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Standing Committee

CONSERVATION OF

FRESHWATER FISH HABITATS IN EUROPE

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CONSERVATION OF FRESHWATER FISH HABITATS IN EUROPE

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1. INTRODUCTION

A recent review of the status of freshwater fish in Europe (Maitland 1986) has highlighted the need for conservation action in relation to many fish species, communities and habitats. The European fish fauna is a restricted but interesting one: in temperate regions of the northern hemisphere, due to recent glaciation, freshwater fish communities are much less diverse than those in the tropics. Even within Europe there is a notable reduction in species from south to north. Over the whole continent, human activities have destroyed fish habitats on a wide scale and over the last two centuries many thousands of populations have disappeared.

Freshwater fish are an important part of the European fauna and many of them are also the subject of important fisheries of a wide variety of types. Altogether, there are some 227 freshwater fish species found in Europe as a whole (Maitland 1977, Lelek, 1980, 1987), including several which are diadromous and a few which are mainly brackish but do come into fresh water for significant periods.

The major threats to fish and fish habitats in Europe (which are reviewed below) include industrial and domestic pollution, eutrophication, acidification, land use changes, river barriers, drainage, fish farming, fishery management and the introduction of new species. Current protection for European freshwater fish exists mainly through legislation, but this is inadequate in many respects and tends to focus mainly on sport and commercial species. There are also a large number of protected areas, of various designations, for native flora and fauna, but very few have ever been established because of their fish species.

2. THREATENED FISH IN EUROPE

Of the 227 species of freshwater fish found in Europe, 200 are regarded as native and 27 as introduced (mostly from North America). Altogether, 122 of the native species are now

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SUMMARY

The freshwater fish fauna of Europe is relatively impoverished compared to that of most other continents. Altogether there are 227 species of freshwater fish, 200 of which are native and 27 introduced (mostly from North America). Many of the native species are endangered and threatened but, although several thousand individual populations have been destroyed, no European species has yet become extinct (though a number are now nearly so). Of the four main active means of achieving successful fish conservation (habitat protection, translocation, captive breeding and cryopreservation), conservation of the habitat is regarded as by far the most important and is the topic reviewed in this report.

There are many hundreds of thousands of fresh waters in Europe, both running and standing, ranging from small high altitude streams and lakes, through medium-sized waters in the valleys and their lowlands to very large rivers (e.g. the River Rhine) and lakes (e.g. Lake Ladoga). The range of fish habitats among all these waters is large - some of them being unproductive, others are highly productive and the basis of important local fisheries. Unfortunately, fish habitats in Europe have been destroyed on an enormous scale due to pollution (domestic, agricultural and industrial), land use (drainage, afforestation, etc.), river and lake engineering (reservoirs, hydro-electric schemes, weirs, etc.), fisheries and fishery management. The degradation and loss of fish habitats across the whole of Europe has been enormous.

Habitat conservation, therefore, is one of the main ways in which fish conservation (and incidentally the conservation of many other species of plants and animals) can be achieved. Already, many wetland habitats are protected both by legislation and active management but this is virtually never for the fish communities there. There is an urgent need for an inventory of fish species already protected in national and international nature reserves across the whole of Europe. In addition, there is a need to consider those waters which are of major importance to fish species and communities but which as yet have insufficient protection. Finally, A number of the most threatened fish species in Europe occur in quite restricted freshwater habitats and it is important to protect these waters to avoid the extinction of these rare species.

Thus there is a need for each country in Europe to: (a) review those waters which are already given substantial protection as nature reserves and assess the status of fish species in them, (b) consider giving protection as nature reserves to other waters which are known to have important fish communities, (c) develop legislation to protect these important sites, (d) review protection given to international waters of conservation importance, and (e) introduce a 'no net habitat loss' policy in relation to freshwater fish habitats.

included in the Bern Convention: 4 in Appendix II and 118 in Appendix III. Only a few of these species are also protected within the CITES listings (Almada-Villela 1988). This leaves 78 unlisted species which either do not occur within Member States or are assumed to require no protection at present.

The recent additions of fish species to Appendices II and III of the Bern Convention arose from an earlier study of the status of freshwater fish in Europe and the threats facing them (Maitland 1986). It was noted then that several difficulties arise in the compilation of lists of threatened species where many countries are involved (Banarescu *et al.* 1971). Firstly, the extent to which a species is threatened can vary from one country to another. Secondly, both commercial and sport fishing have major economic and political implications which need to be taken into account (Maitland 1991), even though the primary aim for each species is the maintenance (or restoration) of threatened species. In many countries too, fish differ from birds and mammals in having no legally protected species. Lastly, protection measures may prove to be very complex and onerous since any decline in numbers may not be due to over-fishing but to a variety, often a combination, of other unrelated factors, especially water quality (Alabaster & Lloyd 1980, Maitland *et al.* 1990).

The same difficulties apply to the factors affecting habitat conservation in this report. The large number of species, the enormous gaps in our knowledge of the biology of many of them, the complexity of much of the legislation involved, as well as other factors, has led to many of the conclusions reached below being pragmatic and to some extent provisional in character.

3. CONSERVATION OPTIONS

From the small number of available approaches to fish conservation, the main options are habitat conservation (management and restoration), stock transfer to new sites (translocation), captive breeding and cryopreservation. The first two of these are regarded as the most useful for the long-term conservation of threatened species, but captive breeding can help with some species and, with further research, cryopreservation may be a major future strategy.

3.1 Habitat conservation

Obviously enormous damage has been done to many fish habitats and the overall situation is often not easy to reverse - especially in the short-term where fish species or communities are severely threatened. In many cases, unique stocks have completely disappeared. Even where habitat restoration is contemplated, stock transfer and captive breeding (discussed below) could be important short-term interim measures. However, there are a number of important examples of habitat restoration in temperate areas and it should be emphasised that, in the long-term, habitat protection and restoration are the principal means through which successful fish conservation will be achieved.

There have been enormous advances in habitat restoration in the form of pollution control in Europe over the last few decades and a number of the worst rivers are now much cleaner. Thus, in Great Britain, 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 decades, however, 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 but the return of the Atlantic Salmon *Salmo salar* to this river after an absence of more than 100 years is a welcome sign.

There is no room for complacency, however, for many rivers and lakes in Europe are in a very bad state. Clearly, it is essential to maintain and improve water quality and the eventual aim should be to return most, if not all, waters to near their original pristine condition.

Habitat management is of major importance to the conservation of threatened fish species in Europe. It is essential that a number of waters, both running and standing, are given high priority in this context by all national conservation and pollution control agencies. Clear management policies for such sites should be formulated soon. Obviously, priority must be given to high quality sites which are not yet too degraded and whose fish stocks are important. Sites which are already degraded and especially those which have lost their valuable fish stocks may be extremely expensive to restore again, especially in the short-term.

3.2 Translocations

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 believed to be 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 (Maitland & Lyle 1991, 1992) are followed as closely as possible. 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 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.

In view of the urgency relating to a number of endangered populations of fish one of the most urgent tasks needing to be carried out is the development of techniques for handling these rare fish and establishing new 'safeguard' populations in suitable 'refuge" sites. It is within this area of translocation work that captive breeding is likely to contribute most.

3.3 Captive breeding

Captive breeding is widely used throughout the world for a variety of endangered animals, including fish (Maitland & Evans 1986). However, with many animals it can really only be regarded as a short-term emergency measure, for a variety of genetic and other difficulties are likely to arise if small numbers of animals are kept in captivity over several generations or more. Moreover, most zoos, which now accept that captive breeding of other vertebrates (especially birds and mammals) for conservation purposes is one of their major functions, have been slow to consider fish in this context.

Short-term captive breeding, involving only one generation, does have some advantages for a number of fish species. It is especially relevant where translocations are desirable but there is difficulty in obtaining reasonable numbers of eggs or young to start a new population because of ecological or logistic constraints. In such cases there are considerable advantages to be gained in rearing small numbers of stock in captivity and then breeding from them to obtain much larger numbers of young for release in the wild. With fish, 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.

3.4 Cryopreservation

Modern techniques for the rapid freezing of gametes to very low temperatures have 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 important possibilities in relation to the short-term conservation of a wide variety of fish species.

4. FISH HABITATS

The major single cause of the extinction of populations of fish (and indeed most other species of both plants and animals) throughout the world is the destruction of habitat. There is little doubt that the conservation and restoration of fish habitat is the single most important conservation management option for fish species and communities in general, although for a few endangered species translocation or captive breeding may be a more important short-term measure.

Though its fish fauna is rather impoverished, for reasons which are discussed above, Europe is richly endowed with a wide variety of freshwater habitats (Table 1). Flowing waters range from numerous small and several large estuaries through lowland rivers to many upland rivers and streams. Standing waters too are abundant, from small and large lowland lakes to numerous small and medium-sized upland ones. There are many artificial water bodies too, especially canal systems, gravel pits and reservoirs. The varied geology and topography found throughout the continent is reflected in these waters and brackish, alkaline and acid systems are found in many areas.

The actual number of water bodies occurring in Europe is enormous. A study of maps has shown that in Great Britain alone there are over 10,000 individual river systems entering the sea all round the coast, while inland there are over 81,000 ponds, lakes and reservoirs (Smith & Lyle 1979). The latter have a total surface area of 2404 km^2, which represents

1.04 per cent of the total area of Great Britain. Clearly the numbers of individual waters over Europe as a whole are very large, although no actual figures are available.

Within the continent of Europe there is a great variety of landscapes within a relatively small land area. This quality reflects the wide range of basic conditions fundamental to the evolution of contrasting land forms: high and low ground, hard and soft rocks, rich and poor soils, high and low rainfalls, a long coastline and a history of various intensive land uses. It follows therefore that this land has also produced a wide variety of natural freshwater habitats, to which must be added the considerable number of artificial water bodies such as the canal networks in the lowlands and numerous reservoirs of all shapes and sizes, mostly in the uplands.

The range of natural freshwater habitats in Europe encompasses the many high altitude systems, with their clear green-tinted waters, ice-free for less than half the year; the large, deep and elongated, glaciated lake basins of mountainous areas, with their 'acid', biologically poor (oligotrophic) waters; the great shallow biologically rich (eutrophic) lakes; the acid peat-stained pools, the source of upland streams; the swift flowing chalk and marl streams with dense vegetation waving in their clear waters; the turbid lower reaches of large rivers, whose systems include tributaries of various characteristics, but whose original natures are now largely masked by the run-off from agricultural land and the discharge of domestic and industrial effluents (but most of which are not polluted to the extent that fish life is excluded); the many estuaries with full ranges of salinity from fresh to salt water; the less common habitats such as the mildly saline water bodies impounded by storm beaches around the coast or found in basins at the heads of tidal systems and the immense variety of ponds, ditches and marshy pools throughout the land.

The most important qualities of freshwater habitats that, in theory, dictate the density and species composition of the fish present are water velocity, level of dissolved oxygen, summer temperatures and the level of chemical, and therefore biological, richness and degree of pollution.

Many of the large rivers which rise in upland areas gradually progress from being fast flowing and oligotrophic to slow flowing and eutrophic. There are many classic examples in Europe (e.g. the Rivers Rhine and Gironde) where the species composition of the fish fauna is closely related to the habitat provided by each particular section of the river. However, further north (e.g. in Scandinavia and the British Isles), with short rivers, impoverished fauna and flora and specialised history of fish colonisation, re-distributions and introductions, this type of correlation is only approximate.

In the mountainous regions the mainly hard insoluble rocks and poor soils mean that the acid waters of their streams and lakes are poor in the minerals required to promote growth and can therefore only support a low level of biological productivity. Their invertebrate life is poor in species and dominated by insects. These habitats, though, favour salmonid fishes, and Atlantic Salmon *Salmo salar*, Brown Trout *Salmo trutta*, Arctic Charr *Salvelinus alpinus*, Powan *Coregonus lavaretus* and Vendace *Coregonus albula* thrive in the cool, clean, well oxygenated waters and clean silt-free gravels which are so important for the survival of their eggs and young stages. Such habitats are the most vulnerable to the impact of 'acid rain' as they have insufficient buffering capacity to neutralise the acids being deposited from the atmosphere. Some coarse fish also inhabit such waters but they seldom dominate the salmonids, for most coarse species do not tolerate the environmental poverty or low summer temperatures.

At the other extreme there are typical lowland river systems flowing over soluble mineral-rich strata and influenced by run-off from the rich agricultural soils in the catchment. This results in high pH 'alkaline' waters and a biologically rich, eutrophic, environment. The turbid waters of these systems usually support much aquatic vegetation and a rich and diverse invertebrate fauna with molluscs and crustaceans as important members. Being at a low altitude, the relatively high summer water temperatures provide the conditions essential to so many coarse fish species for successful ova hatching and fry survival. Such habitats suit most members of the carp family and many other stenohaline fishes. However, where these (especially Pike *Esox lucius*) are absent, salmonid fishes will thrive as long as there are tributaries with good spawning and nursery areas to provide an adequate recruitment to maintain their populations further downstream. Apropos of this, it is interesting to speculate on the immense production of Salmon and Trout that must have taken place in the many rich low-lying rivers in Europe before Pike and other coarse fish became established in them.

Through the passage of time, fresh waters naturally tend to become silted up and more eutrophic, but this process has been greatly accelerated by human activities. This applies even to some water bodies in highland areas due to the ever increasing afforestation that is now taking place. This involves a considerable amount of ploughing and drainage and the application of chemical fertilisers to land newly prepared for tree planting, while the rehabilitation and reclamation of hill land for pasture also results in substantial amounts of fertiliser run-off into feeder streams. An early sign of eutrophication is the appearance of green algae on rocks and stones in or near the stream and along the shores of lakes where this has never been seen before. Slight eutrophication probably has little effect on the fishes of these upland areas, but the accumulation of nutrients, along with those from other human sources in the lower reaches, can and does produce conditions lethal to fish, especially due to low oxygen levels during hot dry weather and low water flows.

In many countries in Europe, water authorities are encouraged to comply with European Community guidelines for the upgrading and maintenance of river water quality. The criteria laid down are based on the chemical conditions that can be tolerated by different groups of fish species. The highest grade on the scale is water suitable for salmonid communities. The lowest is highly polluted and unsuitable for any fish species.

5. THREATS TO FISH HABITATS

Humans have been involved and interacting with fish populations for many thousands of years, and it is often difficult to separate the effects of human impact from changes which have taken place due to more natural processes. Over the last 200 years and particularly the last few decades various new and intense pressures have been applied to fresh waters and very many species have declined in range and in numbers. Some of the more important of these pressures are reviewed below (Table 2) and inevitably many of them are interlinked, the final combination often resulting in a complex and sometimes unpredictable situation.

Box 1. Habitat restoration of acidified lakes by liming.

Many lakes on base poor geology in the northern hemisphere have become acidified as a result of atmospheric pollution and thousands have lost their fish populations. The long-term solution to this problem is the reduction in sulphur and nitrogen oxide emissions from industry but a number of successful experiments have been carried out to demonstrate that short-term amelioration is possible by the addition of lime - either directly to the lake itself or to its catchment. Liming is very popular in Scandinavia, where it is now carried out routinely as part of lake management (Lessemark & Thornelof 1986) but it has also been carried out successfully with lakes in Scotland (Brown *et al.* 1988), Canada (Molot *et al.* 1986) and the United States (Porcella 1989).

The pollution of fresh waters is probably the single 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, killing all the fish species present, or selective, destroying a few sensitive species or so altering the environment that some species are favoured and others not. However, considerable research has been carried out in this area and suitable water quality criteria are now available in relation to freshwater fish. Pollutants present at sub-lethal levels can raise the susceptibility thresholds of fish to other threats, such as heated effluents (Alabaster 1963). Eutrophication is sometimes thought of as a form of pollution whilst the recent acidification from atmospheric pollution of many waters in Scandinavia and elsewhere (Maitland *et al.* 1987) has shown that even waters far away from urbanisation are not necessarily safe. Remedial action is possible.

The impact of various forms of land use on many species of fish can be considerable (Maitland 1984). Land drainage schemes can totally alter the hydrology of adjacent river systems and, in addition, lead to problems of siltation. The type of crop grown on the land can also have a major effect; for instance the recent development of extensive monoculture forests of Spruce or other conifers has led to concern about excessive water loss from catchments through evapotranspiration together with increased acidification of runoff to the streams. A serious problem in 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. the Swamp Minnow *Phoxinus percnurus* in central Europe (Maitland 1986).

River and lake engineering have been responsible for the immediate elimination of various fish species in many freshwater systems all over the world. Migratory species are particularly threatened by dams and other obstructions on water courses and, if they are unable to reach their spawning grounds, may become extinct in these systems in just a few years. Stretches of severe pollution in river systems can act in the same way to such species. Engineering works can also completely destroy the habitat for some fish, often by dredging or siltation of the river or lake bed, or by exposing them to intolerable fluctuations in water level. The technology of fish-pass design and other ways of ameliorating the impact of such works has improved in recent years and most problems can now be solved at the project-planning stage if the will or appropriate legislation is there. Again, remedial action too is perfectly possible in most situations, given adequate finance.

Box 2. Habitat restoration of a river channel, following poor engineering.

The Blanco River in Colorado, USA, was channelised after a flood in 1970 in an effort to protect riparian land from further flooding (Berger 1992). This gave a wide, straight, flat-bottomed trapezoidal channel within a levee system. The engineered changes resulted in channel instability and the creation of a braided reach quite unlike that there previously. Numerous ecological changes followed including both sedimentation and bank erosion, summer temperatures were higher and the whole river froze in winter. Most fish disappeared. In restoring the river, the main objective was to stabilise it within a well-incised but natural looking channel and this was done by modelling the new channel on physical criteria of similar neighbouring rivers. The river now has new meanders and deep pools with stable banks and good riparian vegetation. Major improvements have taken place in the fishery.

The impact of fisheries (both sport and commercial) on the populations which they exploit can range from the virtual extinction of populations (e.g. the elimination of the Lake Sturgeon *Acipenser fulvescens* in Lake Erie in North America(Smith 1972)) to a more or less stable relationship of recruitment and cropping (ideally on a maximum sustainable yield basis) which existed in many old-established fisheries (e.g. that formerly true for Brown Trout in Loch Leven in Scotland (Thorpe 1974)). The essence of success in management is to have a well-regulated fishery where statistics on the catch are consistently monitored and used as a basis for future management of the stock. Where there is any exploitation of a threatened species it is essential that monitoring and control of this type is exerted. Only then can both fish and humans be successful in the long term (Le Cren 1964).

Apart from physical and chemical habitat alterations created by humans, there are also various biological perturbations. Of major importance among these is the introduction of new fish species (Vooren 1972). If these establish themselves they can alter the community structure radically and lead to the extinction of sensitive native species.

For example, in Great Britain, the Ruffe *Gymnocephalus cernua* is indigenous to the south-east of England from where it has spread to the English Midlands and eastern parts of Wales. The previous most northerly record was from Tees-side and the species had never been recorded from Scotland. In 1982, Ruffe appeared in Loch Lomond - 100 km north of its former area of distribution (Maitland *et al.* 1983) and it is now one of the commonest fish in the loch. It is abundant throughout this large loch (71 km^2) and in the main inflow and outflow. Though not proven, it is believed that the Ruffe was introduced to Loch Lomond by anglers from England, who frequently come north to fish for Pike bringing various small fish with them to use as live bait. The impact of this new species on the existing community is uncertain, but it is unlikely to be beneficial, especially to the vulnerable Powan whose eggs it eats in large numbers.

It should be emphasised that the introduction of a new species, which then becomes established, can actually be more serious than many other types of habitat threat - most of which (e.g. pollution, river engineering) are reversible. It is often impossible to eliminate an alien species and thus substantial control costs may be involved indefinitely.

Box 3. An example of major fishery management necessitated by accidental fish introduction.

The history of the accidental introduction of the Sea Lamprey into the Great Lakes of North America has been documented by Lawrie & Rahrer (1973) and others. The opening of the Welland Canal in 1829 gave this species access to the upper Great Lakes, but it was not found in Lake Erie until 1921, Lake Huron until 1937, Lake Michigan until 1936 and Lake Superior until 1946. In the next few decades the population of lamprey developed explosively with catastrophic consequences for the fish species on which it preyed. The commercial fisheries collapsed and in Lake Michigan alone during the mid-1950s the Sea Lamprey destroyed over two million kg of fish a year. The Great Lakes Fishery Commission was set up to study this and other problems and it has developed a series of lamprey control strategies to prevent adult lampreys ascending spawning streams and chemical lampricides to eliminate larvae in nursery streams. The latter technique has proved the most successful and is the main thrust of the continuing Sea lamprey Control Programme run at a cost of some $8,000,000 per annum.

Many introductions of foreign species have been unsuccessful. The ways in which introduced fish can interact with native fish have been analysed by McDowall (1968), Stroud (1975), Li & Moyle (1981) and others. Nilsson (1985) suggests four options. The introduced species could: (1) be rejected because there is no 'vacant niche' or because predators eat out the population at an early stage (e.g. the unsuccessful introductions of Rainbow Trout *Oncorhynchus mykiss* and Danube Salmon *Hucho hucho* into Scandinavia), (2) hybridise with very closely related stocks formerly adapted to the ecosystem (e.g. introductions of Brown Trout into many waters in Great Britain), (3) eradicate or suppress a stock that is either an 'ecological homologue' or an easily available prey (e.g. the introduction of Pike or Powan to waters with Arctic Charr populations), (4) finds 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 (e.g. Ruffe in Loch Lomond or Brook Charr *Salvelinus fontinalis* in Sweden). The latter have established themselves only in the head waters of streams because of competition with Brown Trout elsewhere. When the reverse transfer was made and Brown Trout were introduced to streams in North America, they occupied the more favourable parts of streams and forced the native Brook Charr into the head waters.

Thus fish face a number of problems, some of them common to other forms of wildlife, others more particular to fish (Table 3). In addition, there has been habitat loss on an enormous scale, right across the wide range of aquatic habitats which occur in Europe (Table 1). 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 stations are eventually washed into water courses as "acid rain" (Maitland *et al.* 1987).

Many rivers have become completely fishless as a result, especially those in the industrial and heavily populated lowland areas.

Other factors have affected fish in various ways. Barriers on rivers, such as weirs or hydro-electric 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. 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. Where a native species is found in a few waters only - sometimes only one or two (as is now the case with the Vendace *Coregonus albula* in the British Isles) - it is obviously very vulnerable and urgently needs 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.

6. HABITAT CONSERVATION

Habitat conservation is one of the main ways (probably *the* main way) in which fish conservation (and incidentally the conservation of many other species of plants and animals) can be achieved. Already, many wetland habitats are protected both by legislation and active management but this is virtually never the case for the fish communities there. There is an urgent need for an inventory of fish species already protected in national and international nature reserves across the whole of Europe.

In addition, there is a need to consider those waters which are of major importance to fish communities but which as yet have insufficient protection.

A number of the most threatened fish species in Europe occur in quite restricted freshwater habitats and it is important to protect these waters to avoid the extinction of these rare species. One of the most notable examples here is the Asprete *Romanichthys valsanicola*, which occurs only in one very restricted catchment (the River Arges, a tributary of the River Danube) in Europe (Dumitrescu *et al.* 1957, Stanescu *et al.* 1971). Other endangered species in Europe have been reviewed by Maitland (1986).

6.1 Legislation

Most countries already have some legislation which gives protection to certain geographic areas and habitats - usually described as nature reserves. However, most of the existing reserves have been established for their plants, birds or mammals and very rarely have any of them been established for fish species. There is a clear need to redress this balance.

6.2 Management

The management of important habitats which have been established as nature reserves or protected areas of some kind is clearly essential for their full protection. Such management is particularly difficult with many freshwater systems (especially running waters) which can be affected by activities elsewhere in their catchments - sometimes many kilometres away from the protected water itself. Thus, as well as local management, due consideration must be given to the eventual long-term solution of integrated catchment management

6.3 Restoration

Because of the wide scale of habitat loss in the past there is considerable scope in many countries for successful restoration of important habitats and there are at present a number of schemes with the specific objective of fish habitat restoration. This may involve a number of restoration activities, particularly the elimination of pollution, the removal of artificial dams, weirs and other barriers and the enhancement of riparian zones.

Obviously enormous damage has been done to many fish habitats and the situation is often not easy to reverse - especially in the short term where fish species or communities are severely threatened. Even where habitat restoration is contemplated, stock transfer (discussed above) could be an important interim measure. However, there are a number of important examples of habitat restoration in temperate areas. The River Thames in England and the River Clyde in Scotland have been already mentioned in this context and successful habitat restoration has also been carried out in many lakes.

Box 4. An example of lake habitat restoration.

Lake Trummen in Sweden received sewage and industrial discharges for about 30 years and changed rapidly from an oligotrophic to a eutrophic system (Bjork 1972, Andersson et al. 1975). Significant changes in its fish community took place during this period. The extensive layers of rich sediment which were deposited were so great that although the sewage was eventually diverted, the lake showed no sign of recovery during the following decade. Because of this, the rich surface sediments (amounting to some 300,000 m^3) were suction dredged in 1970 and 1971. Following this, the concentration of nutrients decreased considerably and oxygen conditions improved. Blooms of blue-green algae disappeared and transparency increased in summer. The sediment removed was used to improve the nutrient poor soils of the area and fish communities have recovered so that sport fishing is again important.

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7. DISCUSSION

It can be seen from the above review that a number of conservation options exist for threatened fish in Europe. The conservation action required varies considerably among the threatened species and habitats concerned and is controlled by several constraints including varying status and ecology, as well as logistics and finance. This is an appropriate time to review the conservation of fish habitats in view of the recent Directive from the European Community (1992) on the conservation of natural habitats and of wild fauna and flora. This Directive is undoubtedly of major importance to the conservation of fish habitats, though its implementation is likely to be slow and a number of shortcomings are already apparent (WWF UK 1992).

The general picture in Europe, and indeed around the world, is that fish conservation has been sadly neglected, especially compared to the attention which has been given to birds, mammals, plants and some invertebrates. There are a few exceptions to this, the outstanding one being the United States where there is active conservation management for threatened fish species, some of this in premises designed for the purpose, such as the Dexter National Fish hatchery in New Mexico (Johnson & Rinne 1982). Its main objective is to maintain a protected gene pool of rare fish species, to develop techniques for rearing and maintaining species, and to hatch sufficient numbers to re-establish species in their historic habitats. Since 1974, more than 20 endangered species of fish have been handled successfully at this hatchery, which is an outstanding example of what is needed in many other parts of the world, including Europe.

The present review of fish conservation in Europe has provided an initial foundation for the conservation of fish habitats and it is hoped that the proposals emanating from it will be implemented in future years. The general conclusion is that although there has previously been some legislation and management in relation to both fish and various general aspects of habitat conservation (such as the establishment of nature reserves), little of this has been aimed directly at the protection of threatened fish species. This situation must be improved if further valuable stocks of native species are not to be lost and there is thus a clear need for further action in fish habitat conservation management

There appear to be two major problem areas in relation to the protection of the habitats of freshwater fish in Europe. The first of these is the lack of available information concerning the national distribution of fish habitats in each country and how these relate to the distribution of threatened fish species. The second is the problem of providing adequate protection of important fish habitats against the many modern threats which face them (Table 2).

One quite straightforward way of countering both problems is to initiate in each state a review all fish species and communities in nature reserves and protected areas of all kinds (e.g. national nature reserves, RAMSAR sites, etc.). This has already been done in Great Britain for all 235 National Nature Reserves (Lyle & Maitland 1992). The great advantage of such a scheme is that it indicates which important fish species and communities are already given protection within the aquatic habitats in these notified sites. By inference, it may also suggest which fish (and fish habitats) do not have such protection.

Thus, it is also important to carry out reviews which will identify additional important sites and habitats of particular concern for endangered fish species and communities. Consideration may then be given to how these can best be protected.

In addition to important fish habitats in waters entirely within national boundaries special attention should be paid to a review of the protection of waters of international importance for fish especially those with transnational boundaries (e.g. River Danube).

Having identified sites and habitats with national and international importance a major objective should be to develop legislation to protect these sites and habitats in each member state.

A simple, but very important, new concept which is being considered in various countries in one form or another - and has already been accepted by Canada (Department of Fisheries & Oceans 1986) in relation to fish habitat - is that of 'no net habitat loss'. This looks to the future in relation to developments of any kind which may threaten fish habitats and makes it clear that approval will be given only if (a) there is no loss of fish habitat involved, or (b) the development is modified in such a way that there is no loss of fish habitat, or (c) 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.

Thus there is a need (Table 4) for each country in Europe to: (a) review those waters which are already given substantial protection as nature reserves and assess the status of fish species in them, (b) consider giving protection as nature reserves to other waters which are known to have important fish communities, (c) develop legislation to protect these important sites, (d) review protection given to international waters of conservation importance, and (e) introduce a 'no net habitat loss' policy in relation to freshwater fish habitats.

As well as the implementation of conservation management programmes for fish habitats, research and monitoring studies are also needed in order to aid management and maintain a watch on populations of important species.

The importance of conserving this resource - both marine and freshwater - for the future in virtually all continents and countries is clearly imperative. The size of the task is vast, however, taking into account the enormous number of species involved over almost the whole globe, and the problem must be tackled in a variety of ways and by many individuals and organisations if any measure of success is to be achieved.

It is hoped that the present recommendations concerning the conservation of fish habitat in Europe, if implemented, will substantially advance the cause of freshwater fish conservation. Given adequate support, all threatened fish species, unusual races and communities and indeed fish stocks in general can be managed more positively, thereby saving for posterity this valuable and renewable resource, so important for scientific, recreational, educational, commercial and aesthetic purposes.

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Table 1. A simple diagrammatic classification of fish habitats in Europe. The diagram represents a continuum - which is actually the commonest situation, for most water bodies interconnect with others. In some large catchments, all these different water types may be found.

GEOLOGY (rock & soil)	SIZE (area & depth)	ALTITUDE (& latitude)	FISH	
POOREST	*SMALLEST*	*HIGHEST*	*PERHAPS NONE*	
dystrophic & oligotrophic systems	shallow pools & trickles	cool waters often frozen	*LOW*	salmonids may dominate
mesotrophic systems			*MEDIUM*	*SPECIES DIVERSITY*
eutrophic & hypertrophic systems	deep lochs & rivers	warmer waters rarely frozen	*HIGH*	coarse fish may dominate
RICHEST	*LARGEST*	*LOWEST*	*SOME BRACKISH*	

Table 2. A summary of the main pressures facing freshwater fish and their habitats in Europe.

	DANGER	EFFECT
1	Industrial and domestic effluents	Pollution, poisoning, blocking of migration routes
2	Acid deposition	Acidification, release of toxic metals
3	Land use (farming and forestry)	Eutrophication, acidification, sedimentation
4	Industrial development (including roads)	Sedimentation, obstructions, transfer of species
5	Warm water discharge	Deoxygenation, temperature gradients
6	River obstructions (dams)	Blocking of migration routes, sedimentation of spawning beds
7	Infilling, drainage and canalisation	Loss of habitat, shelter and food supply
8	Water abstraction	Loss of habitat and spawning grounds, transfer of species
9	Fluctuating water levels (reservoirs)	Loss of habitat, spawning and food supply
10	Fish farming	Eutrophication, introductions, diseases, genetic changes
11	Angling and fishery management	Elimination by piscicides, diseases, introductions
12	Commercial fishing	Overfishing, genetic changes
13	Introduction of new species	Elimination of native species, diseases, parasites
14	Global warming	Loss of some southern or low altitude populations. Movement north of southern species

Table 3. Some characteristics of freshwater fish populations and habitats, which are especially relevant to their communities and conservation.

1. DISCRETENESS They are confined within their systems; this leads to independent populations with individual stock characteristics developed since their isolation.

2. NUMBERS Because each population is often confined to a single (often small) aquatic system, within which there is usually significant water movement, the entire population is vulnerable - to pollution, disease, etc. Thus for any species, the number of populations is of far greater importance than the number of individuals.

3. MIGRATIONS These are a feature of the life cycles of many species of fish and during migration they may be particularly vulnerable. In particular, in diadromous riverine species, the whole population has to pass through the lower reaches of their river at least twice in each life cycle. If the river is polluted, obstructed or has many predators, the entire populations of several species may disappear leaving the community above permanently impoverished.

4. LIFE CYCLES Large slow-growing species and small very short-lived species are very vulnerable to fishing pressures and can be fished to extinction.

5. HABITATS Because they are often 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.

6. ECOLOGICAL NICHE There must be a satisfactory ecological niche within the system to allow population maintenance. This could be disrupted by changes in habitat or the introduction of new species which are predators or competitors.

Table 4. Summary of the main recommendations concerning the conservation of freshwater fish habitats in Europe.

Each member state should:

1. Review all fish species and communities in nature reserves and protected areas of all kinds (e.g. national nature reserves, RAMSAR sites, etc.).

2. Identify additional sites and habitats of particular concern for endangered fish species and communities.

3. Develop legislation to protect these important sites and habitats in each member state.

4. Review protection of waters of international importance for fish especially those with transnational boundaries (e.g. River Danube).

5. Introduce the 'no net habitat loss' concept as national policy.