rio Dam was built about 100 km from the river mouth. Altogether, the channelisation schemes have brought about a considerable reduction in the length of the river (50 km) and the hydrology has been markedly influenced by channelisation and dams. Since 1931, Sea Lamprey and Sturgeon have disappeared from the river since they cannot reach their spawning grounds above the Alcac del Rio dam. Shad are virtually extinct for the same reason and only Eel and mullet are still abundant[1].

In the Duero River system in northern Spain, the construction of the Burgomilodo Reservoir for hydropower had a severe effect on the ecosystem downstream, with major changes in the composition of the invertebrate and fish communities. The main physicochemical factors involved are oxygen deficit and short-term fluctuations in the flow.



Historical changes in the Guadalquir River basin in Spain.

Source: modified from Granado-Lorencio, 1991

1 - Granado-Lorencio, 1991

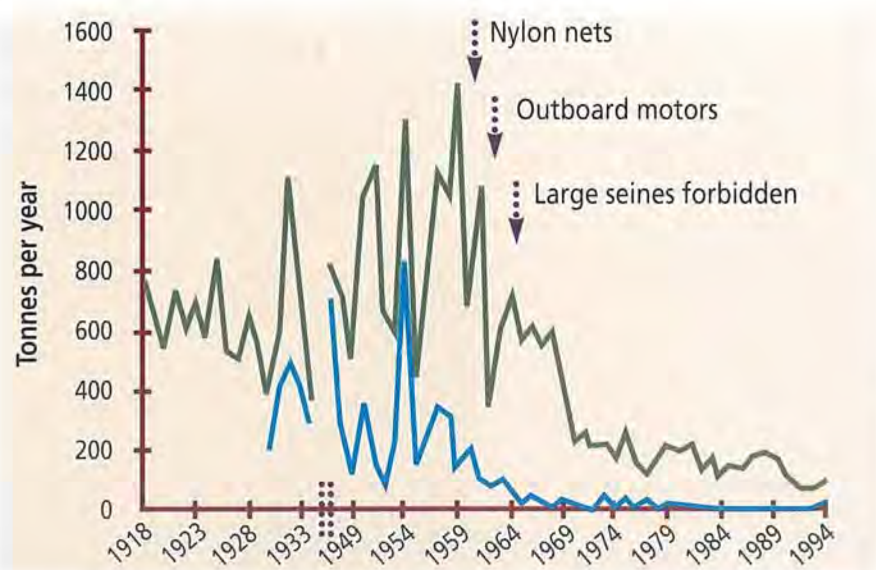
Overfishing

The impact of fisheries (both sport and commercial) on the populations which they exploit can range from the virtual extinction of populations to a more or less stable relationship of recruitment and cropping which exists in many old-established fisheries.

The essence of success in fisheries is to have a well-regulated fishery where statistics on the catch are regularly monitored and used as a basis for future management of the stock. This is particularly essential when the fishery exploits a threatened species.

After habitat degradation, overfishing is the most important factor involved in the decline of fisheries in the wetlands of the Mediterranean region.

In Lake Koronia (4,200 ha) in northern Greece the average annual yield for the period 1918-34 with a fishing effort of 14 fishermen per km^2 was 156 kg per ha, which is remarkably high for a lake in this region. Between 1948 and 1960, before the introduction of nylon nets and outboard motors, the average yield increased to 205 kg per ha per year, with a fishing effort of 11 fishermen per km^2. Thereafter, there was an intermediate period between 1961 and 1971 with a yield of 138 kg per ha per year with an effort of about 5 fishermen per km^2. Finally, between 1972 and 1983 the catch dropped to 42 kg per ha per year with an effort of about 3 fishermen per km^2. Although the total quantity of fish captured per fisherman per year was the same in 1971-83 as in 1918-34, the quantity of Carp (the fish with the highest market value) declined dramatically, thus reducing the income of the fishermen. During the period concerned there was also a complete disappearance of four fish species from the lake – Common Bream *Abramis brama*, Danube Catfish, Pike and Goldfish.



Fisheries production at Lake Koronia in norther Greece. Blue line: production of Carp, the principal target species.

Source: Crivelli, unpublished

Conserving the Atlantic Sturgeon

The Atlantic Sturgeon is a large anadromous fish which was formerly of considerable commercial importance in many parts of Europe. However, like other species of sturgeon, it is very vulnerable to overfishing, pollution and obstacles in rivers and in recent years has undergone a serious decline. Formerly occurring widely in European coastal waters from southern Norway to the Adriatic, it had spawning populations in many of the major rivers entering this region.

The Atlantic Sturgeon was formerly an important fish in the River Guadalquivir in Spain. Originally it was able to migrate from the sea to its highest spawning grounds some 230 km upstream. However, the construction of a dam in 1930 reduced the spawning area to a short stretch near the mouth, just above the tidal limit. At the same time, a factory for processing caviar and sturgeon flesh was built in the area. The story since then is a depressing one. Between 1932 and 1954, 3,186 Sturgeons were caught, 2,544 of these being females. After 1940, the catch dropped dramatically and no fish have been taken since 1975 when the last individuals were recorded[1].

This species has been officially protected in Spain since 1983 and is listed in the Red Data Book. However, it is now considered extinct in the area, having disappeared from other Spanish rivers, such as the Ebro (the last specimen here was caught in the 1950s), Turia and Jucar Rivers. The main causes overall have been overfishing and the construction of dams, though water pollution and the extraction of gravel from spawning grounds have also had a negative impact.

The decline over the whole of Europe has been so serious in the last decade that the Gironde in France seems to be the only river which this species now enters to breed (in very small numbers) and it is likely that this species will become extinct in the next decade.

In France, CEMAGREF are making a serious attempt to save this species from extinction and have established an excellent fish conservation facility in the valley of the Dordogne, near St Sevrin. The primary objective here is the conservation of the Atlantic Sturgeon but the facility has already developed techniques for the commercial farming of other (less endangered) sturgeon species – the Sterlet *Acipenser ruthenus* and the Siberian Sturgeon *Acipenser baeri*. Both of these have now been taken through a full life cycle at St Sevrin and the techniques for handling and rearing them at all life stages are fully established. The main conservation effort is directed at the Atlantic Sturgeon, which is now so rare that specimens are treated on an individual basis. At present there are just six fish of this species here, though efforts are being made to obtain others. Of these fish, one is 12-13 years old, another is 10 years old whilst the four others are about 5 years old. The difficulties of eventually breeding from just these six fish are immense – for example, it will be 5-10 years before these young fish are mature enough to spawn.

In Italy, a similar project is under way with the Adriatic Sturgeon *Acipenser naccarii*. Here, the artificial spawning and captive rearing of this threatened species is in its early stages but there has been some success (5,800 young produced in 1990) and it is hoped that this work will help to save this rare species[2].

1 - Elvira et al., 1991
2 - Giovanni et al., 1991

Fish introductions

Many species have been introduced over the last hundred years and several of these are now regarded as having an important role in fisheries in natural waters and fish farms. Some managers feel that these introductions cause no problems to either existing fisheries or to their environment. However, the introduced cyprinid *Pseudorasbora parva* can cause serious damage in rearing ponds and the Goldfish is considered to be a pest in fish farms.

Apart from physical and chemical habitat alterations created by humans, one of the major biological perturbations is the introduction of new fish species. If these establish themselves they can alter the community structure radically and lead to the extinction of sensitive native species.

There are six possible outcomes to the introduction of new fish species when it interacts with the native population. The introduced species may:

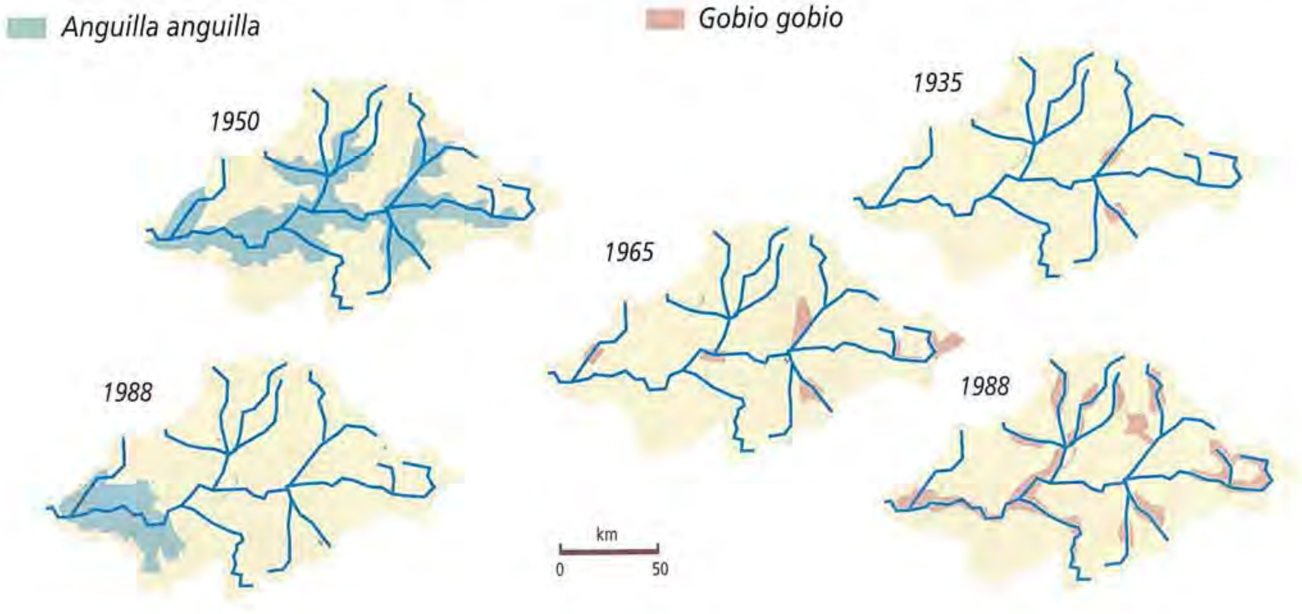
- die off because there is no 'vacant niche';
- be consummed by local predatory species at an early stage;
- hybridise with very closely related species formerly adapted to the ecosystem;
- eradicate or suppress a species that is an 'ecological homologue' ;
- eradicate an easily available prey, in the case of predatory species;
- find a 'vacant niche' within the community, which means that it adapts to resources that are not fully exploited by native species and thus is able to survive as a member of the community.

The ecological consequences of some introductions have been catastrophic, but there are also examples from different parts of the world where the results have been beneficial – at least from some points of view.

The impact of fish introductions is thus often controversial, and real evidence relating cause and effect is normally lacking. One scientist reviewed the situation in Lake Kinneret in Israel, where 13 exotic species and two native to other parts of Israel have been introduced,

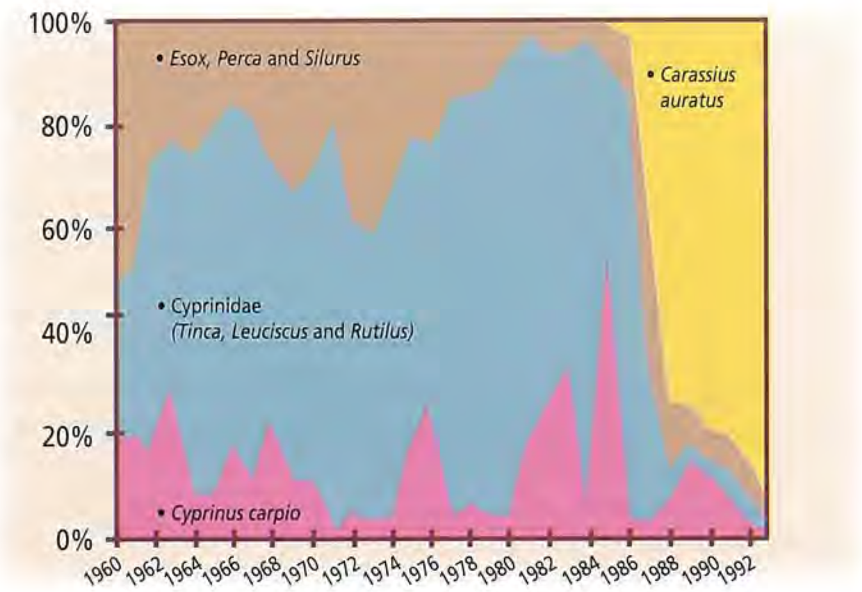
Historical changes in the distribution of eel, a native species and of Gudgeon, an introduced species in the River Duero basin.

Modified from Lobon-Cervia et al., 1989



The introduction of Grass Carp into Lake Ouberia in Algeria did increase the catch but eliminated much of the aquatic vegetation and reduced the numbers of native fish and wildfowl.

some intentionally, others accidentally. He concluded that the introduction of exotic species has 'proved to be economically advantageous'[1]. However, this conclusion was rebutted by other workers who produced contrary evidence and concluded 'We ask the simple question. Which should be more effective in developing a stable and productive system: Man and his introduction of exotic species or 20,000 years of Lake Kinneret evolution? We suggest the latter.'[2]



Percentage composition of the annual catch of the fishery of Lake Kastoria, western Greece.

Source: Crivelli & Catsadorakis, unpublished data

Fish introductions in the Mediterranean area

Owing to the decline in commercial catches, the introduction and translocation of fish species have increased tremendously in the Mediterranean area in recent years. For example, 13 introduced species have been recorded among the 45 which are found in Lake Skadar in Former Yugoslavia. Six of the 16 species in Lake Mikri Prespa in Greece are introduced and 14 out of 19 in Lago di Trasimeno in Italy.

Most of these introductions have been made as a result of recommendations from fishery biologists or civil servants. Some are accidental and others have been made by local fishermen themselves. Instead of taking measures against the real cause of the decline of the fishery, decision makers and fishermen have preferred to introduce new species to their waters, believing that such introductions will resolve the problem of declining catches. Lack of state, regional and local fishery officers, the absence of conservation action for fish, the fact that most fish hatcheries are state owned (and thus maintain their existence by stocking almost any species anywhere without caring too much about the results) are the main causes of present practices[3].

1 - Ben-Tuvia, 1981
2 - Gophen et al., 1983
3 - Crivelli, 1995

Recreation

The increasing human population, and the leisure time available to it, is placing an enormous demand on fresh waters which are often the focus for a variety of recreational activities (e.g. sailing, river rafting, power-boating, water-skiing, fishing, wildfowling, bathing and general picnicking).

The recreational use of many Mediterranean fresh waters is high. For example, Lake Kinneret, which is the only large freshwater lake in Israel, is very popular for recreational activities including camping, swimming, water skiing, wind surfing, sailing, tourist cruises, etc. It is estimated that 50,000-80,000 people use the beaches every day during the main holiday period (May - October)[1].

It is unfortunate that the most important waters for recreation are not those within urban areas, but those further away – because of the natural preference for clean rivers and clear lakes as opposed to turbid and eutrophic waters. The most popular areas for tourists lie in river valleys where the greatest number and most important nature reserves are situated.

Many wetland areas are being actively managed for the benefit of humans in different parts of the world. Some are set aside and managed solely on the basis of their scientific interest, and recreation is actively discouraged. In other areas, various recreational activities are compatible with the aims of the reserve. While the primary interest in these areas may be wildlife or recreation, economic operations can yield substantial financial returns, and may even increase the value of the area for the wildlife or recreational activity concerned.

Many recreational uses of fresh waters (wildfowling, angling, sailing, bathing, boating and water skiing) cause pollution and disturbance to

M. Gunther / Bios

Will there be any room left for fish ?

1 - Gophen, 1985

Stocking – good or bad ?

A consequence of angling management for recreation in all parts of the world is that stocking is regarded as a panacea for all problems in the fishery – real or perceived. This has led to enormous numbers of fish being stocked in rivers and lakes – often with substantial damage to stocks of native species and rarely with any subsequent evidence that any good has been done.

In some Mediterranean countries fish are produced regularly in hatcheries and stocked in local waters. In the province of Turino in Italy, for example, in 1986 and 1987, one million fry and 400,000 fingerling Brown Trout and 60,000 fry and 30,000 Marbled Trout were produced for stocking. Elsewhere in Italy, over the last 20 years, 20 million Brown Trout, five million *Barbus plebejus*, 1,200,000 Common Carp, 800,000 Tench and 20,000 Pike *Esox lucius* have been stocked in the River Esino[1].

In the River Duero in Spain, the fish communities have changed dramatically over the last 50 years due to numerous introductions of alien species which are favoured by anglers but often detrimental to sensitive native fish. Introduced species which have become well established include Goldfish, Common Carp, Rainbow Trout, Brook Charr *Salvelinus fontinalis* Gudgeon , Minnow *Phoxinus phoxinus*, Mosquito Fish, Pike, Largemouth Bass and Danube Salmon *Hucho hucho*. More recently a new problem has been identified – the introduction of small species, usually casually, by aquarists[2].

Elsewhere in Spain, in 1981 for example, 4.7 million fish (Rainbow Trout, Brown Trout, Largemouth Bass and Common Carp) were released into the streams and rivers of the River Ebro basin in Catalonia. This represents about 23 fish for each angler fishing in the area[3].

certain animal species by actively killing them (wildfowl or fish) or frightening them away – an important problem with many nesting birds. Areas of shoreline and stands of macrophytic vegetation may be affected by trampling or the frequent passage of boats. Accumulations of lead from boats and oil from their motors are causing considerable pollution in many lakes[4].

1 - Bianco, 1995
2 - Lobon-Cervia et al., 1989
3 - De Sostoa & Lobon-Cervia, 1989
4 - Maitland & Turner, 1987

A. J. Crivelli

Fish conservation

In any consideration of fish conservation and biodiversity a number of factors must be taken into account. A site which is rich in fish species is of high conservation value.

This is closely linked with diversity of habitat, water chemistry and the size of a site. There is a tendancy for the number of species of both plants and animals to be positively correlated with the area of the site. This is not detrimental as larger sites are easier to conserve. Latitudinal and altitudinal differences influence the number of species possible and this should also be taken into account.

The occurrence of fish species, communities or habitats which are rare, or outside their normal range of distribution, adds to the importance of a site. Species which are existing at the edge of their range may present various research possibilities and be genetically distinct from other populations. Some species and communities are rare because they have specialised habitat requirements (e.g. coregonid fishes which require unpolluted lakes). Many have greatly retracted their distribution as a result of human pressures, such as reservoir construction and pollution.

A conservation programme for Marbled Trout is underway in the River Soca and its tributaries, Slovenia.

Fish conservation is hampered by the difficulty of accurately assessing and monitoring populations sizes which requires specialised manpower and equipement.

An example in the Mediterranean area is the freshwater goby fauna of Greece. Here, four freshwater gobies are of note, some of them having been described only recently. All of them are vulnerable and already the type waters of two of them *(Economidichthys pygmaeus* and *Knipowitschia thessala)* have been drained and these local populations lost. The latter species and *Economidichthys trichonis* are restricted to single drainage systems. Conservation of these two species is urgent: both are endemic to Greece and *E. trichonis* is of especial interest as Europe's smallest freshwater fish.

Care must be taken not to apply too much weight to certain groups, for example, some migratory fish, with their strong capacity for movement, can arrive as vagrants, breed, and equally suddenly disappear a year or two afterwards, independent of the management being applied.

Geographical distribution of freshwater gobies in Greece.

Source: modified from Economidis & Miller, 1990

Habitat management

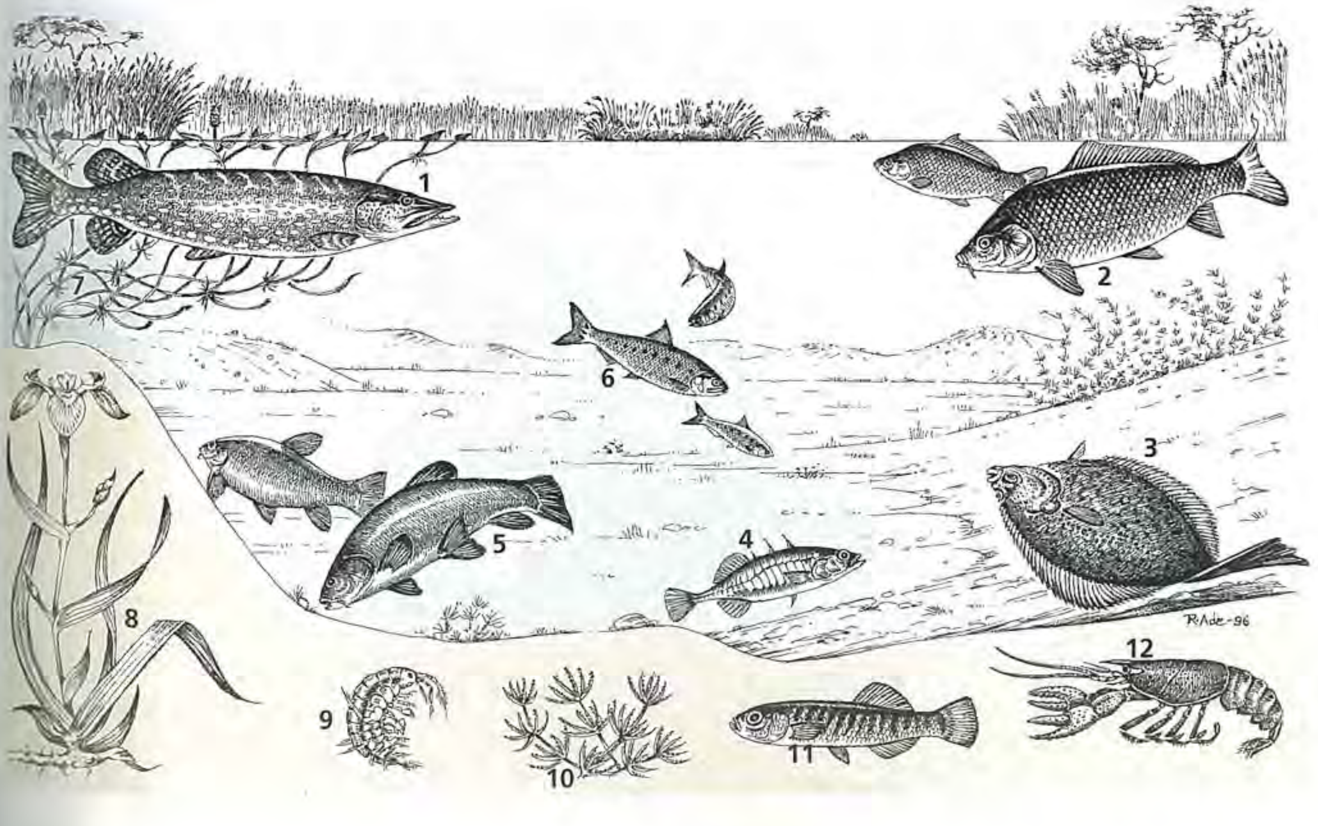
In a few countries (e.g. United States, Canada, United Kingdom, France), the concept of integrated water usage on the basis of large catchment areas has become accepted as the most rational approach to water conservation.

In the United States, the Commission on Water Resources Policy recommended that new proposals for water resource development should be submitted only in the form of programmes which deal with entire river basins and which take into account all relevant features of water and land development. However, there are problems with trying to develop an integrated approach to water management. Although the World Conservation Strategy listed as one of their priorities, that by 1995 'all high income countries will have established cross-sectoral mechanisms for integrated water management based on drainage basins and the application of an ecological approach' in few Mediterranean countries does the statutory framework meet this requirement. In fact, the complexity of the framework for managing fresh waters actually hinders conservation management in some areas, while in other areas statutory provision is completely absent.

River delta

1. *Esox lucius*
2. *Cyprinus carpio*
3. *Platichthys flesus*
4. *Gasterosteus aculeatus*
5. *Tinca tinca*
6. *Alosa fallax*
7. *Potamogeton natans*
8. *Iris pseudacorus*
9. *Gammarus spp.*
10. *Chara spp.*
11. *Aphanius fasciatus*
12. *Orconectes spp.*

Drawing by Robin Ade



Minimum flows

Throughout Europe, major flow regulation schemes date from the 19th century, although the peak of dam building activity was in the 1960s. River regulation may be carried out for a variety of reasons – to reduce the natural within-year and between-year flow variability, to reduce floods, to increase low flows, or to transfer water in or out of a river catchment. Although the concept of 'minimum acceptable flow' in river management has long been accepted as important for fisheries and for the dilution of sewage and industrial effluents, much damage has been done to the fish and other biota in rivers where it has been ignored. Even where minimum flows or compensation flow agreements exist, the policy may be ignored during periods of drought when they are most needed[1].

Much attention has been given recently to establishing a sound basis for the determination of acceptable minimum flows in rivers and four general approaches have been adopted:

- relating regulated flows to the natural flow regime ;
- providing a flow that will maintain a specific habitat quality ;
- using a regional approach by comparing regulated with comparable unregulated systems ;
- developing simulation models which integrate habitat preferences of fish and other biota with measured flows.

All of these approaches have a common philosophy – that there is a strong link between hydrology and ecology. Different species of fish and other biota are adapted to various flow regimes and when these are provided a strong foundation exists for an appropriate natural riverine ecosystem.

One of the most useful models developed in recent years is PHABSIM (Physical HABitat SIMulation) which is now used in the USA, France, Norway, New Zealand, Canada, Australia and the United Kingdom. The purpose of the PHABSIM system is the simulation of the relationship between streamflow and available physical habitat (defined by depth, velocity, substrate and cover). For each life stage of any target species the model requires expressions of the relative suitability for that species of the full range of values taken by these variables. These univariate curves are habitat suitability indices: they may be derived from expert opinion, from existing literature or by sampling techniques[2].

1 - Harper & Ferguson, 1995
2 - Institute of Hydrology, 1994

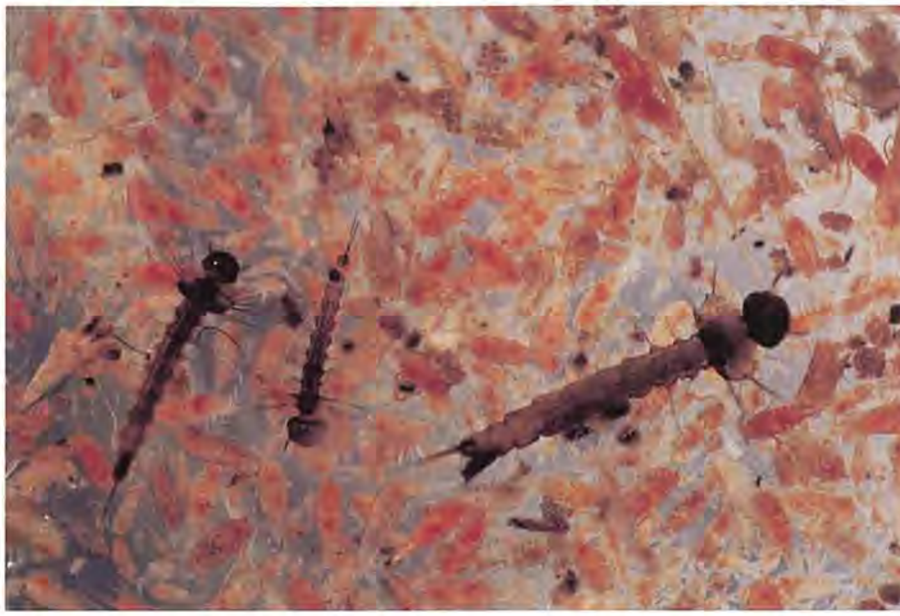
In developing national strategies for water use and catchment management the question of sustainability must remain paramount. There is little point in promoting wild fisheries in certain rivers if the fishing effort allowed is so great that stocks decline and disappear; or agreeing to water transfer in the upper reaches of a river if this means that the reaches below virtually dry up in summer. Looking to the future, the concepts of sustainable integrated resource and catchment management are likely to become increasingly important.

However, the advantages of forward-thinking management schemes to the restoration of wetlands are clear and numerous. For example, the destruction of artificial drainage systems within areas to be set-aside from agriculture in the long-term would restore a more natural runoff to adjacent rivers. This, combined with the cessation of the spread of chemicals (fertilisers, herbicides and pesticides) onto these lands would greatly reduce the input of such chemicals to rivers. The actual geographical layout of set-aside ground could also be used wisely by maximising strips alongside rivers. Agricultural ground which was formerly defended against floods but which now could be flooded is yet another value to the river which could result from the intelligent use of long-term set-aside schemes[1].

If fish populations are to be protected, restoration of eutrophicated wetlands is essential.

J. Roché / Bios

1 -WWF, 1995


J. Roché / Bios

Invertebrates form the basis of wetland food chains and should be included in management regimes.

Lake Kinneret catchment management

Since 1964, when the National Water Carrier system started to operate, Lake Kinneret, Israel, has been used primarily as the national reservoir for fresh water. The lake is also extensively exploited for fisheries recreation and tourism. Recent anthropogenic activities have significantly affect both the drainage basin and the lake; the latter is now heavily loaded with nutrients from sewage, wastes from aquaculture and the degradation of organic soils (peat). The management programmes for fisheries and stocking of the lake are aimed at food production and not at the improvement of water quality.

Two main food chains occur in Lake Kinneret:

- the alga *Peridinium* which is eaten by the St Peter's Fish *Tilapia galilaea. Peridinium* is very poorly consumed by zooplankton and much of it is degraded via a detrital pathway,
- Nanoplanktonic algae eaten by herbivorous zooplankton in turn eaten by fish (mainly *Mirogrex* and *Acanthobrama*). The increase of nutrients initiates a shift towards *Peridinium* suppression and nanoplankton enhancement. An increase in the latter also results from a reduction in zooplankton (due to increased predation by fish). These successive events adversely affect water quality because it is difficult to remove nanoplankton from water supplies.

A management programme for the lake and its drainage basin has been prepared and initiated. This programme is based on the structure of the food web in the lake and involves the reduction of nutrients entering the lake from sewage, aquaculture wastes and peat degradation. In addition, policies concerning the management of the fishery and the stocking of fish have been revised[1].

1 - Gophen, 1985

Species management

The conservation of fish and fish communities has received little attention relative to other vertebrates. Yet across Eurasia and North America numerous important stocks of various fish species have been eliminated and there are now thousands of lakes and rivers which are fishless or possess only degraded communities.

The main problems are caused by engineering works, industrial and domestic pollution, acidification, fishing and fishery management, and land use practices. The major conservation objective, perhaps fortified by legislation, must be habitat restoration and management, but short-term programmes can usefully involve translocations, captive breeding and cryopreservation*.

As well as habitat restoration, one of the most positive areas of management lies in the establishment of new populations, either to replace those which have become extinct or to provide an additional safeguard for isolated populations. Any species which is found in only a few waters is in potential danger and the creation of additional independent stocks is an urgent and worthwhile conservation activity. The transfer of stock can be done without any threat to existing populations provided specific criteria are followed as closely as possible.

F. Ardito / Panda photo / Bios

The fishfarm at Lake Trasimeno, Italy, produces millions of fry of exotic species each year in order to improve the commercial fishery.

With most of the stocks of fish concerned it should be possible to obtain substantial numbers of fertilised eggs by catching and stripping adults during their spawning period. These fish can then be returned safely to the water to spawn in future years. Fortunately, most fish are very fecund and so substantial numbers of eggs can be taken at this time without harm. Having identified an appropriate water (usually one in which the species was previously present) in which to create a new population, the latter can be initiated by placing the eggs there, or incubating the eggs in a hatchery and introducing the young at various stages of development.

Short-term captive breeding, involving only one generation, does have some advantages for a number of fish species. It is especially relevant where there is difficulty in obtaining reasonable numbers of fish to start a new population. In such cases there are considerable advantages to be gained in breeding stock in captivity to obtain young for release in the wild. Because of genetic problems related to inbreeding* and loss of genetic diversity, this procedure should ideally be restricted to just one generation from the wild stock.

Stripping of eggs in a fish farm.

G. Lopez / Bios

Cryopreservation, using modern techniques for rapid freezing of gametes to very low temperatures has proved successful for a variety of animals, including fish. After freezing for many years and then thawing the material is still viable. However, the technique is successful only for sperm and though much research is at present being carried out on fish eggs, no successful method of egg cryopreservation has yet been developed. The technique is therefore at the moment only of limited value in relation to the conservation of fish species. However, where a particular stock seemed in imminent danger of dying out it is worthwhile giving consideration to saving at least some of its genetic material through the cryopreservation of sperm. When it is possible to preserve female gametes in a similar way, the technique will have obvious possibilities in relation to the short-term conservation of a wide variety of fish species[1].

Captive breeding of endangered Mediterranean fish

The technique of captive breeding is being used in the conservation of several endangered fish species in the Mediterranean area.

The Marbled Trout has been bred in Slovenia and in northern Italy since the 1980s. Some of this work has developed because of concern about the decline of this species caused by hybridisation with stocked Brown Trout[2].

The populations of the endemic Spanish cyprinodont *Valencia hispanica* have declined in recent decades and this fish is now regarded as critically endangered. A recovery programme for the species is being implemented where special aquatic reserves are created for populations in the wild and the species is also being bred in captivity, the objective being to reintoduce it to waters in which it previously occurred[3].

Because of the restricted habitat and high degree of threat to the recently discovered Karst Sculpin, some of this species have been brought into captivity. Fish have been successfully bred in indoor tanks and management techniques and rearing protocols are being developed as experience is gained. The intention is to ensure that small captive populations of this species are maintained in several institutions as 'a good insurance against fatal events in its small habitat'[4].

1 - Maitland, 1995
2 - Forneris et al., 1990
3 - Planelles & Reyna, 1996
4 - Persat et al., 1996

Fishery management

The problem in most fisheries is really a twofold one. Firstly, it is now known that fish populations (and fish production) can be very variable from year to year. Secondly, the statistics which are essential to successful management policies (e.g. the Catch Per Unit Effort: CPUE) are usually lacking.

One of the major problems with fisheries of all kinds is that their management is rarely based on scientific principles or conceptions of conservation and sustainability and the usual approach is a short-term one of maximizing yield regardless of the consequences to the fish populations concerned. As a result, many fisheries (and, consequently, local fish-based economies) have collapsed – especially those where multinational ownership of the fishery is concerned.

In order to avoid such catastrophes, substantial effort has been made by fishery biologists to develop quantitative theories of fisheries management and this has led to the development of various mathematical models.

Control of gear

Part of the solution to the development of a sustainable fishery must also lie in the choice of gear – for ideal catch quotas should be set, not only in terms of total allowable tonnage, but also in the size (age) structure of the fish to be taken. This can usually only be regulated by controlling some aspects (e.g. mesh size) of the gear to be used.

If, for example, a small mesh size is used and fish are caught when they are very young, the catch will typically consist of large numbers of very small individuals. This will give a numerically large catch but not necessarily a large weight of fish. Conversely, if fish are not caught until they are very old, the catch will tend to consist of a relatively small number of large fish. Again, the aggregate weight may not be large. The best approach is to determine the appropriate average age or size at which to capture each species so as to maximise the sustainable yield in weight per year class entering the fishery.

There are various ways of achieving this, and one of the best of these is to regulate the age (or size) at first capture by regulating the mesh size. This will protect juvenile fish from capture and ensure that sufficient fish survive to maturity. This may be especially important for stocks which are exploited at such a high level that there is danger of recruitment failure due to diminished stock size[1].

1 - Jones, 1980

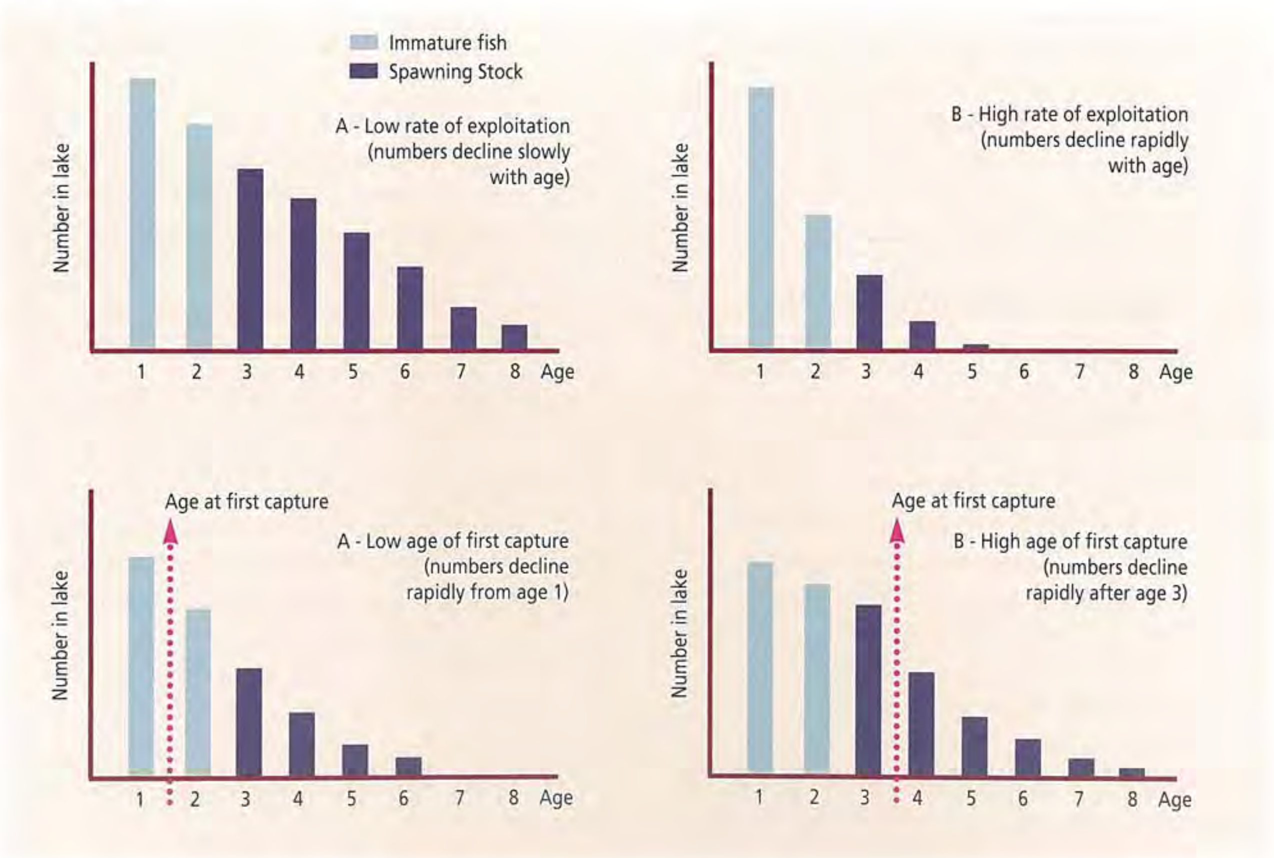
By implication therefore, successful management of freshwater fish populations for their sustainable use requires regular statistics on the populations of each species, in particular:

- the annual CPUE in the fishery concerned;
- the age structure in the catch and in the population;
- the growth rate of each year class.

Most fisheries should have a closed season of some kind (usually during the spawning season) and the above data for the previous season can be analysed then. If the results are available for the start of the next fishing season, then catch quotas for the whole fishery can be set at limits which will allow a successful fishery to be sustained.

Effects of exploitation rate and age at first capture on spawning stock in a fishery.

Source: Jones, 1981



International legislation

In addition to legislation within the individual countries of the Mediterranean area, there is also some important relevant international legislation – notably the Bern Convention on 'the Conservation of European Wildlife and Natural Habitat' and the EC Directive on 'the Conservation of Natural and Semi-Natural Habitats and of Wild Fauna and Flora'.

The appendices of the Bern Convention list species which are given protection. Fish, originally absent, were added to these appendices in the 1980s. Appendix II (species given full protection) now includes four fish species. Appendix III (species partially protected) includes 118 fish species, several of which occur in the Mediterranean area, including Atlantic Sturgeon, Allis Shad and Twaite Shad. A recent report[1] to the Council of Europe includes a recommendation for Appendix IV of the Bern Convention, which sets down prohibited means of killing, capture or exploitation of the fish species listed in Appendix III.

The Council Directive on the conservation of natural habitats and of wild fauna and flora

Fish were not concerned by any protection measures in the European Union before the so-called 'Habitats Directive'[2] was signed in 1992. Only the 'Birds Directive'[3] required member states to protect habitats of certain bird species. The 'Habitats Directive' has fortunately changed this situation and lists a wide range of European habitats and plant and animal species which require protection.

The onus is now with the fifteen member states of the European Union to carry out the requirements of the Directive. The list of fish from the various Annexes of the Directive is presented in pages 86-87. It is worth noting that this list requires substantial updating considering that many endemic Mediterranean fish taxa are not included and the taxonomy of several species has been recently revised.

1 - Maitland, 1994
2 - Directive 92/43.EEC of May 1992
3 - Directive 79/409/EEC of April 1979

A positive step from the Ramsar Convention

The Ramsar Convention was signed in February 1971 in Iran. Its Secretariat is based at present in Gland, Switzerland, and funded by subscriptions from the Convention parties. In July 1996, there were 92 Contracting Parties representing 838 designated wetlands with a total surface area of 53,837,165 ha. Until now, the designation of wetlands of international importance under the Ramsar Convention has been based essentially on their importance as habitats for waterfowl. However, at the Kushiro Conference in 1993, a recommendation was made by the Contracting Parties to develop criteria and guidelines based on the importance of wetlands for fish, both as regards biodiversity and fishery yields, but taking into account the wise use principle that the fisheries shall have no negative impact on the wetland.

The Scientific and Technical Review Panel has subsequently made proposals for these criteria, to be used when identifying wetlands of international importance as fish habitat or as nurseries for fisheries. Thus, a wetland should be considered internationally important if: (a) it supports a significant proportion of indigenous fish subspecies, species or families, life history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity or (b) it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

These criteria were agreed in 1996 and will allow countries to include as Ramsar sites, wetlands which have no value for waterfowl, but have great value for fish and fisheries. Such an inclusion is a very positive step towards improving the conservation of fish habitats and of rare and threatened fishes[1].

Outside Europe, a simple, but very important, new concept – which is being considered in various countries in one form or another – has already been accepted by Canada in relation to fish habitat. This makes it clear that approval for developments which potentially threaten fish habitats will be given only if :

- there is no loss of fish habitat involved, or
- the development is modified in such a way that there is no loss of fish habitat, or
- any fish habitat which must be lost because of the development is compensated by the restoration or creation of equivalent fish habitat elsewhere in the same system, so that there is no net loss of habitat[2].

1 - Ramsar Bureau
2 - Department of Fisheries and Oceans, 1986

A. J. Crivelli

Conclusion

Humans have been involved and interacting with fish populations for many thousands of years, and it is often difficult to separate the effects of this impact from changes which have taken place due to more natural processes. Over the last 200 years and particularly the last few decades many new and intense pressures have been applied to fresh waters and very many species have declined in range and in numbers.

Fish face a number of problems, some of them common to other forms of wildlife, others more particular to fish. In addition, there has been habitat loss on an enormous scale. As indicated above, many smaller lakes have been drained or filled in and streams have been piped. Rivers and, to a lesser extent, lakes are repositories of enormous amounts of human waste, ranging from toxic industrial chemicals through agricultural slurries and herbicides to domestic sewage. Even aerial pollutants such as sulphur dioxide from power station chimneys are eventually washed into water courses as "acid rain". Many rivers have become completely fishless as a result, especially those in the industrial and heavily populated lowland areas of the Mediterranean area.

For how much longer will the nets be repaired ?

Fish populations are limited by land boundaries to their immediate water body and thus the whole population is vulnerable to a single incident of toxic spillage or acidification.

Other factors have affected fish in various ways. Barriers on rivers, such as weirs or hydro-dams have blocked the passage of migratory fish to their spawning grounds and so eliminated them. Enrichment from farm fertilisers, overfishing and the introduction of new fish species (many of them from abroad) have all contributed to the decline of fish stocks – especially those of the rarer and more sensitive native species. Where a native species is found in a few waters only it is obviously extremely vulnerable and in urgent need of protection.

On the positive side, some new types of habitat have been created by humans, notably numerous reservoirs of a variety of sizes and, in lowland areas, canals. Most of these have provided extremely suitable habitats for fish communities, but although many have been developed for sport fisheries or occasionally for commercial fisheries, very rarely have they been exploited for fish conservation purposes.

There have also been enormous advances in pollution control in some parts of Europe over the last few decades and a number of the worst rivers are now much cleaner. Thus, in the United Kingdom, the Rivers Clyde and Thames are now far less polluted than 50 years ago and fish have been returning to them in increasing numbers. At their worst, both rivers were virtually fishless in their lower reaches. Over the last two

A steel factory returns hot, polluted cooling water to the river.

Drain / Still / Bios

decades, many freshwater and estuarine species have returned to the lower Thames which now supports a diverse community, not unlike its original one. Rehabilitation of the River Clyde has been rather slower. However, salmonid fish are conclusive evidence of high water quality and the return of the Atlantic Salmon to this river after an absence of more than 100 years is a tribute to decades of work by the local river purification board.

However, in the context of catchment management in the Mediterranean area, although the pollution control authorities in some countries have been successful in controlling point discharges of pollution they have been less successful with non-point sources, such as agricultural fertilisers, runoff from roads and open soil, etc. Fortunately this topic is giving rise to much discussion at the moment and it is likely that some progress in this difficult area may be made in the next few decades.

Freshwater fishes are an important source of human protein on a worldwide basis and the annual commercial catch is many millions of tonnes. In addition, there are important subsistence fisheries in several countries (the catches usually unknown), whilst sport fishing, in some countries at least exceeds the commercial catch and is now a major source of income to the economy of many, otherwise poorly resourced, areas.

Many freshwater fisheries using traditional (but often inefficient) methods have shown themselves to be sustainable – for, by definition, they have existed successfully for hundreds of years. In fact, their success has been due mainly to the under-utilisation of the stocks concerned. Most modern fisheries have shown themselves to be unsustainable, for the use of electronic location methods, modern fisheries gear and boats and the possibility of freezing and storing enormous quantities of fish has created the ability to decimate populations within a few years.

Thus, the successful management of freshwater fish populations to allow their conservation and sustainable use must rely on a sensible mixture of annual scientific information about each species and the extrapolation of this, using appropriate statistical models, into the allowable catch for the following year. There must also be equitable policies where international waters are concerned and a realisation that, in the long-term, the status of freshwater fish populations is dependent not only on the quality of the water in which they live but also on the land use and other activities by humans in the catchment which it drains.

List of fish mentioned in the annexes of the "Habitats Directive"

Family	Taxa	Annex II	Annex IV	Annex V
Petromyzonidae				
	Eudontomyzon mariae (Berg, 1931)	◆		
	Eudontomyzon hellenicus Vladykov, Renaud, Kott & Economidis, 1982	◆		
	Lampetra fluviatilis (Linnaeus, 1758)	◆		◆
	Lampetra planeri (Bloch, 1784)	◆		
	Lethenteron zanandreai (Vladykov, 1955)	◆		◆
	Petromyzon marinus Linnaeus, 1758	◆		
Acipenseridae				
	Acipenser naccarii Bonaparte, 1836	◆	◆	◆
	Acipenser sturio Linnaeus, 1758	◆	◆	◆
Clupeidae				
	Alosa alosa (Linnaeus, 1758)	◆		◆
	Alosa fallax (Lacepede, 1800)	◆		◆
	Alosa macedonica (Vinciguerra, 1921)	◆		◆
	Alosa caspia vistonica Economidis & Sinis 1986	◆		◆
Salmonidae				
	Thymallus thymallus (Linnaeus, 1758)			◆
	Hucho hucho (Linnaeus, 1758)	◆		◆
	Salmo salar (Linnaeus, 1758)	◆		◆
	Salmo marmoratus Cuvier, 1817	◆		
	Salmo macrostigma (Dumeril, 1858)	◆		
Coregonidae				
	Coregonus oxyrhynchus (Linnaeus, 1758)	◆	◆	◆
Cyprinidae				
	Alburnus vulturius (Costa, 1838)	◆		
	Alburnus albidus (Costa, 1838)	◆		
	Anaecypris hispanica (Steindachner, 1866)	◆	◆	
	Aspius aspius (Linnaeus, 1758)	◆		
	Barbus comiza Steindachner, 1865	◆		◆
	Barbus capito (Guldenstaedt, 1772)	◆		◆
	Barbus meridionalis (Risso, 1826)	◆		◆
	Barbus plebejus Valenciennes, 1842	◆		◆
	Chalcalburnus chalcoides (Guldenstaedt, 1772)	◆		
	Chondrostoma genei (Bonaparte, 1839)	◆		
	Chondrostoma lusitanicum (Collares-Pereira, 1980)	◆		
	Chondrostoma polylepis Steindachner, 1865	◆		
	Chondrostoma soetta Bonaparte, 1840	◆		
	Chondrostoma toxostoma Vallot, 1836	◆		
	Gobio albipinnatus Lukasch, 1933	◆		
	Gobio uranoscopus (Agassiz, 1828)	◆		
	Iberocypris palaciosi (Doadrio, 1980)	◆		
	Ladigesocypris ghigii (Gianferrari, 1927)	◆		

List of fish mentioned in the annexes of the "Habitats Directive"

Family	Taxa	Annex II	Annex IV	Annex V
	* *Leuciscus lucumonis* Bianco, 1982	◆		
	* *Leuciscus souffia* Risso, 1826	◆		
	* *Phoxinellus pleurobipunctatus* (Stephanidis, 1939)	◆		
	* *Phoxinellus stymphalicus* (Valenciennes, 1844)	◆		
	* *Rutilus alburnoides* (Steindachner, 1866)	◆		
	* *Rutilus arcasii* (Steindachner, 1866)	◆		
	* *Rutilus friesii meidingeri* (Heckel, 1852)	◆		
	* *Rutilus lemmingii* (Steindachner, 1866)	◆		
	• *Rutilus pigus* (Lacepede, 1804)	◆		
	* *Rutilus macrolepidotus* (Steindachner, 1866)	◆		
	* *Rutilus rubilio* (Bonaparte, 1837)	◆		
	• *Rhodeus sericeus* (Pallas, 1776)	◆		
	* *Scardinius graecus* Stephanidis, 1937	◆		
Cobitidae				
	• *Cobitis conspersa* (Cantoni, 1882)	◆		
	• *Cobitis larvata* Filippi, 1859	◆		
	* *Cobitis trichonica* Stephanidis, 1974	◆		
	• *Cobitis tænia* Linnaeus, 1758	◆		
	• *Misgurnus fossilis* (Linnaeus, 1758)	◆		
	* *Sabanejewia aurata* (De Filippi, 1865)	◆		
Siluridae				
	* *Silurus aristotelis* (Agassiz, 1856)	◆		◆
Cyprinodontidae				
	* *Aphanius fasciatus* Cuvier & Valenciennes, 1821	◆		
	* *Aphanius iberus* (Valenciennes, 1846)	◆		
	* *Valencia hispanica* (Valenciennes, 1846)	◆	◆	
Percidae				
	• *Gymnocephalus schraetzer* (Linnaeus, 1758)	◆		
	• *Zingel zingel* (Linnaeus, 1758)			
	• *Zingel streber* (Siebold, 1763)	◆		
	* *Zingel asper* Linnaeus, 1758	◆	◆	
Gobiidae				
	• *Pomatoschistus canestrini* (Nini, 1882)	◆		
	* *Podagobius nigricans* Canestrini, 1867	◆		
	* *Podagobius panizzai* Verga, 1841	◆		
Cottidae				
	• *Cottus ferruginosus* Heckel & Kner, 1858	◆		
	* *Cottus petiti* Bacescu, 1964	◆		
	• *Cottus gobio* Linnaeus, 1758	◆		

◆ Annex II: Animal and plant species of community interest whose conservation requires the designation of special areas of conservation
◆ Annex IV: Animal and plant species of community interest in need of strict protection
◆ Annex V: Animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures
* Endemic north Mediterranean fish taxa

Glossary

Acidification: increased acidity of water due to human activity.

Anadromous: spawning and early growth in fresh water, but maturing in the sea.

Biodegradable: subject to natural breakdown by living organisms.

Biodiversity: the range or variety of living organisms found in a habitat or geographic area.

Biota: living plants and animals.

By-catch: fishes which are caught incidentally during fishing and are not the main target species (or desired size group of the target species).

Catadromous: spawning and early growth in the sea, but maturing in fresh water.

Cryopreservation: preserved alive, but deep frozen.

Diadromous: living both in the sea and in fresh water at different stages of the life cycle.

Endemic: native to, and occurring only in, a particular geographic area.

Euryhaline: qualifies aquatic species able to tolerate wide fluctuations in salinity.

Eurythermal: tolerant of a wide range of ambient temperatures.

Eutrophic: rich in nutrients and hence having excessive plant growth which kills animal life by deprivation of oxygen.

Fecundity: the relative numbers of eggs or young which an animal can produce.

Food chain: sequence of organisms in which each is the food of the next member of the chain.

Genetic pollution: the introduction of foreign genes or genetic material to a population of plants or animals.

Homing instinct: the innate ability to return to a particular area, often from long distances.

Hypertrophic: over-enrichment with nutrients.

Inbreeding: reproduction by closely-related individuals.

Indigenous: native or occurring naturally in a particular area.

Lotic: Pertaining to fast running-water habitats (rivers and streams).

Primary freshwater species: aquatic species which are confined entirely to fresh water and have no recent marine relatives.

Stratification: the separation of the upper warm layer of water from the lower cold layer during warm still weather.

Trophic: relating to nutrition.

Univariate: only a single character is varied during the analysis.

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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. The 2500 ha 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.

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.

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.

WWF aims to conserve nature and ecological processes by:
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