IRELAND'S MOST THREATENED AND RARE FRESHWATER FISH: AN INTERNATIONAL PERSPECTIVE ON FISH CONSERVATION

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ABSTRACT

Ireland's native fish fauna, like that of much of the rest of Europe, is declining. It is likely that some of the unique elements of Ireland's fish communities will become extinct in the next few decades unless urgent action is taken soon. This paper reviews the relevant international conventions and legislation related to fish conservation as well as Ireland's obligations to meet these. Several management options are available, including further legislation, habitat management, translocation, captive breeding and cryopreservation. The present activity in Great Britain in relation to the preparation of Biodiversity Action Plans and other statements of intent is commendable, but what is really needed is prompt practical action in the field if many of these unique wildlife resources are not to be lost.

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INTRODUCTION

Due to recent glaciation, temperate fish communities are much less diverse than those of the tropics, and in Europe there is a marked reduction in species from south to north. In particular, islands like Ireland are especially impoverished since, for the most part, only fish with marine affinities were able to reach them. Worldwide, human impact has destroyed fish habitat on a wide scale and many populations of rare species have disappeared over the last two centuries. In addition, numerous distinct stocks of common species and a number of important fish communities have become extinct (Maitland 1986; 1987a).

For many years, fish were greatly neglected in terms of conservation, and most attention was given to conserving animals and plants of more appeal to the public, for example, birds, mammals and flowers. Starting in the 1970s, however, it was gradually realised that all over the world fish were facing severe threats, and that many species were declining or becoming extinct (Maitland 1974; 1987b). Gradually, more and more countries started to assess the status of the members of their fish fauna and appropriate conservation legislation and Red Data Books started to appear. Unfortunately, much of the action taken so far is too little too late, for Red Data Books and Red Lists are only the beginning and not the end of the conservation process. Ireland is fortunate in having had a Red Data Book for fish for many years (Whilde 1993), whereas Great Britain, in spite of criticism (Maitland and Lyle 1990; 1991), has so far failed to produce one.

In most countries, freshwater fish are a significant part of the biodiversity, and many of species of freshwater fish also support a wide variety of important fisheries. Altogether, there are over 250 freshwater fish species found in Europe as a whole (Maitland 2000), including several species that are diadromous and a few that are mainly brackish but also come into fresh water for significant periods. A number of international agreements have come into effect over the last 30 years and these are aimed at protecting Europe's most threatened species. Without such agreements it is likely that many countries would have taken no action to protect their native fish faunas.

Numerous difficulties arise when many countries are involved in the compilation of lists of threatened species. 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 that need to be taken into account, even though the primary aim is the maintenance (or restoration) of threatened species. In many countries too, no species of fish are legally protected, whereas individual bird and mammal species have legal protection. One of the major obstacles in assessing the threat to many fish species (especially non-commercial ones) concerns the enormous gaps in our knowledge of their biology. Lastly, protection measures may prove to be complex and onerous since any decline in numbers may not be due solely to overfishing. Decline can be due to a variety, often a combination, of other

unrelated factors, especially water quality (Maitland 1984; Maitland *et al.* 1987; 1990).

SOME BASIC PRINCIPLES

Several major principles are involved in establishing conservation criteria for fish and applying these to populations in the wild. Certain characteristics of freshwater fish 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 during their isolation. This is true even of migratory species for whom, even though there is substantial mixing of stocks in the sea, the homing instinct has meant that there is a strong tendency for genetic isolation.

Because each fish population is usually confined to a single body of water, the entire population is vulnerable to the effects of pollution, disease and other factors. Thus for a fish species, the number of separate populations is usually of far greater importance than the number of individuals. Migration is a feature of the life cycle of many fish species, and at migration times these may be particularly vulnerable. This is most marked in diadromous riverine species, where the whole population has to pass through the lower section of its natal river on its journey to and from the sea. If this section of river is polluted, obstructed or subject to heavy predation, entire populations of several species may disappear leaving the upstream community permanently impoverished.

DEFINING CONSERVATION STATUS

One of the first tasks in preparing conservation plans for the fish fauna of any geographic area is a proper assessment of the conservation status of each species. This is essential for prioritising those species under greatest threat and for the preparation of conservation management plans. Most countries now accept the IUCN (1994) definitions of threat, which are summarised in Table 1.

TAXONOMY AND CONSERVATION

Conservationists often fail to realise just how important taxonomy is in relation to the conservation of animal (and plant) species. Firstly, the animal must have a scientific name. A number of years ago, this led to Scott and Rines (1975) giving a scientific name — *Nessiteras rhombopteryx* — to an aquatic animal popularly known as the Loch Ness monster, so that legal steps could be taken to protect it. Secondly, the more distinct a species is in relation to other species, the greater the priority given to its conservation. Thus, in the jargon of taxonomy, 'lumpers' and 'splitters' can have an important influence on the conservation status, and indeed the future, of fish populations.

Table 1 — Summary of IUCN (1994) definitions of threat.

Threat	*Abbreviation*	*IUCN definition*
Extinct	EX	When there is no reasonable doubt that the last individual has died.
Extinct in the wild	EW	When it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range.
Critically endangered	EC	When it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered	EN	When it is not critically endangered but is facing an extremely high risk of extinction in the wild in the near future.
Vulnerable	VU	When it is not critically endangered or endangered but is facing a high risk of extinction in the wild in the medium-term future.
Lower risk	LR	When it has been evaluated, does not satisfy the criteria for any of the categories critically endangered, endangered or vulnerable.
Data deficient	DD	When there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.
Not evaluated	NE	When it has not yet been assessed against the criteria.

A good example of the importance of taxonomy in conservation is the vendace, *Coregonus albula*. In Great Britain, this was originally described as the Lochmaben or Cumberland vendace, *Coregonus vandesius* Richardson, found only in two lochs in southern Scotland and two lakes in northern England (Maitland 1966). As a rare endemic species therefore, it should have a high conservation status. Then Ferguson (1974) showed, using electrophoretic analysis of tissue proteins, that this fish was really just the same species as the relatively common European form *C. albula*, and therefore of relatively low conservation status in world terms. More recently, however, in his controversial and challenging paper, Kottelat (1997) has suggested that *C. vandesius* should actually be regarded as a valid species, thus re-opening the debate about its conservation status. Kottelat's views would imply that this fish is, as originally proposed, a rare endemic with only two interconnected populations worldwide.

GENETICS

Not only must the taxonomy of the species to be conserved be reliable, but it is highly desirable also to have some knowledge of the genetics of any species being managed, and of course taxonomy and genetics are closely interrelated. Many populations of a single species of fish are actually made up of independent subpopulations, and there may be no—or very little—interbreeding between these. For example, Brown trout, *Salmo trutta*, and Arctic charr, *Salvelinus alpinus*, are species in which this may occur (Ferguson 1986; Adams *et al.* 1992). For some species, their genetics can vary across their geographic range so that the gene pools of populations of the same species at either extreme of their geographic range may be quite different from one another. In conservation management work involving the manipulation of fish stocks it is ideal, some would say essential, to be aware of the range of genetic variation in any of the species being handled, both within a stock and across stocks.

SPECIES BIOLOGY

Unless a reasonable amount is known about the biology of a species that is in need of conservation, it is very difficult to develop an adequate conservation management plan. Many species have complex life cycles, or very specific habitat requirements: it is essential to be aware of these in order to analyse potential threats and develop remedial measures for their conservation. The sturgeon, *Acipenser sturio*, an anadromous species, is a good example. It requires a specific habitat for spawning and then another for its first few years in fresh water. It then moves to the sea, where it may spend the next ten to fifteen years feeding and growing in a quite different habitat. It is a very large species, with desirable flesh and ovaries, and is long-lived. All of these factors are related to its extreme decline and must be taken into account in its conservation. The bitterling, *Rhodeus sericeus*, is an unusual fish established in England but absent in Ireland. It lays its eggs in the mantle of large bivalve mussels. If these molluscs decline and disappear, then so will the bitterling.

INTERNATIONAL CONSERVATION AGREEMENTS

There are a number of international conventions and directives that affect fish or their habitats indirectly. Only those with direct relevance to fish are considered below.

RAMSAR CONVENTION 1971

The first international conservation agreement was the Ramsar Convention, concluded in Iran in 1971, for the protection of internationally important wetlands. By 2000, there were 1,005 wetland sites designated by 116 Contracting Parties. These sites cover 71 million hectares. The main objective of this convention is the protection of habitat—individual species are not protected as such. However, many of the sites have open waters, thereby giving habitat protection to their freshwater fish; for example Loch Lomond is a Ramsar site that has fifteen native fish species (Lyle and Maitland 1994).

CITES 1975

The Convention on International Trade in Endangered Species (CITES) seeks to encourage governments to regulate, and in some cases prohibit, trade in species threatened with extinction. Several fish species are listed in the CITES appendices (Almada-Villela 1988), but only one of these occurs in Europe, the sturgeon, *Acipenser sturio*.

BERN CONVENTION 1979

The Bern Convention on the Conservation of European Wildlife and Natural Habitats requires the protection of endangered and vulnerable species of flora and fauna in Europe together with their habitats. Appendices list species for which exploitation and other factors should be controlled. No fish species in Great Britain or Ireland are listed in Appendix II (strictly protected species),

but Appendix III includes the fish species listed in Table 2.

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 should be noted that both bitterling and wels catfish are alien to Great Britain and Ireland.

BONN CONVENTION 1979 AND 1994

The Bonn Convention on the Conservation of Migratory Species of Wild Animals requires the protection of migratory animals, from the Arctic to Africa. No fish species of relevance to Great Britain and Ireland are listed.

CONVENTION ON BIOLOGICAL DIVERSITY 1992

The Convention on Biological Diversity was signed by 150 heads of state and government at the Earth Summit in Rio de Janeiro in June 1992. Following this, in the United Kingdom, the UK Biodiversity Action Plan was published in January 1994, setting out a biodiversity strategy for the next twenty years (Department of the Environment 1995). Schemes for the conservation of certain endangered wildlife habitats as well as species of animals and plants are a vital part of the strategy. The aim of these schemes will be to preserve, and wherever possible enhance, the range and biodiversity of naturally occurring wildlife in the UK. The Priority List of species in the United Kingdom for which Species Action Plans have been prepared includes the freshwater fish species listed in Table 3.

Table 2—List of species present in Great Britain and Ireland and listed in Appendix III, protected species, of the Bern Convention 1979.

Common name	*Latin name*
River lamprey	*Lampetra fluviatilis*
Brook lamprey	*Lampetra planeri*
Sea lamprey	*Petromyzon marinus*
Sturgeon	*Acipenser sturio*
Allis shad	*Alosa alosa*
Twaite shad	*Alosa fallax*
Vendace	*Coregonus albula*
Pollan	*Coregonus autumnalis*
Powan	*Coregonus lavaretus*
Houting	*Coregonus oxyrinchus*
Grayling	*Thymallus thymallus*
Atlantic salmon	*Salmo salar*
Bitterling	*Rhodeus sericeus*★
Spined loach	*Cobitis taenia*
Wels catfish	*Silurus glanis*★
Common goby	*Pomatoschistus microps*

★Introduced species.

HABITATS DIRECTIVE 1992

The European Union adopted the Habitats Directive (Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna) in May 1992. The main aim of the directive is 'to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements' (Department of the Environment 1995). The Habitats Directive provides for the creation of a network of protected areas across the European Union, which are to be known as Natura 2000. These protected areas will consist of Special Areas of Conservation (SACs) designated under the Habitats Directive and the much older Special Protection Areas (SPAs) designated under the Birds Directive (Directive 79/409/EEC on the conservation of wild birds).

The Habitats Directive also requires all Member States to set up an effective system to prevent the capture, killing, injuring or damaging disturbance of certain endangered species. Together, these measures aim to maintain or restore the extent and quality of rare habitat types. They will also ensure that rare species can survive and maintain their populations and range on a long-term basis (Boon 1994).

Freshwater fish are included in three annexes in the directive: Annexe II (conservation requiring SACs), Annexe IV (species in need of strict protection), and Annexe V (species affected by taking in the wild and exploitation that may be subject to management measures). Species relevant

Table 3—Freshwater fish species included in the Priority List of species in the United Kingdom for which species action plans have been prepared.

Common name	*Latin nomenclature*
Allis shad	*Alosa alosa*
Twaite shad	*Alosa fallax*
Vendace	*Coregonus albula*
Pollan	*Coregonus autumnalis*
Houting	*Coregonus oxyrinchus*
Burbot	*Lota lota*

to Great Britain and Ireland that are included in this directive are listed in Table 4.

WATER FRAMEWORK DIRECTIVE 2000

The Framework Directive for Water (Directive 2000/60/EC), commonly known as the Water Framework Directive, was published in December 2000. It identifies its key purpose as preventing further deterioration of aquatic systems together with the protection and enhancement of their status in Europe. Member States will be required to achieve 'good surface water status' in inland surface waters, transitional waters and coastal waters. Ground waters must also be protected and restored to ensure the quality of dependent surface water and terrestrial ecosystems.

There are a number of annexes that detail the nature of the information required to determine ecological status. There is a classification of high, good, moderate, poor and bad ecological status for all types of water body. For surface waters the biological elements that need to be monitored in order to classify status include: the composition and abundance of aquatic flora, the composition and abundance of aquatic macroinvertebrates, and the composition, abundance and age structure of the fish fauna. No particular fish species are mentioned.

Table 4 — Species relevant to Great Britain and Ireland included the Habitats Directive.

Common name	*Latin name*	*Annexe*
River lamprey	*Lampetra fluviatilis*	IIa, Va
Brook lamprey	*Lampetra planeri*	IIa
Sea lamprey	*Petromyzon marinus*	IIa
Sturgeon	*Acipenser sturio*	IIa, IVa
Allis shad	*Alosa alosa*	IIa, Va
Twaite shad	*Alosa fallax*	IIa, Va
Vendace	*Coregonus albula*	Va
Pollan	*Coregonus autumnalis*	Va
Powan	*Coregonus lavaretus*	Va
Houting	*Coregonus oxyrinchus*	IIa, IVa
Grayling	*Thymallus thymallus*	Va
Atlantic salmon	*Salmo salar*	IIa, Va
Barbel	*Barbus barbus*	Va
Bitterling	*Rhodeus sericeus*	IIa
Spined loach	*Cobitis taenia*	IIa
Bullhead	*Cottus gobio*	IIa

UNITED KINGDOM

THE WILDLIFE AND COUNTRYSIDE ACT 1981 AND 1985

The Wildlife and Countryside Act (1981 and 1985) is the main piece of conservation legislation for the United Kingdom, and for implementing EU conventions. It is intended to protect both species and sites of UK importance, and it is an offence to 'kill, injure or take any wild animal included in Schedule 5', to 'damage, destroy or obstruct any shelter or disturb any Schedule 5 animal there', and to 'possess any live or dead wild animal (or part of) included in Schedule 5'. The freshwater fish species listed in Schedule V are given in Table 5.

It is clear from the notes with each species that such legislation was indeed too little, too late, and on its own has no chance of making much difference to the future conservation prospects of these (or other) threatened fish species in the United Kingdom.

PRACTICAL MANAGEMENT

As well as strong legislation to protect species and habitats (some would say in spite of it), most threatened species require practical 'hands on' management of some kind. The processes involved have been described in greater detail elsewhere (Maitland 1989; Maitland and Lyle 1991; 1992) and only a brief outline is given here.

HABITAT MANAGEMENT

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

Table 5 — Freshwater fish species listed in Schedule V of the Wildlife and Countyside Act (1981 and 1985).

Common name	*Latin nomenclature*	*Status*
Sturgeon	*Acipenser sturio*	Almost extinct worldwide
Allis shad	*Alosa alosa*	No longer breeding in the UK
Vendace	*Coregonus albula*	Extinct in Scotland; English stocks under threat
Powan	*Coregonus lavaretus*	Populations stable, though threatened
Burbot	*Lota lota*	Extinct in UK

species or communities are severely threatened. In many cases, unique stocks have completely disappeared. Even where habitat restoration is contemplated, stock transfer (discussed below) could be an important interim measure. However, there are a number of important examples of habitat restoration in temperate areas and it should be emphasised that habitat protection and restoration are the principal long-term means by which successful sustainable fish conservation and restoration of biodiversity will be achieved.

There have been enormous strides in pollution control in many countries over the last few decades, and a number of the worst rivers are now much cleaner. In Scotland, for example, the Rivers Clyde and Carron are now so much better than 50 years ago that fish have been returning to them in increasing numbers. At their worst, both rivers were virtually fishless in their lower reaches and no migratory fish could pass through the polluted stretches to reach the clean upland waters. Rehabilitation of the River Clyde has been a slow but steady process. The final arbiters of water quality are surely the fish themselves and the return of the Atlantic salmon, *Salmo salar*, to this river after an absence of more than 100 years is a marvellous tribute to decades of work by the former Clyde River Purification Board.

Many fresh waters in Scandinavia, North America and Scotland have lost their fish populations over the last three decades because of acidification, and altogether many thousands of individual stocks have disappeared. Various ways of ameliorating the impact of acid precipitation have been investigated, most of them involving adding calcium in some form, either directly to the water body or to the catchment of the system involved. Most of the pioneering work in this form of habitat restoration has been carried out in Scandinavia.

In Scotland, various attempts at liming to ameliorate freshwater acidification have been attempted, most notable among which has been the work at Loch Fleet. Here, the former healthy population of brown trout started to decline during the 1950s and became extinct during the 1970s. In 1984, a restoration project costing over £1.5 million was initiated and calcium carbonate was added to the catchment in various ways. The loch responded quickly and the pH rose from about 4.5 to 6.5 within a few weeks; at the same time the amount of aluminium in the water decreased. Adult fish were introduced to the system in 1986 and these subsequently spawned successfully. As expected, this experiment verified the earlier work of others, but though successful, its results were transitory and very expensive. While providing a possible short-term answer to the acidification problems affecting important local stocks of fish, e.g. the Arctic charr at Loch Doon, liming does not provide a satisfactory long-term form of habitat restoration.

Habitat management is of major importance to many of our native fish species. It is essential that a number of waters, both running and standing, are given high priority in this context. Habitat management is also of importance in relation to any new stocks that are initiated from translocation experiments. Such sites should also be viewed in relation to overall habitat management proposals. The restoration of habitats from which important stocks have disappeared is a much more difficult and expensive procedure, and in some cases may not be considered worthwhile. In many cases, catchment management is the main tool, and it is probable that only with integrated catchment management will the eutrophication of waters such as Upper Lough Erne be reversed, a process which will take many years.

TRANSLOCATION

Where rare fish are threatened, stock transfer can be undertaken without any threat to the existing stocks, but it is important that certain criteria are taken into account in relation to any translocation proposal. 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 body in which to create a new population, translocation can be initiated by placing the eggs directly in the new habitat, or by hatching the eggs in a hatchery and introducing the young.

Translocation projects for threatened fish species in Scotland have proved to be one of the most realistic ways to help to conserve several species, at least in the short term. In general, these projects are likely to be less expensive and have a greater chance of success than many habitat restoration proposals, especially in the short term. All translocation proposals should follow scientific guidelines (Maitland 1989). In Ireland there would seem to be two species for which translocation is warranted as soon as possible: pollan, *Coregonus autumnalis*, and the Killarney shad, *Alosa fallax killarnensis*.

CAPTIVE BREEDING

Captive breeding is widely used throughout the world for conserving a variety of endangered animals, including fish. However, for most animals captive breeding can really only be regarded as a short-term emergency measure, as 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. Captive breeding in the long term does not seem appropriate to any of the freshwater fish species at present under threat in Great Britain or Ireland, unless the numbers of fish that can be obtained for translocation from some sites is very small.

However, short-term captive breeding involving only one generation does have some advantages for a number of species and has already been carried out by the author with Arctic charr. It is especially relevant where translocations are desirable but reasonable numbers of eggs or young are difficult to obtain 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 stripping them to obtain much larger numbers of young for release in the wild. Because of genetic problems related to the bottleneck effect and inbreeding, captive breeding should not be carried out for more than one generation from the wild stock, and as many parent fish as possible should be used.

CRYOPRESERVATION

Modern techniques for 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 being conducted at present into the rapid freezing of eggs, no successful method of cryopreservation has yet been developed for female gametes. The technique is therefore of only limited value in relation to the conservation of fish species.

However, if a particular fish stock appeared in imminent danger of dying out, it would seem worthwhile giving consideration to saving at least some of its genetic material through the cryopreservation of sperm. The European sturgeon is a good example of where this approach has been considered. 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. For the reasons explained above, however, cryopreservation does not seem to be a realistic option for any of the threatened British and Irish species at the moment. However, this is an active research area of considerable relevance to fish conservation and as such should be supported.

IRELAND'S FISH FAUNA

There have been several previous assessments of the status and conservation requirements of Ireland's fish fauna (Whilde 1993; Maitland 1996; Quigley and Flannery 1996). Yet relatively little action has been taken so far, in spite of the obvious decline in the populations of some species, notably the pollan (Winfield and Wood 1990). Using the IUCN (1994) guidelines, the following notes are the author's assessment of the status, in relation to Ireland, of the most threatened native species at the beginning of the new millennium. The 1993 Red Data Book assessments (Whilde 1993) are given in parentheses.

Species: River lamprey *Lampetra fluviatilis*
Status: Lower risk (Indeterminate)
Notes: This species should benefit from the establishment of suitable SACs.

Species: Brook lamprey *Lampetra planeri*
Status: Lower risk (Indeterminate)
Notes: This species should also benefit from the establishment of suitable SACs.

Species: Sea lamprey *Petromyzon marinus*
Status: Vulnerable (Indeterminate)
Notes: As the most threatened of the three lamprey species, priority should be given to the conservation of this species. Since many of the habitat requirements of the three species are the same, such measures (e.g. the creation of SACs) should benefit all three species.

Species: Sturgeon *Acipenser sturio*
Status: Critically endangered (Not Evaluated)
Notes: Although this species does not breed in Ireland, it is now very rare around Ireland's coasts and almost never enters large rivers (Went 1984), Ireland can still take measures to help with the conservation of this and other sturgeon species. Such measures could include alerting commercial fishermen to the plight of this species and encouraging them to record captures and release any specimens immediately and banning, or at least discouraging, the sale of caviar from wild fish.

Species: Allis shad *Alosa alosa*
Status: Endangered (Endangered)
Notes: The past status of this fish as a breeding species in Ireland seems uncertain (Bracken and Kennedy 1967; Aprahamian and Aprahamian 1990). However, any measures taken for the benefit of twaite shad are likely to benefit this species, but commercial fishermen should be alerted to its plight and encouraged to record captures and release any caught specimens immediately.

Species: Twaite shad *Alosa fallax*
Status: Vulnerable (Vulnerable)

Notes: This species, which has been recorded from a number of aquatic systems in Ireland (Went 1946, 1953; Fahy 1982; O'Maoiléidigh 1990; O'Maoiléidigh *et al*. 1988), has declined all over Europe and requires conservation measures in most countries. The establishment and management of suitable SACs should be of major benefit.

Species: Killarney shad *Alosa fallax killarnensis*
Status: Endangered (Endangered)
Notes: As an endemic subspecies, confined to one lake system (Regan 1912; Trewavas 1938; Went 1946), it is critical that this fish receives urgent conservation attention. This should include not only a habitat management plan for Lough Leane and its catchment, but rapid consideration of a translocation scheme to at least two other suitable waters, preferably in the south-west of Ireland. These actions are urgently required!

Species: Atlantic salmon *Salmo salar*
Status: Lower risk (Internationally important).
Notes: Although there are considerable commercial concerns over this species, it is not seriously threatened at the moment and the establishment of suitable SACs should help it in the future.

Species: Arctic charr *Salvelinus alpinus*
Status: Vulnerable (Vulnerable).
Notes: Though originally found in many Irish loughs (Thompson 1856; Went 1946; 1971; Quigley and Nolan 1984; Ferguson 1981), this species is suffering decline across much of its range in both Ireland and Great Britain (Maitland 1992; Igoe *et al*. 2001; Igoe and Kelly-Quinn 2002), and has virtually no legal protection. It is essential that this situation is given further consideration, but more importantly, that a National Species Action Plan is prepared for this species and implemented as soon as possible if its further decline is to be prevented.

Species: Pollan *Coregonus autumnalis pollan*
Status: Endangered (Endangered).
Notes: As an endemic, but declining subspecies whose biology is now reasonably well known (Twomey 1956; Ferguson *et al*. 1978; Wilson 1983), it is essential that the full range of conservation options is considered for this fish. These must include not only habitat restoration, which is likely to be successful only in the long term, but also translocation to suitable new sites, and possibly captive breeding and cryopreservation of gametes. These actions are urgently required!

Species: Smelt *Osmerus eperlanu*s
Status: Vulnerable (Vulnerable).
Notes: Though suffering decline across much of its range in both Ireland and Great Britain (Kennedy 1948; Vickers 1974; Hutchinson and Mills 1987), this species has virtually no legal protection. It is important that its status is given further consideration, but more important that a Species Action Plan is prepared for this species and implemented soon if its further decline is to be prevented.

OTHER SPECIES

Other native Irish species in need of assessment of their conservation status are: brown (and sea) trout (*Salmo trutta*), European eel (*Anguilla anguilla*), three-spined stickleback (*Gasterosteus aculeatus*), nine-spined stickleback (*Pungitius pungitius*), sea bass (*Dicentrarchus labrax*), common goby (*Pomatoschistus microps*), thick-lipped grey mullet (*Chelon labrosus*), thin-lipped grey mullet (*Liza ramada*), golden grey mullet (*Liza aurata*) and flounder (*Platichthys flesus*). It is probable that these species can all be considered, at the moment, to be of Lower Risk status—with the following provisos: (a) there is concern about individual populations of some species (e.g. brown and sea trout), and (b) there is a general lack of information concerning most of Ireland's native species, except those of commercial interest.

DISCUSSION

Most of the recent activity concerning freshwater fish in Britain and Ireland has been directed at preparing reports about what needs to be done. Many projects have stopped there! In fact, it is direct action, based on scientific principles, that is required, and for some species such action must be initiated soon. In translating ideas into action, the experience of other countries should be taken into account, for example the principle of 'no net loss of fish habitat', which is now law in Canada (Department of Fisheries and Oceans 1986).

THREATS TO FRESHWATER FISH

Humans have been interacting with fish populations for many thousands of years, and it is often difficult to separate human impact on fish populations from changes that 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 freshwater resources, and very many fish species have subsequently declined in their range and numbers. Many of the pressures are interlinked, the final combination of factors often resulting in a complex, sometimes unpredictable, situation.

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. Most pollution comes from domestic, agricultural or industrial waste. It can be totally toxic, thereby killing all the fish species present, or selectively toxic, destroying a few sensitive species or altering the environment to such an extent that some species are favoured and others not. Considerable research has been carried out in this area, and sensible water quality criteria for fish are now available. Many pollutants are present at sub-lethal levels and these can raise the susceptibility thresholds of fish to other threats, such as heated effluents. Eutrophication is a product of nutrient enrichment of waters and is of widespread concern in Ireland. Atmospheric pollution of waters in Scandinavia and elsewhere has shown that rivers and lakes far away from urban settlements are not necessarily safe.

The impact of land use on many species of fish can be considerable. Land drainage schemes can totally alter the hydrology of adjacent river systems and can 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 (*Picea sitchensis*) or other conifers has led to concern about excessive water loss from catchments through evapotranspiration, together with increased acidification of runoff to the surrounding streams. A problem in many lowland areas is the drainage or filling in of ponds that were formerly important sites for fish.

River and lake engineering has been responsible for the elimination of fish species in fresh waters all over the world. Migratory species are particularly threatened by dams and other obstructions and, if they are unable to reach their spawning grounds, may become extinct in a few years. Stretches of severe pollution in rivers can have a similar effect. Engineering works can also completely destroy the habitat for some species by dredging or siltation, or through creating 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.

The impact of both sport and commercial fisheries on the stocks these activities exploit can range from the virtual extinction of populations to—ideally—a stable relationship of recruitment and cropping (on a maximum sustainable yield basis). The essence of success in management terms is to have a well-regulated fishery in which 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 co-exist successfully in the long term.

Apart from physical and chemical habitat alterations created by humans, there are also various biological perturbations to aquatic ecosystems. Of major importance among these is the introduction of new fish species. If these establish themselves, they can radically alter the community structure and lead to the extinction of sensitive native species. Genetic modification of native strains due to introgression of non-native or farmed strains as a consequence of stocking or escapes from marine fish farms, has recently been demonstrated to be an issue that must be taken more seriously by government (McGinnity *et al*. 2003). An example of such genetic modification is the Atlantic salmon along the west coast of Ireland and Scotland.

There is increasing evidence that human activities are altering the atmosphere to such an extent that global warming may create major climatic changes over the next few centuries. Rising sea levels and atmospheric temperatures, especially at high latitudes, are the most likely changes. These changes are likely to affect fish (Maitland 1991). Everywhere there is likely to be a shift of southern species to the north and a retreat northwards of northern species. In the open sea, changing temperature and circulation patterns are likely to affect pelagic, demersal and migratory species. Along the coast and in estuaries increased sea levels will create changes to shallow waters and produce problems for humans in low lying areas. In freshwaters, as well as the latitudinal changes, there are likely to be parallel changes related to altitude, with coldwater species moving into higher, cooler waters and their place being taken in the lowlands by warmwater species. In nutrient-rich lakes in summer there will be an increasing tendency to hypolimnetic anaerobic conditions, with associated 'summer kill', while there will be less freezing in winter and so a lesser incidence of 'winter kill' in these lakes.

Thus fish populations 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, right across the wide range of aquatic habitats that occur in Europe.

LOSS OF BIODIVERSITY

Thus, the main human pressures on native fish stocks in Europe are exploitation, pollution, loss of habitat, changing land use and the irresponsible movement of disruptive fish species into and around most countries. In recent years there has

been a marked trend away from natural mixed native fish populations towards artificially maintained stocks of a few species for sporting and commercial purposes. Probably the greatest threat to fish stocks has been habitat destruction.

The main emphasis within pollution control has been the improvement of water quality, and little attention has been paid to artificial weirs and other physical obstructions. Any action taken has been concerned with salmonids while other migratory fish, such as allis and twaite shad and smelt, have been ignored. Thus, obstacles that can be surmounted by active leaping salmonids have been regarded as satisfactory, but the fact that they can be complete barriers to less agile species has been ignored. The combination of such obstacles with severe pollution in lower rivers and commercial fishing in estuaries has undoubtedly been a major factor in the decline of sturgeon, allis shad, twaite shad, houting and smelt across the whole of their European distribution. An important part of the conservation management of such species is a review of the physical (and chemical) obstacles in the lower reaches of any rivers in which it is hoped to conserve these species.

In spite of existing legislation, there are still potential dangers from disease introduced with ornamental fish. The bulk of such fish are of tropical origin and destined for private indoor aquaria: there is probably very little risk here. However, there are definite disease and parasite risks associated with the introduction of temperate species, and both fish and parasites could become established in the wild. Moreover, even if the host fish were unable to establish a permanent population in the wild, a parasite might well do so by transferring to native species.

THE FUTURE

There is still substantial work to be done in the field of fish conservation. In addition to establishing the status of fish in each geographic area, much effort must go towards identifying the specific conservation needs of the most endangered species and implementing appropriate measures as soon as possible. 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 that 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 (Maitland 1985; Maitland and Morgan 1987).

The general conclusion reached from this brief review is that, although there has previously been some legislation and management in relation to both fish and various general aspects of conservation (such as the establishment of nature reserves), little of this activity has been aimed directly at the protection of fish species. This situation must be improved if further valuable stocks of native species are not to be lost. There is a clear need for further action in fish conservation management. It should be emphasised that the eventual long-term value of restored stocks of commercial species such as sturgeon, Atlantic salmon and sea trout, will be worth many times the actual cost of restoring them.

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